Introduction to shape grammars

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MIT/Miyagi Workshop: Lecture Notes
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Introduction:
What is a shape grammar and how is it used?

Developing and applying a standard shape grammar.

Developing and applying a parametric shape grammar.

Assignment.

What is a shape grammar?

Definitions

Generative Design:

Method in which the drawings are generated by applying a set of algorithm rules, allowing the exploration of new concepts and solutions

Shape grammar (invented by George Stiny):

Set of rules of transformation applied recursively to an initial form, generating new forms

A → B

Noam Chomsky, Syntactic Structures, 1957 → Generative Linguistics

Vocabulary: set of recognized words

Rules: coordinates used to make a system functioning

Syntax: rules that operate the behaviour of the system, from it's internal structure to it's function.

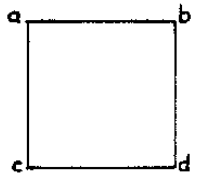
Semantics: meaning of the sentences. what is their meaning.

Grammar: set of individual rules that allow language use through form, composition and words inter-relation.
(contemporary grammar = cognition; phonetics; morphology; syntax; etymology; semantics; literature; logics)

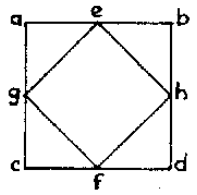
Language: sign system that serves as communication media. (contains grammar and style)

Algorithm for designing a gothic spire (Roriczer)

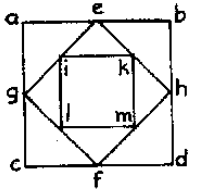
If you want to draw a base plan for a pinnacle, according to the masons' technique [derived] out of correct geometry, then begin by making a square as shown hereafter with the letters *a b c d*, so that it is the same distance from *a* to *b* as from *b* to *d*, *d* to *c*, and *c* to *a*, as in the figure drawn hereafter.



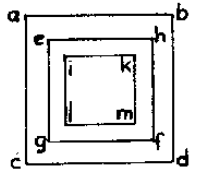
Then make the square equal in size to the preceding; divide [the distance] from *a* to *b* into two equal parts, and mark an *e* [at the midpoint]. Do the same from *b* to *d* and mark an *h*; from *d* to *c* and mark an *f*; from *c* to *a* and mark a *g*. Then draw lines from *e* to *h*, *h* to *f*, *f* to *g*, and *g* to *e*, as in the example of the figure drawn hereafter.



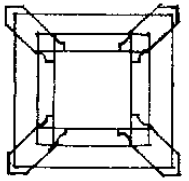
Then make the above-derived square equal in size to the preceding; divide [the side] from *e* to *h* into two equal parts, and mark a *k* [at the midpoint]. Do the same from *h* to *f* and mark an *m*; from *f* to *g* and mark an *l*; from *g* to *e* and mark an *i*. Then draw lines from *e* to *h*, *h* to *f*, *f* to *g*, and *g* to *e*, as in the example of the figure drawn hereafter.

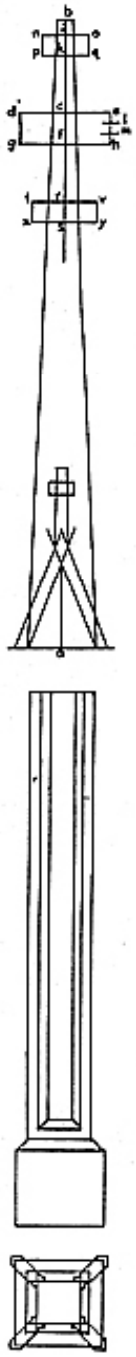


Then make the two squares *a b c d* and *i k l m* equal in size to the preceding, and rotate the square *e h g f*, as in the example of the figure drawn hereafter.



Then when you eliminate the remaining lines that are not needed for the setting out, there remains such a form as shown below.





Procedure for defining the entasis of a column (Palladio)

The columns in each order ought to be form'd in ſuch a manner, that the diameter of the upper part of the column may be ſmaller than at the bottom, with a kind of a ſwelling n the middle.

As to the manner of making the ſwelling in the middle, we have no more to ſhew from VITRUVIUS but his bare promiſe; which is the reaſon that moſt writers differ from one another upon that ſubject.

The method I uſe in making the profile of the ſwellings is this; I divide the fuſt of the column into three parts, and leave the lower part perpendicular; to the ſide of the extremity of which I apply the edge of a thin rule, of the ſame length, or a little longer than the column, and bend that part which reaches from the third part upwards, until the end touches the point of the diminution of the upper part of the column under the *collarino*. I then mark as the curve directs, which gives the column a kind of ſwelling in the middle, and makes it project very gracefully.

And although I never could imagine a more expeditious and ſucceſsful method than this, I am neverthelefs confirmed in my opinion, ſince Signor PIETRO CATANEO was ſo well pleaſed when I told him of it, that he gave it a place in his Treatiſe of Architecture, with which he has not a little illuſtrated this profeſſion.

A B, *the third part of the column, which is left directly perpendicular.*
B C, *the two thirds that are diminiſhed.*
C, *the point of diminution under the* collarino.

Le Corbusier's Modular System

Red series: 113.0 182.9 295.9 478.8 . . . .
Blue series: 226.0 365.8 591.8 957.6 . . . .

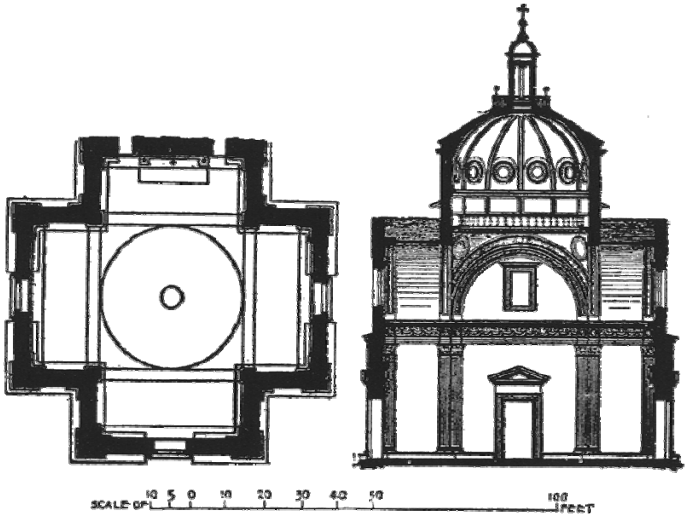
Procedures for computing the series

Red series: red term$_n$ = red term$_{n-1}$ + red term$_{n-2}$
Blue series: blue term$_n$ = red term$_n$ x 2

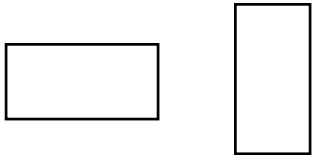
Value of algorithms

productive

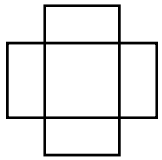
explanatory



Shapes



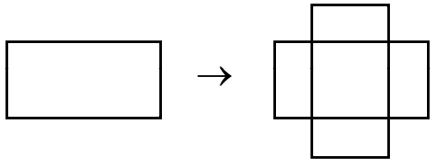
Spatial relation



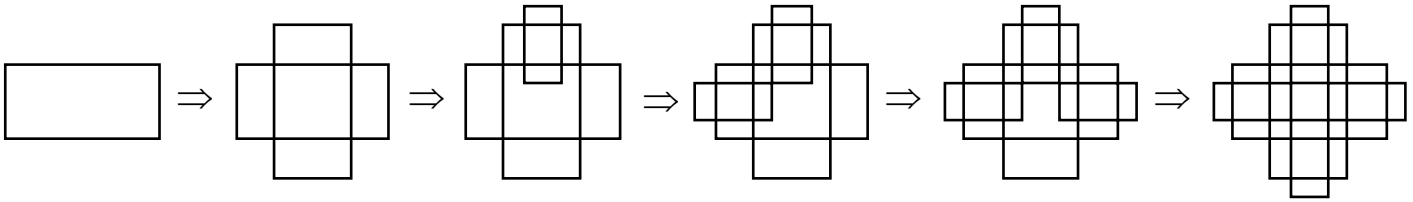
SHAPE GRAMMAR

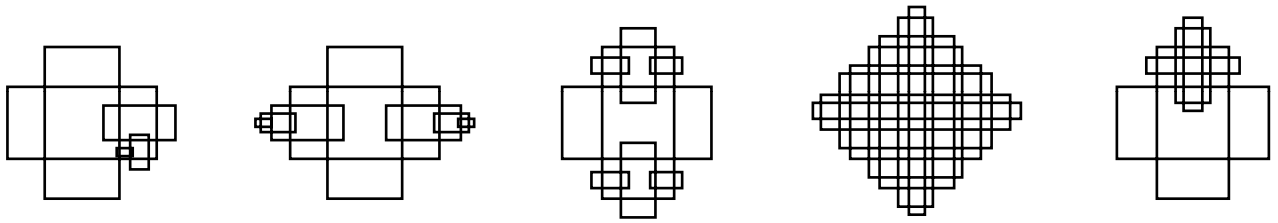
initial shape

rule



DERIVATION



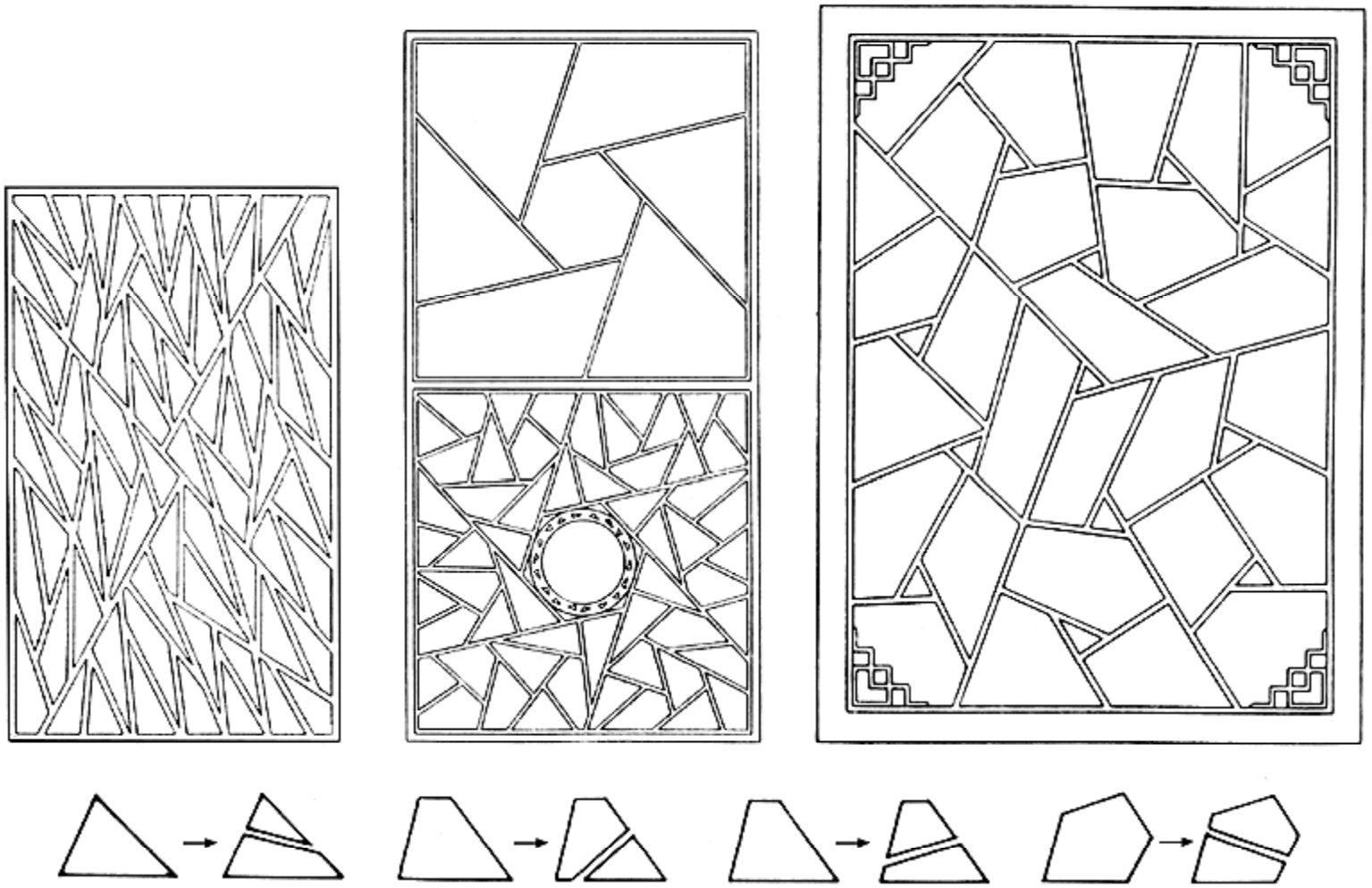


OTHER DESIGNS IN THE LANGUAGE

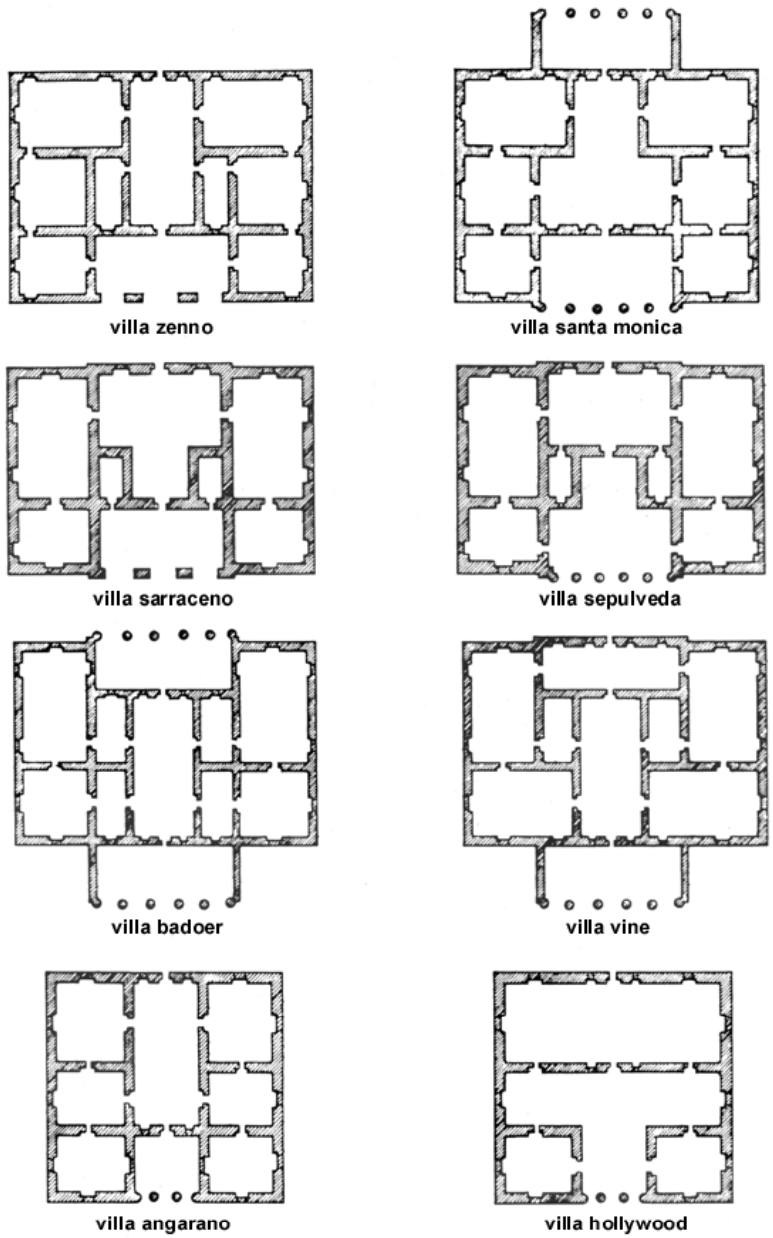
Shape grammar applications

analysis

original design

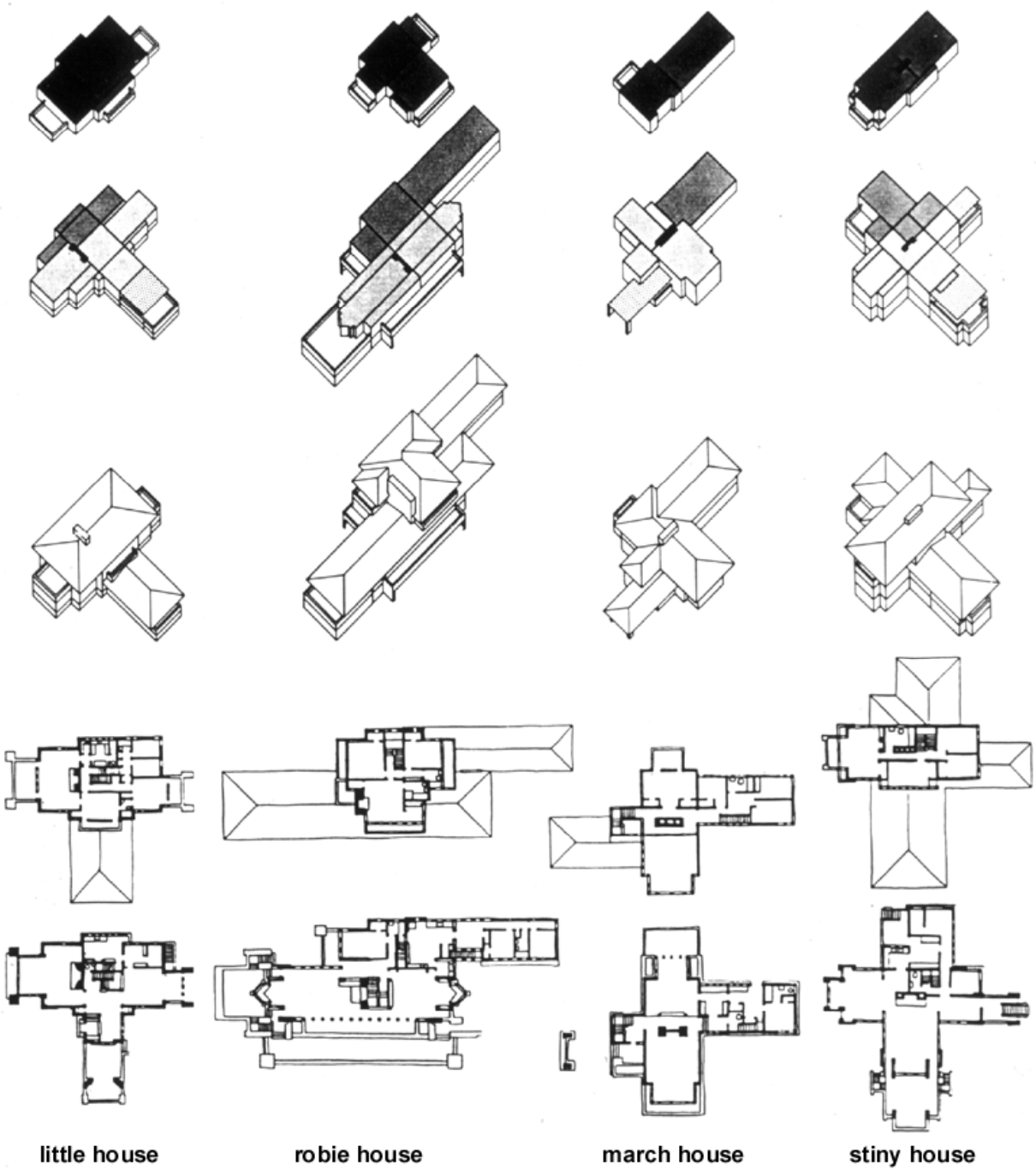


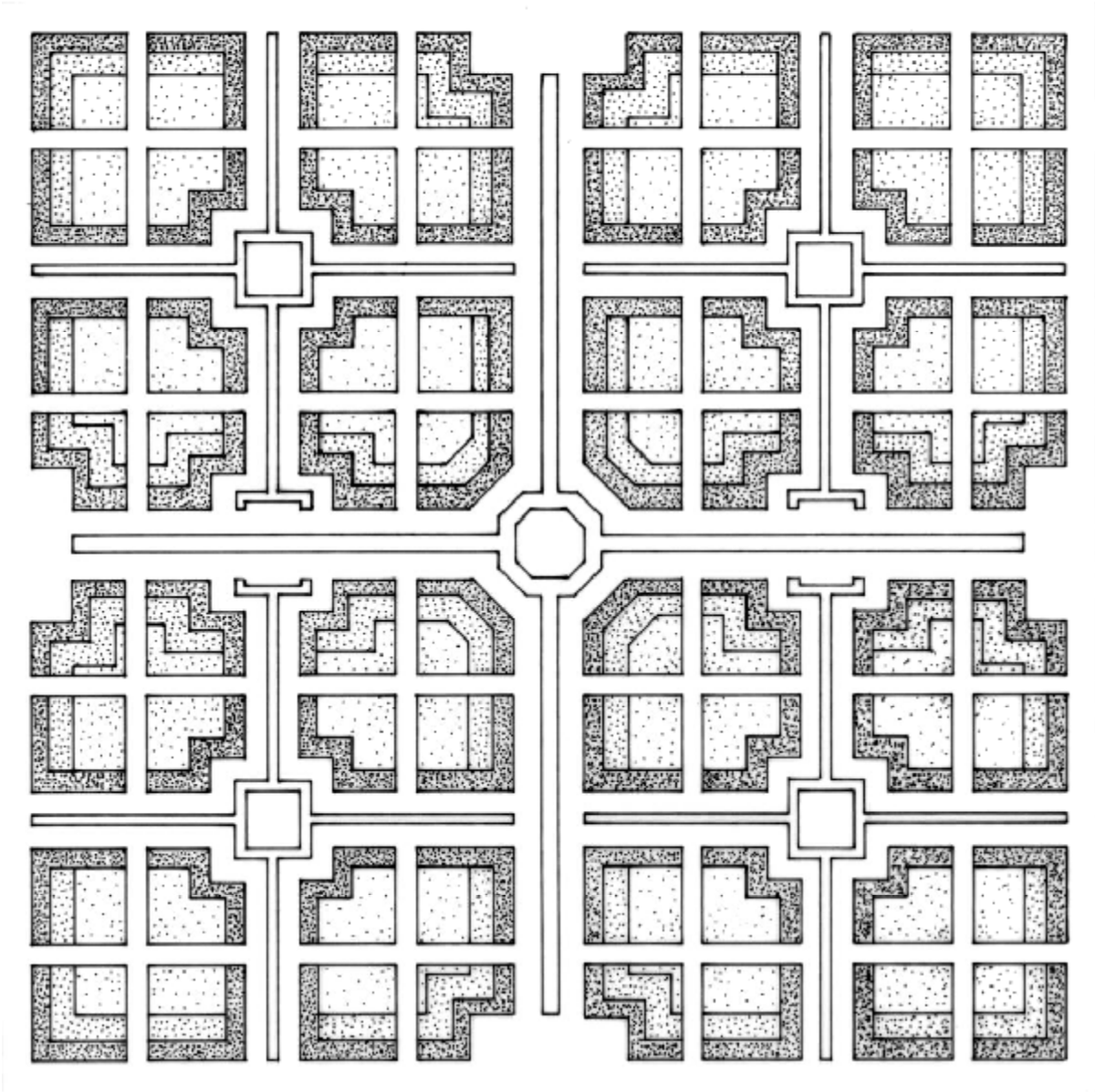
Ice-ray grammar



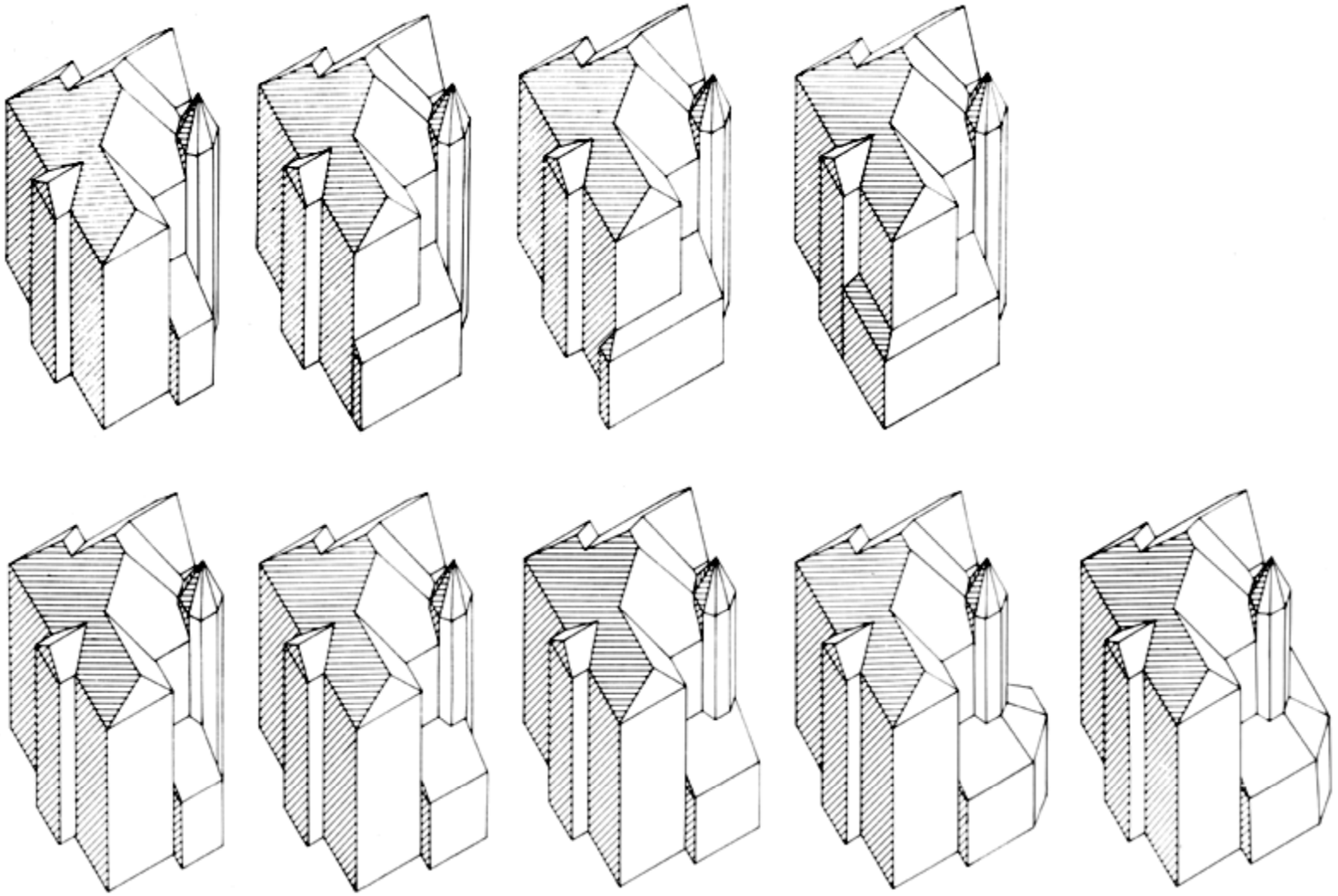
Palladian villa grammar

Wright prairie house grammar

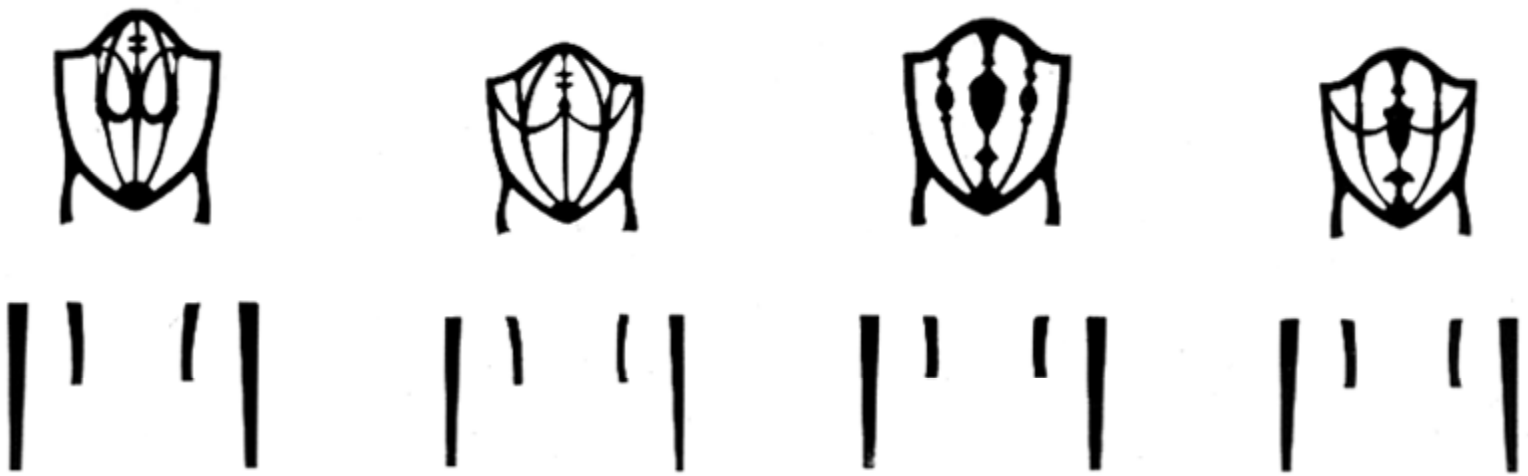




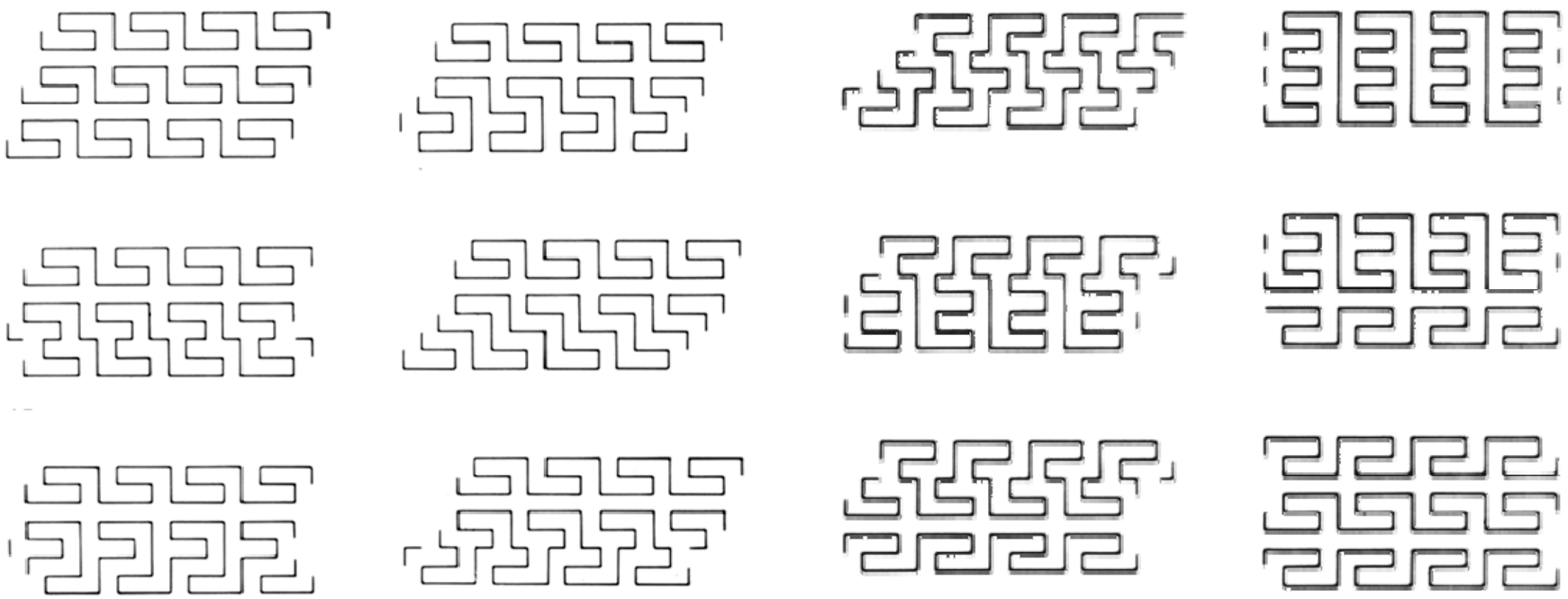
Mughul garden grammar



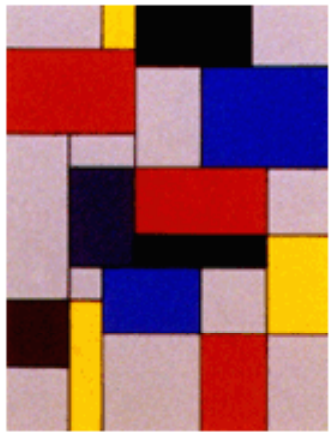
Queen Anne grammar



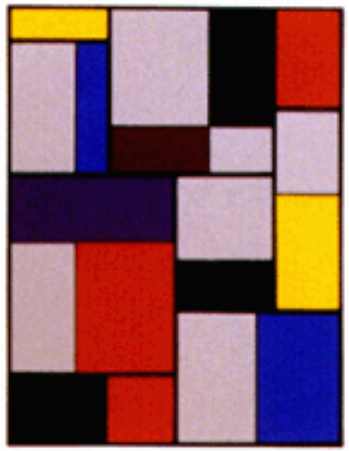
Hepplewhite chair grammar



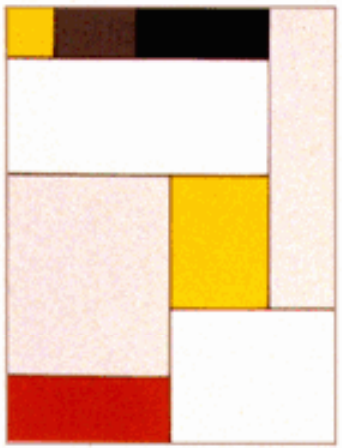
Ancient Greek meander grammar



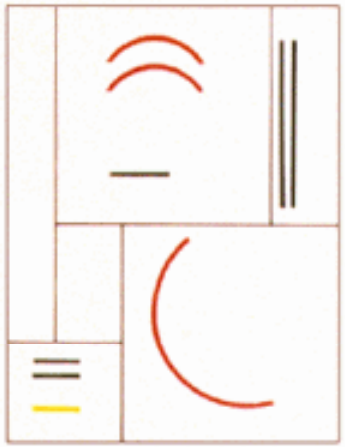
stage I



stage II



stage III

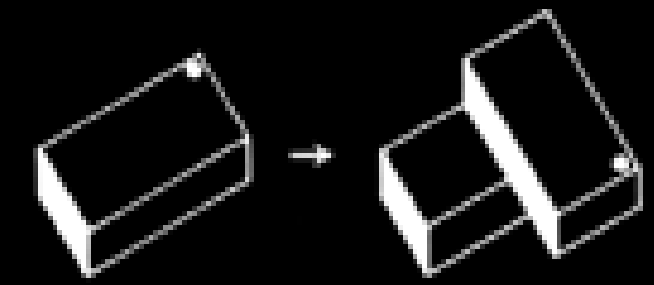


stage V

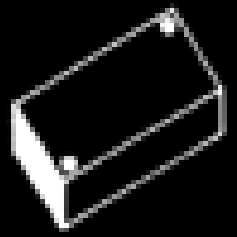
stage VI

stage VII

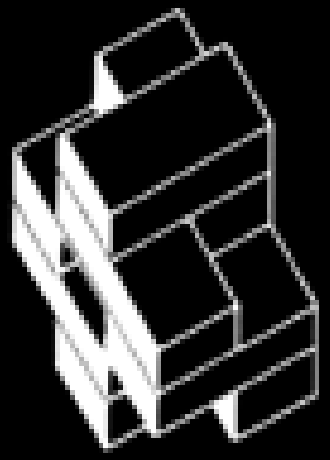
De Stijl painting grammar



shape rules



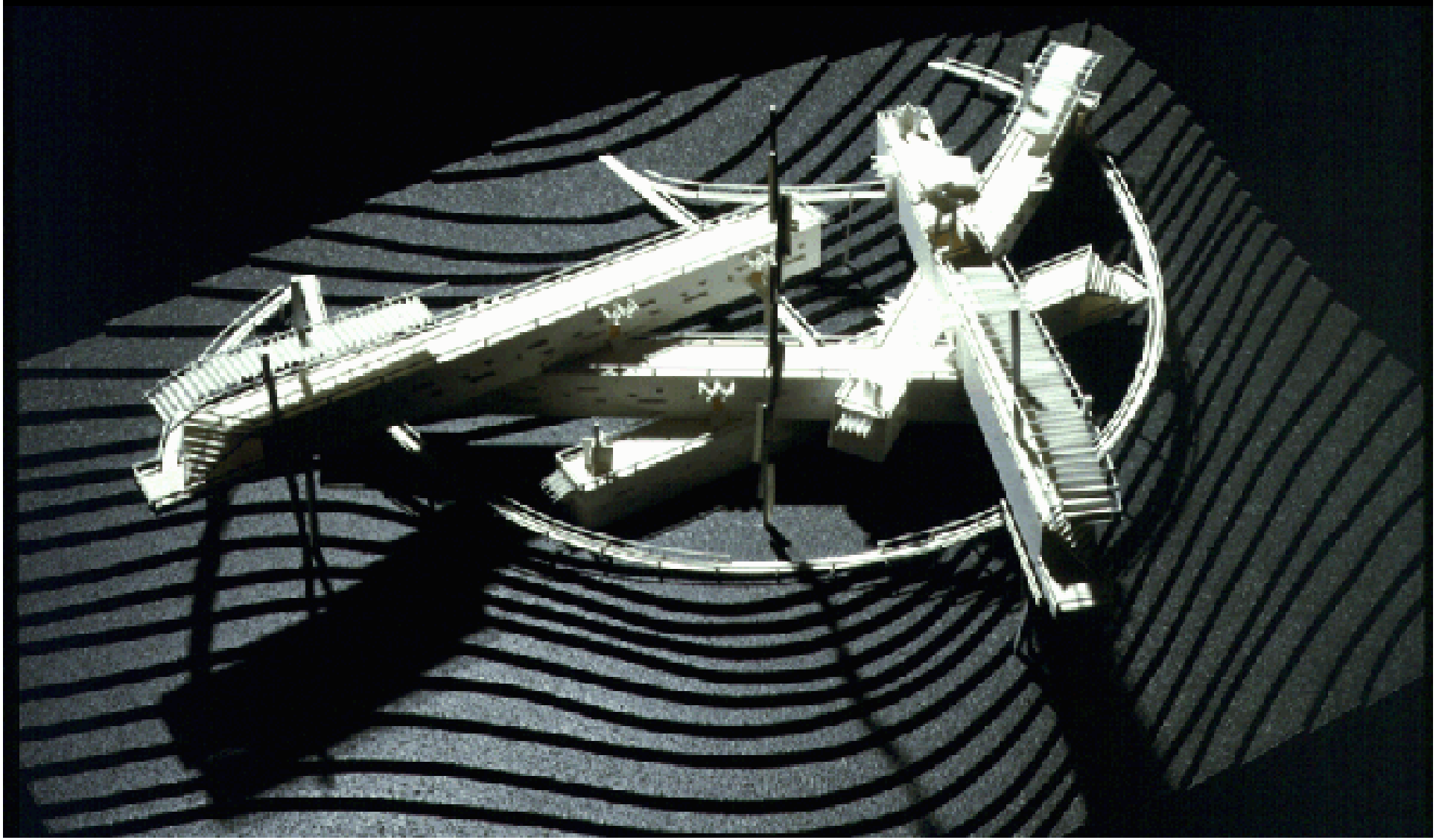
initial shape



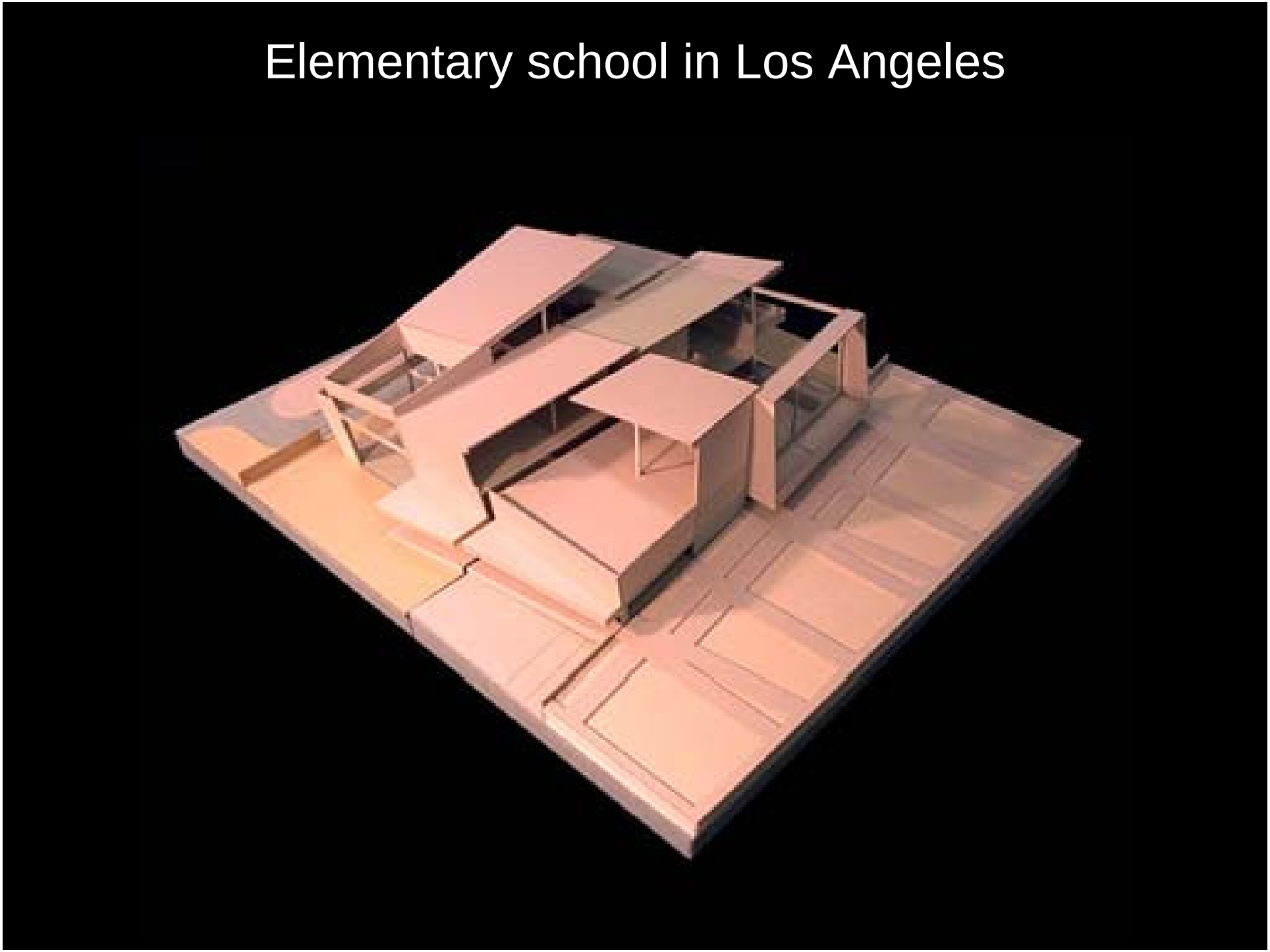
design in language

Froebel block grammar

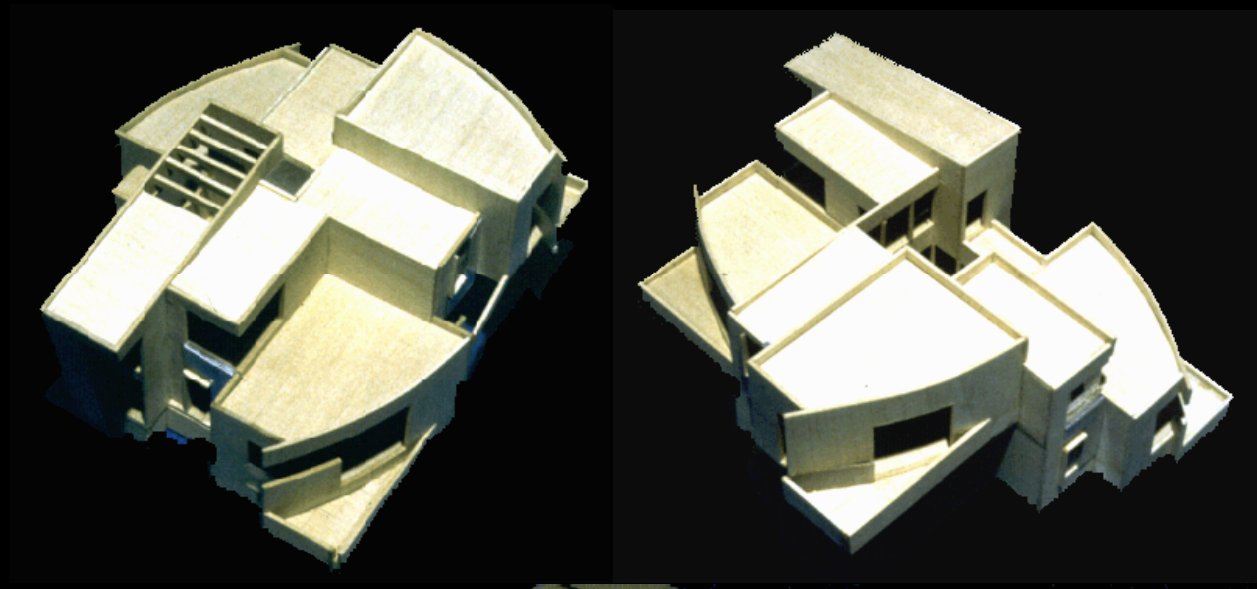
Museum in Italy

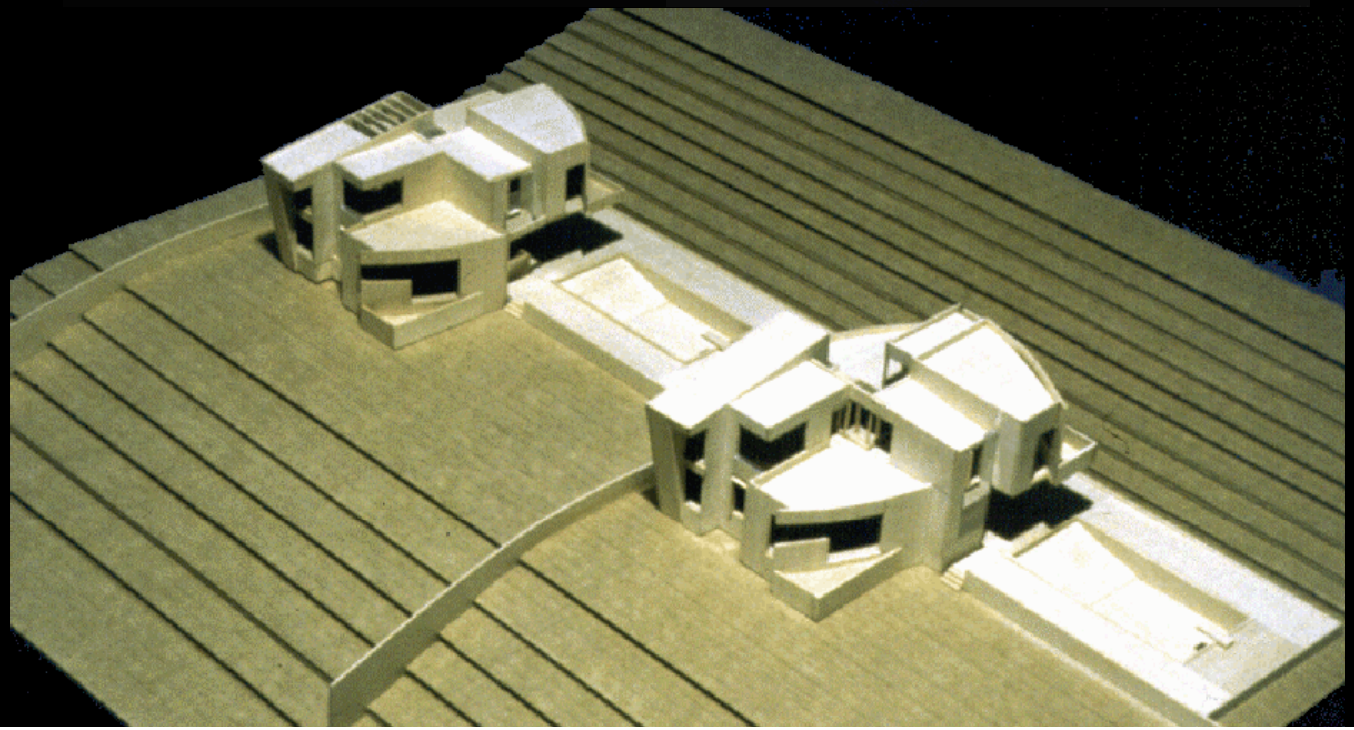


Elementary school in Los Angeles

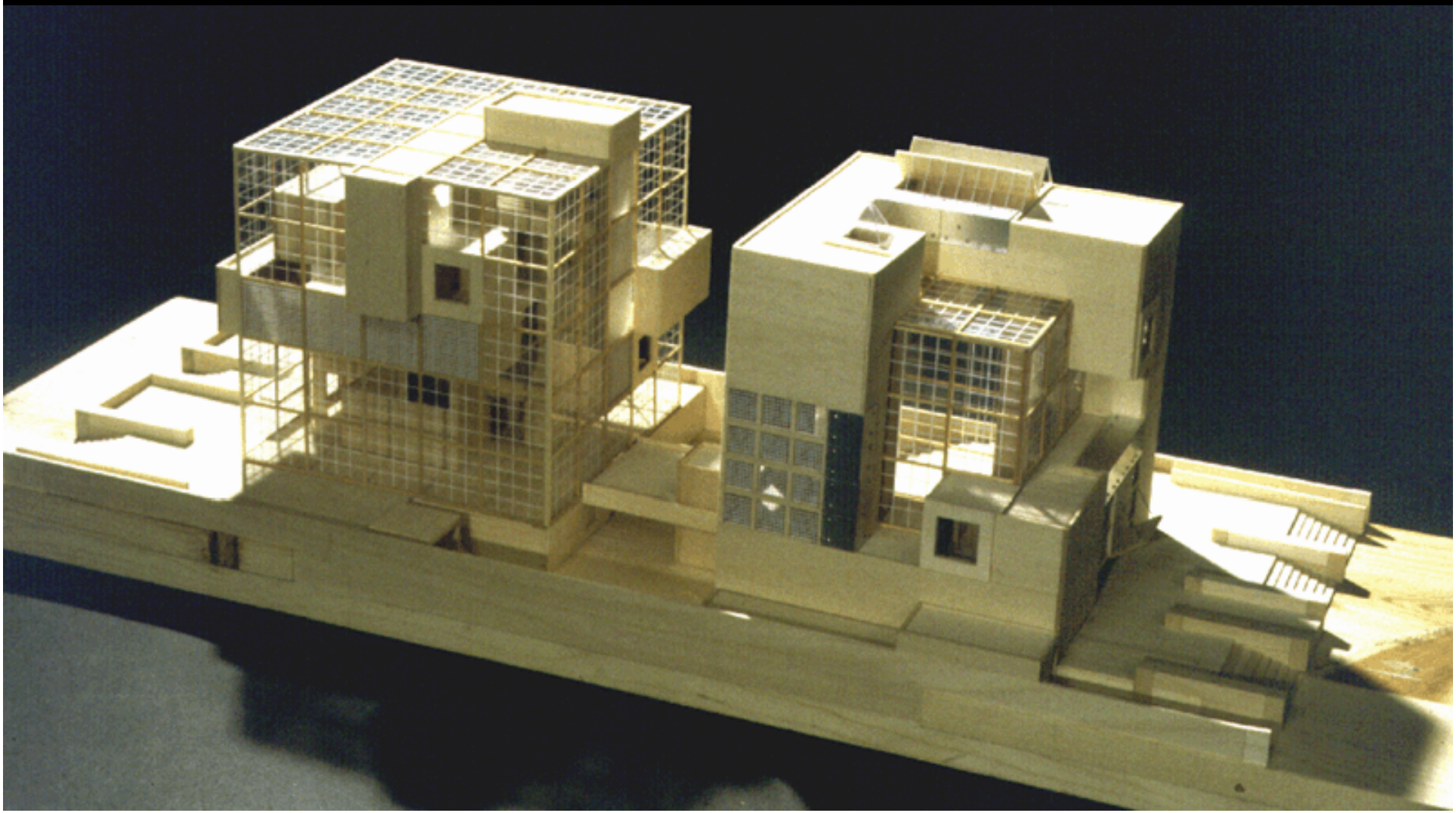


Courtyard houses in Malibu



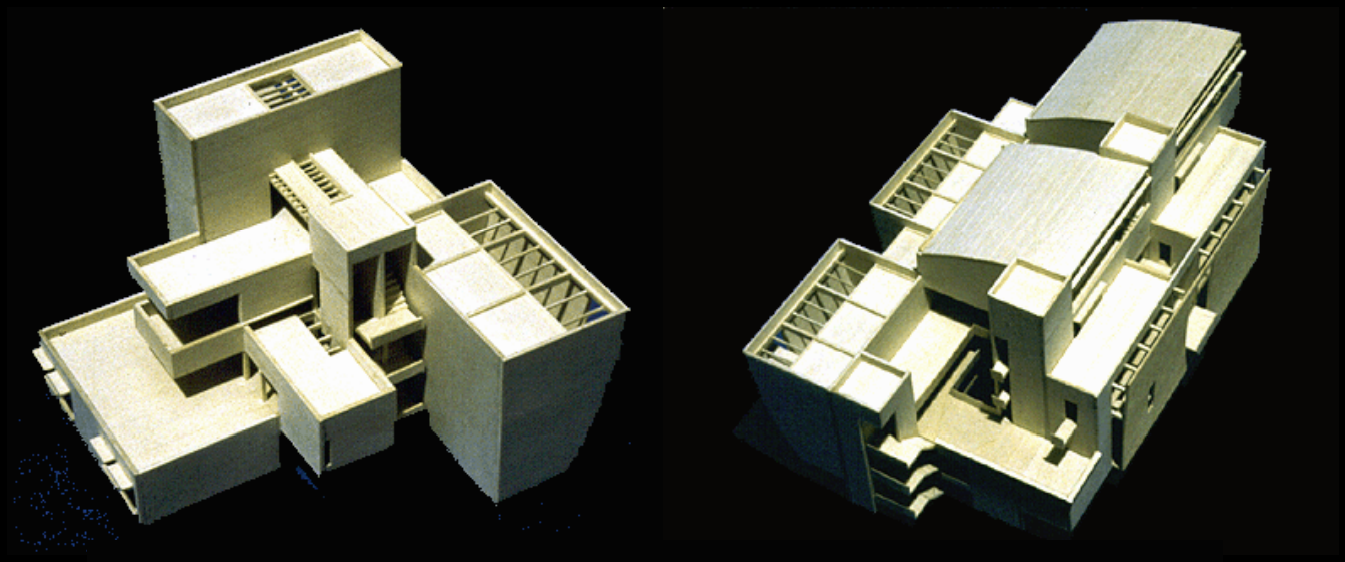


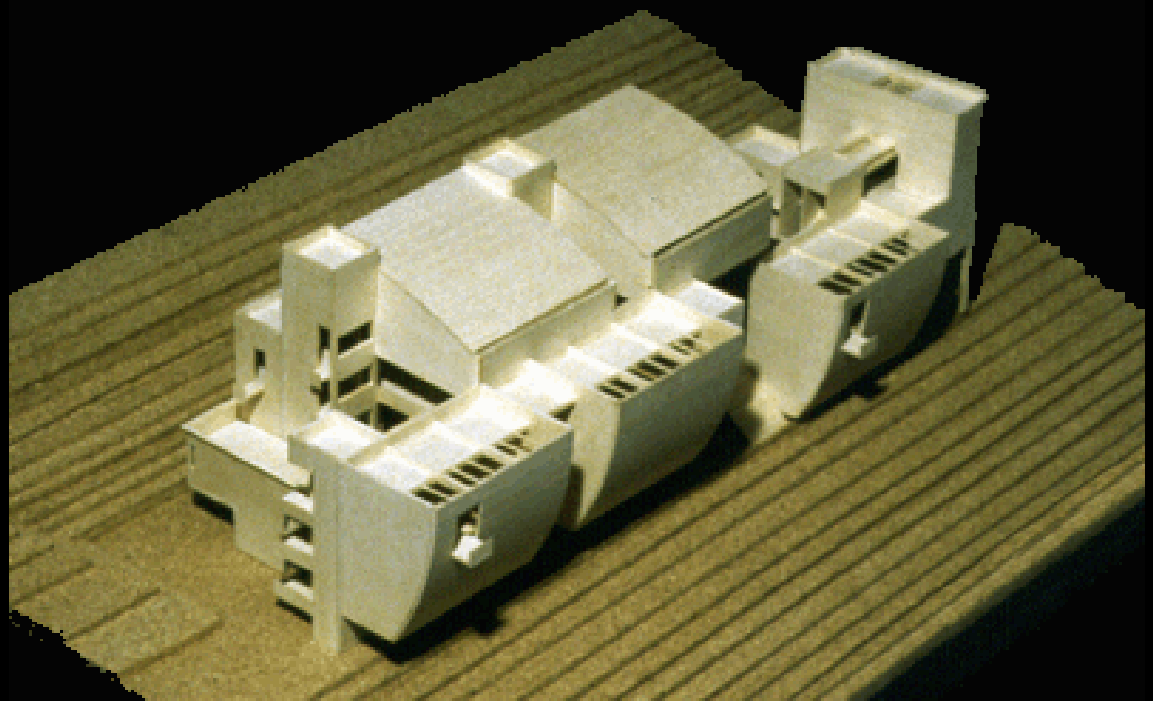
Fine arts museum in Taipei



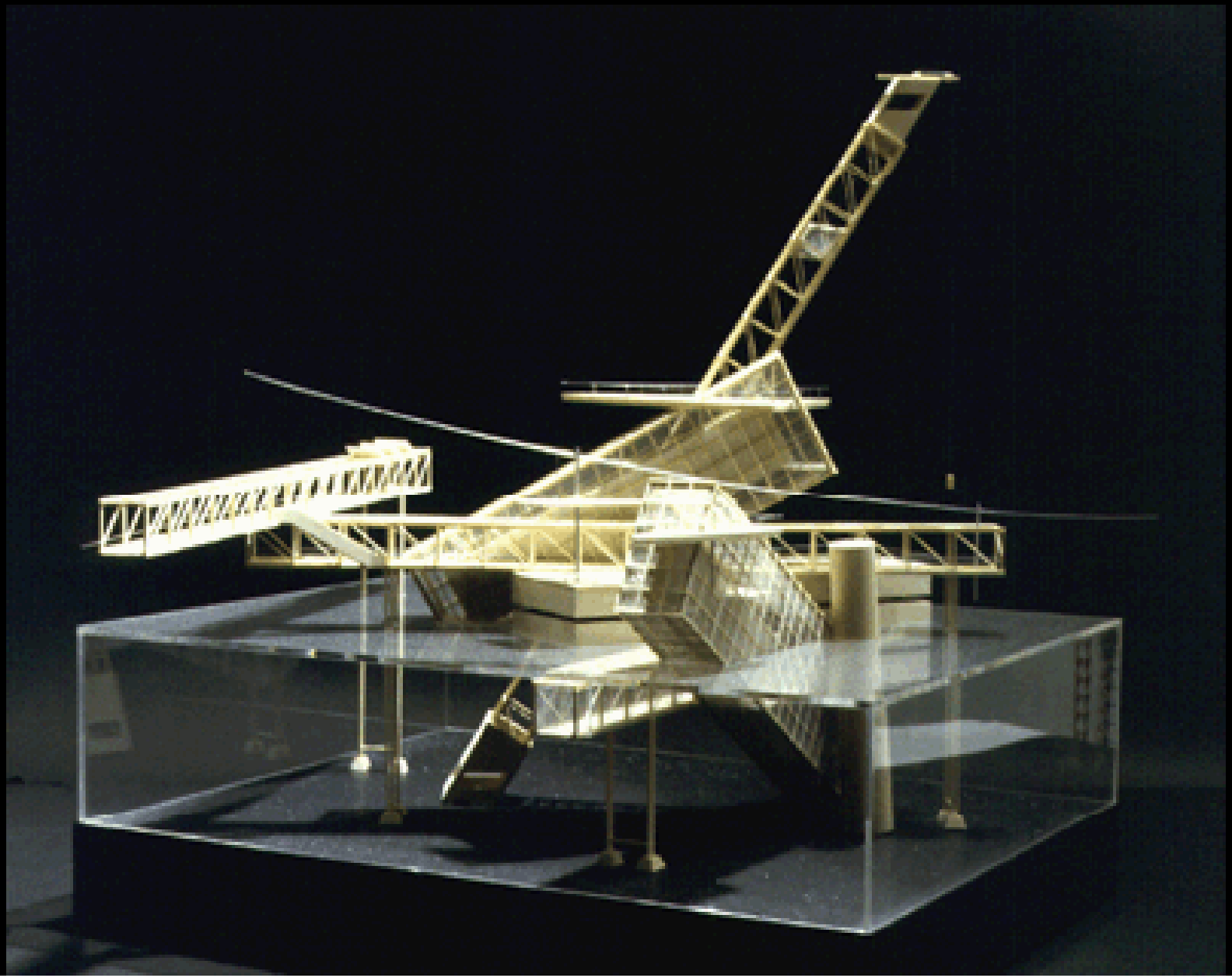
Apartment building in Manhattan

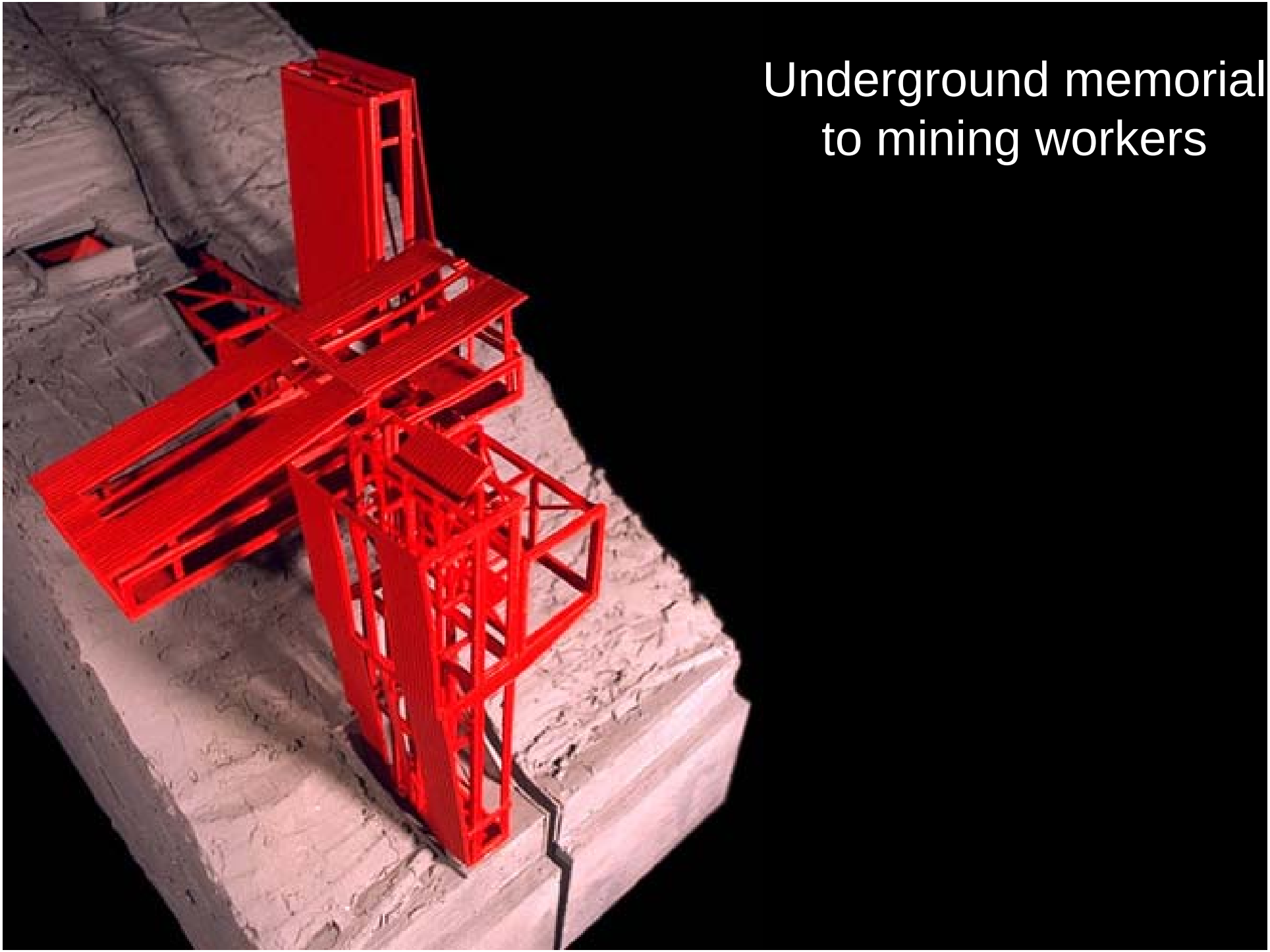
Cultural history museum in LA





Ocean museum in California





Underground memorial
to mining workers

Developing and applying a standard shape grammar

Spatial transformations

translation

rotation

reflection

scale

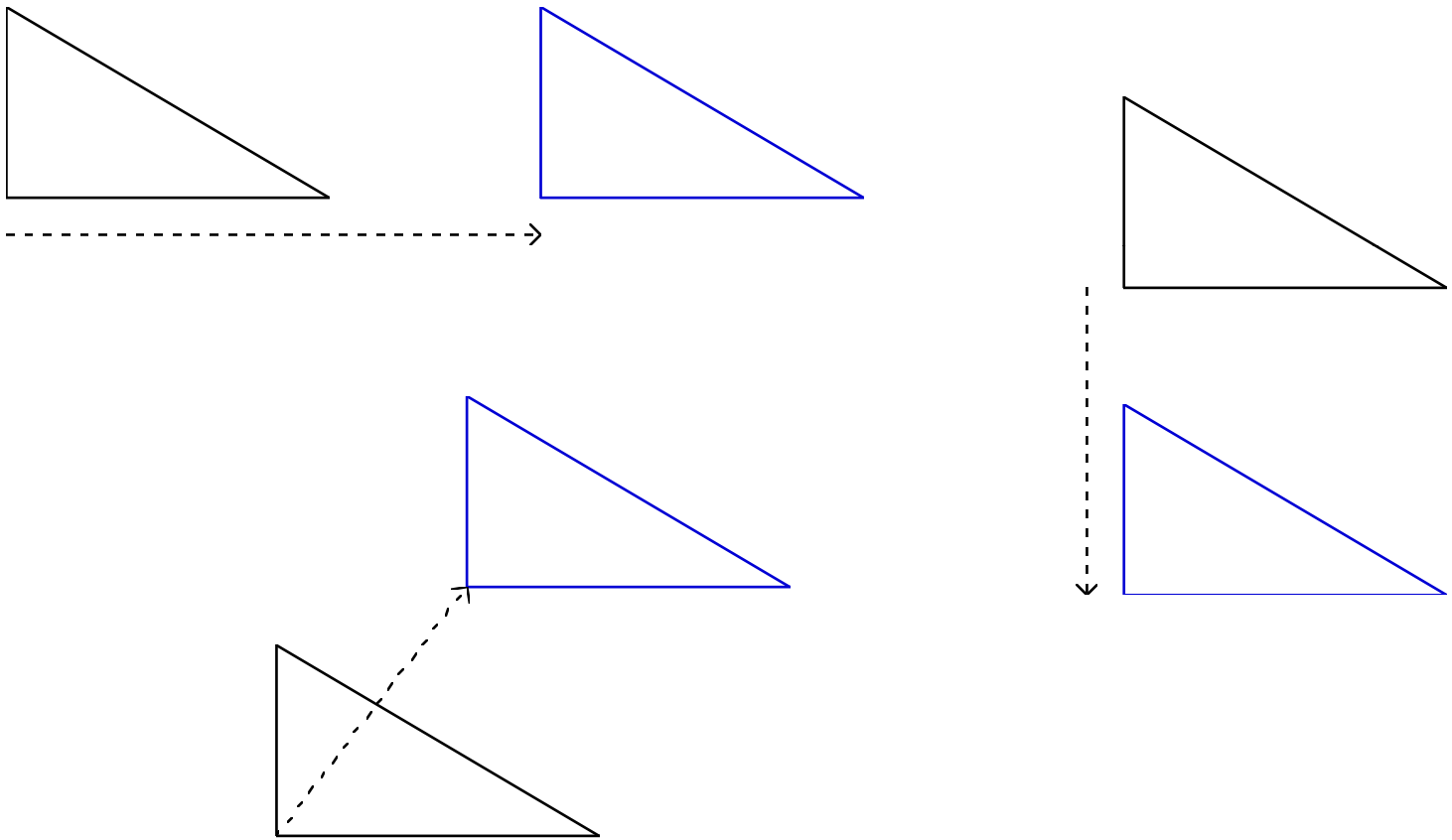
Boolean operations

union

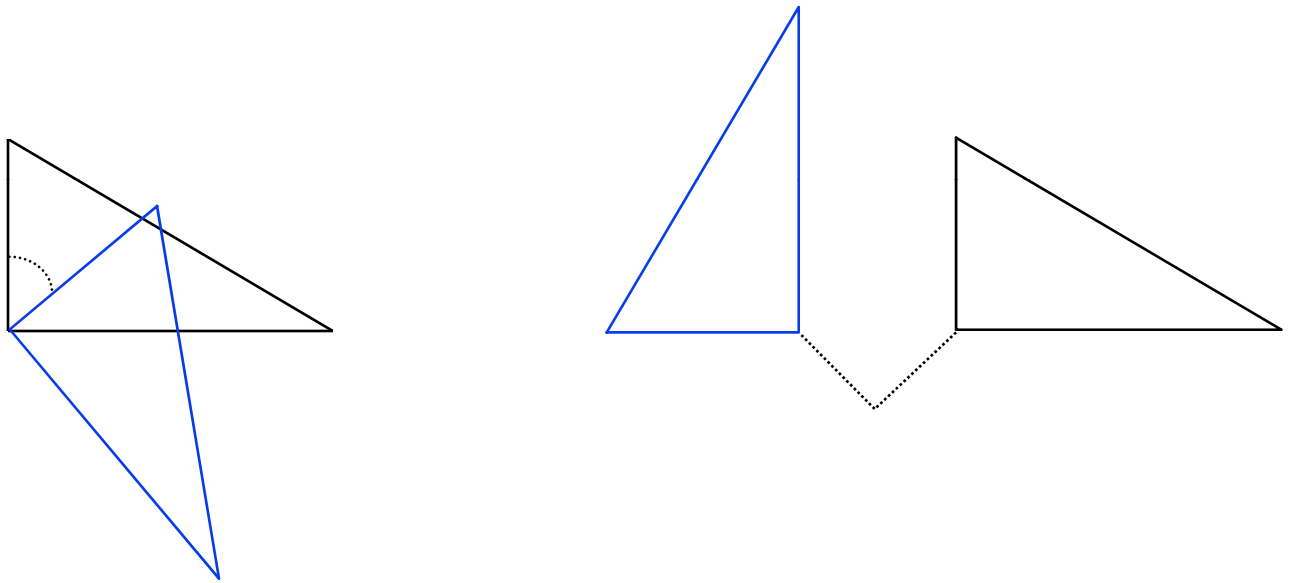
intersection

subtraction

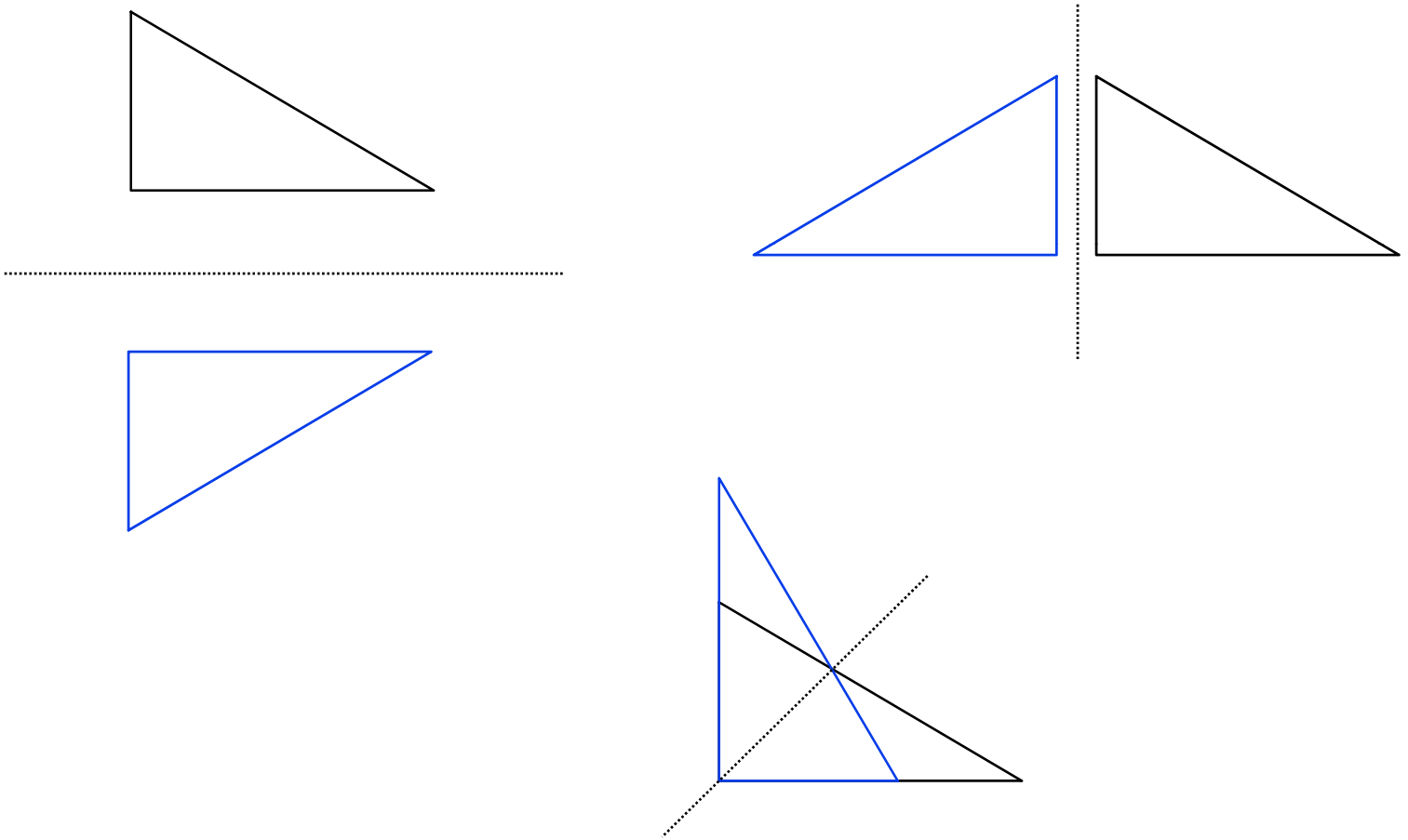
Translation



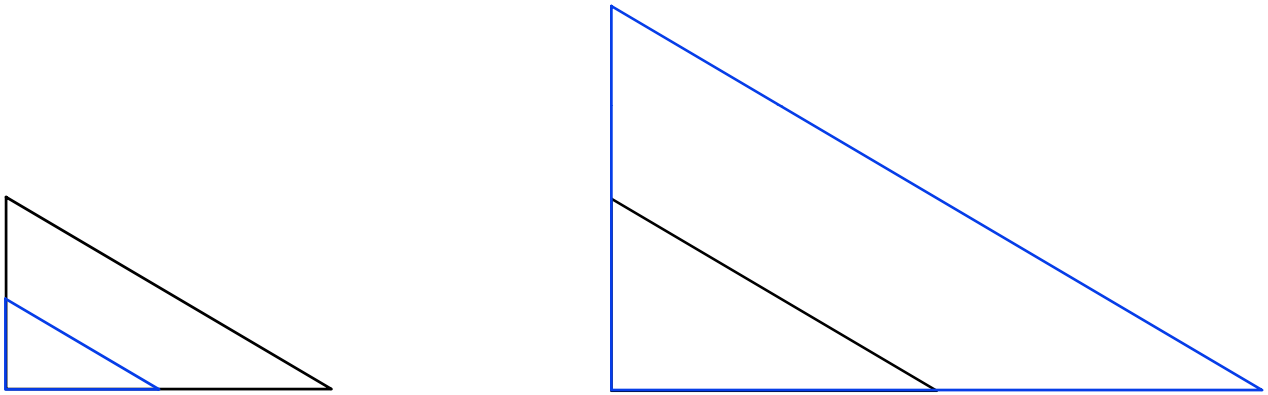
Rotation



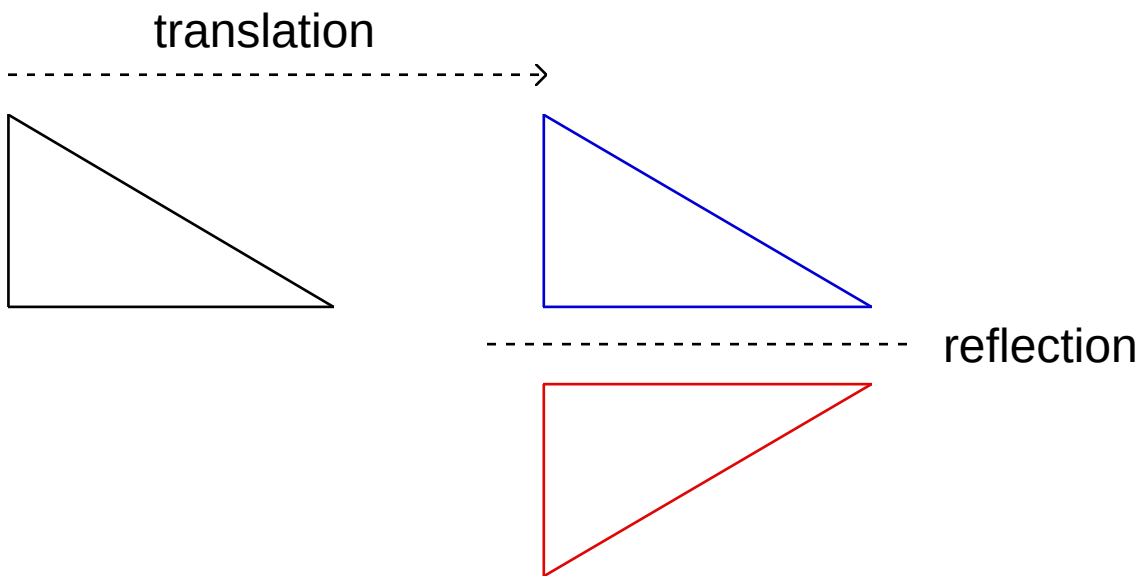
Reflection



Scale



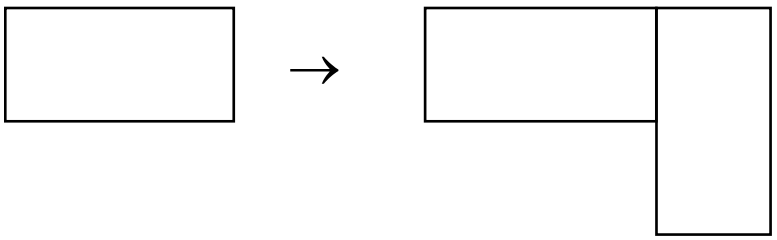
Combinations of transformations



Shape rule:

$A \rightarrow B$

example:



Shape rule: $A \rightarrow B$

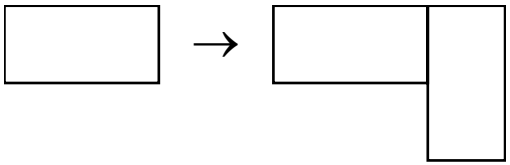
Design

A rule applies to a Design:
whenever there is a transformation *t* that makes the left-side A
a part of the Design.

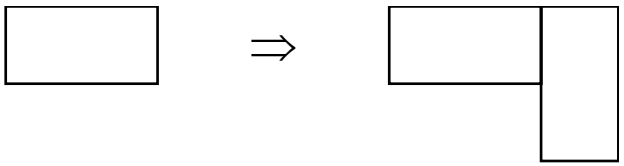
To apply the rule:
first subtract the transformation *t* of the left-side A from the Design,
and then add the same transformation *t* of the right-side B to the Design.

The result of applying the rule is a New Design:
New Design = [Design - *t* (A)] + *t* (B)

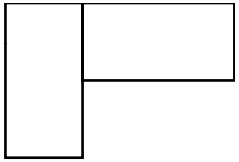
rule



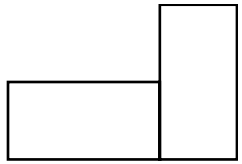
possible rule applications



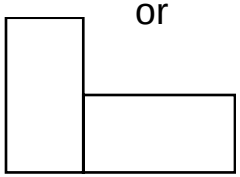
or



or

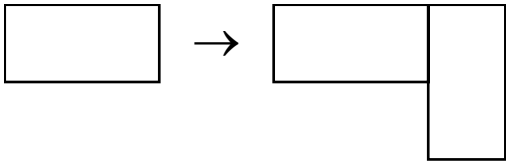


or

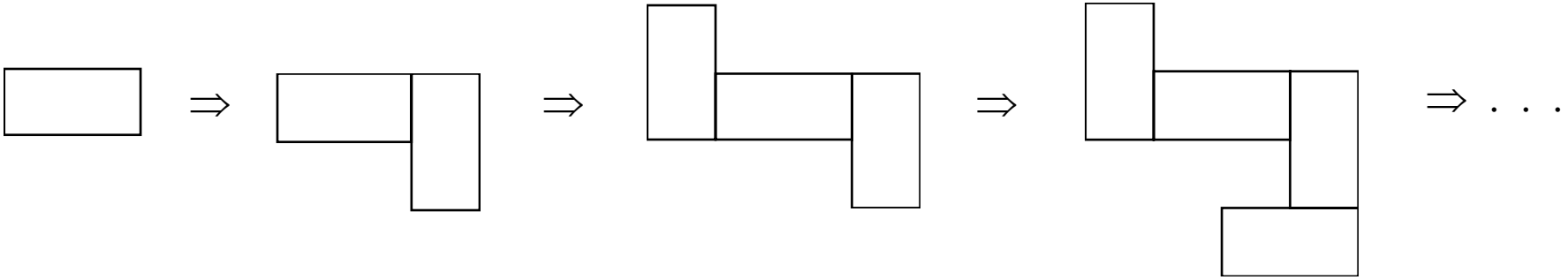


SHAPE GRAMMAR

initial shape 

rule 

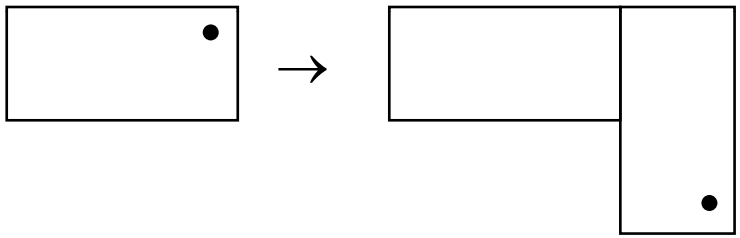
DERIVATION



Labels

symbols, numbers, or words that restrict the way that rules apply

labeled rule

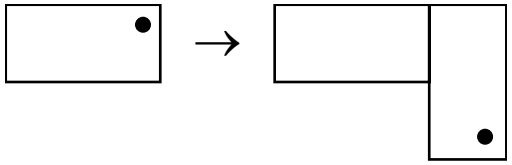


erasing rule

$\bullet \quad \rightarrow$

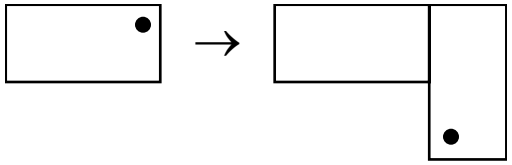
SHAPE GRAMMAR

initial shape 

rules 

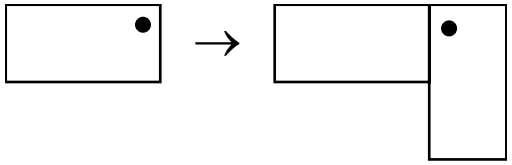
SHAPE GRAMMAR

initial shape 

rules 

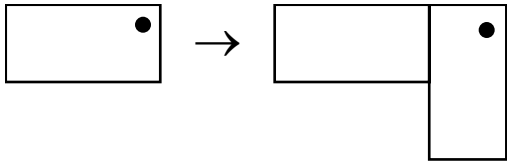
SHAPE GRAMMAR

initial shape 

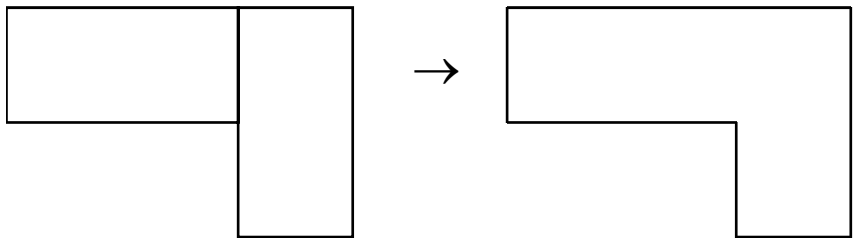
rules 

SHAPE GRAMMAR

initial shape 

rules 

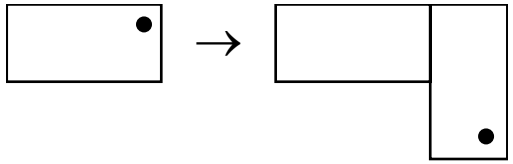
subtraction rule

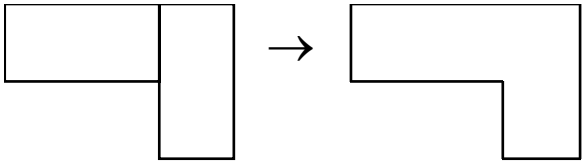


SHAPE GRAMMAR

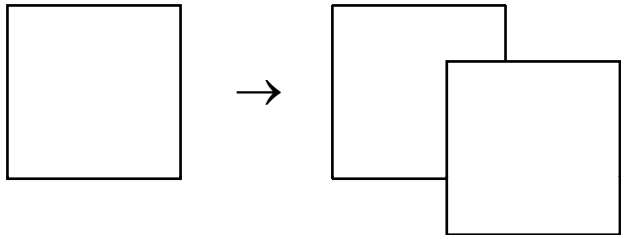
initial shape

rules

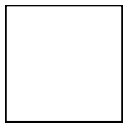


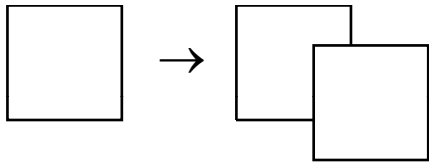


addition and subtraction rule

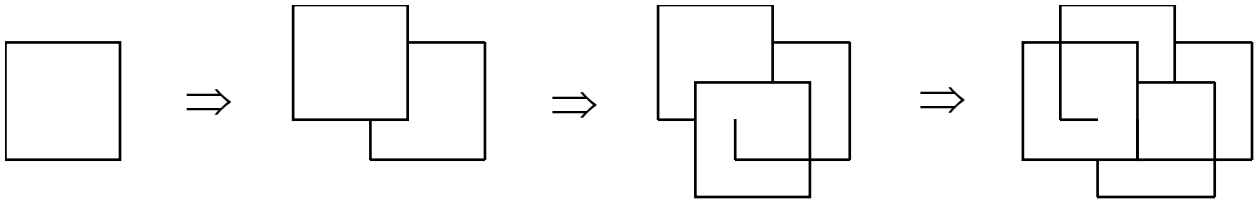


SHAPE GRAMMAR

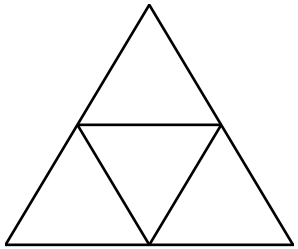
initial shape 

rule 

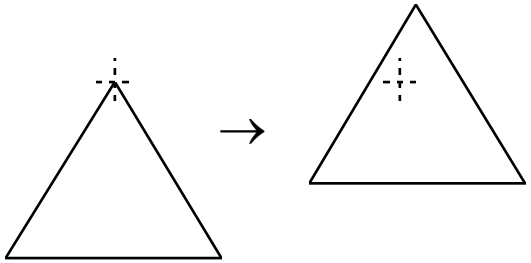
DERIVATION



SHAPE GRAMMAR

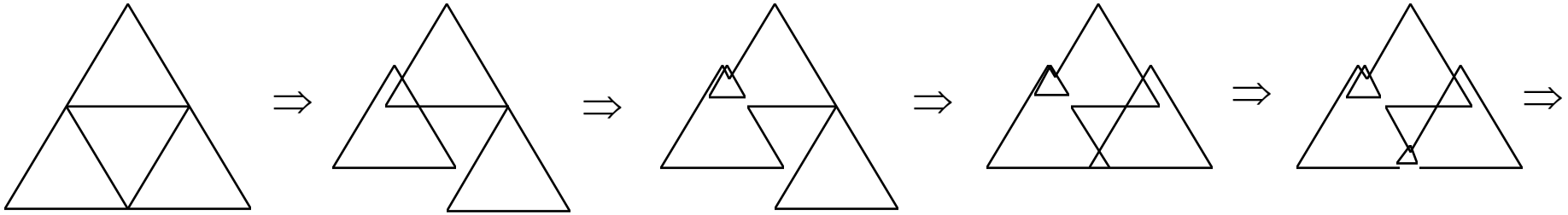


initial shape

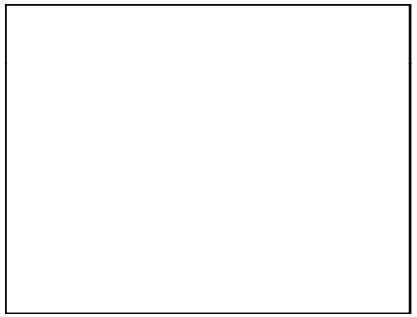


rule

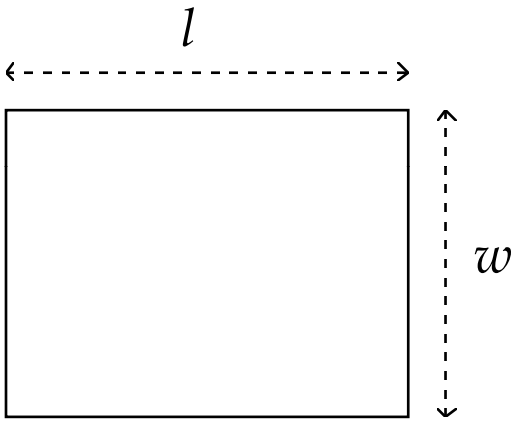
DERIVATION



Developing and applying a parametric shape grammar

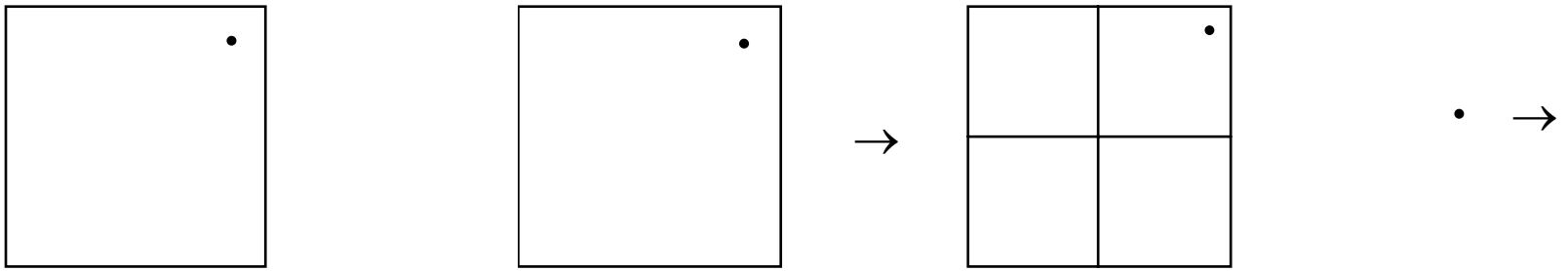


shape



shape schema

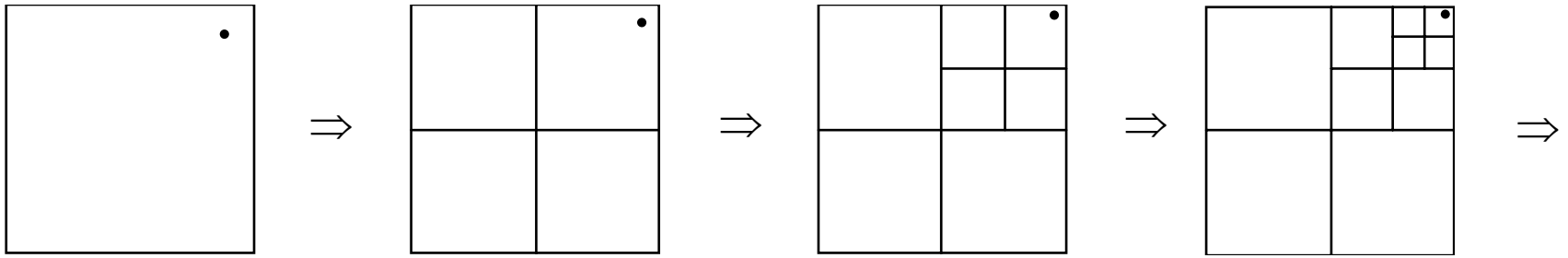
SHAPE GRAMMAR

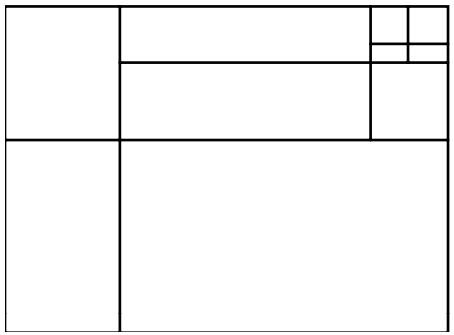


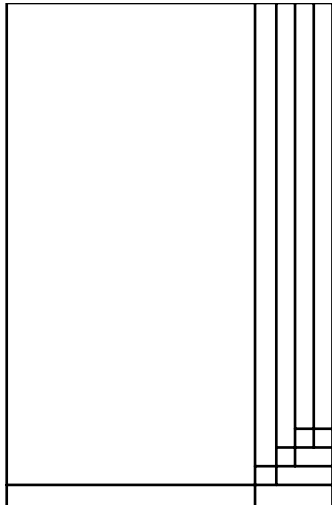
initial shape

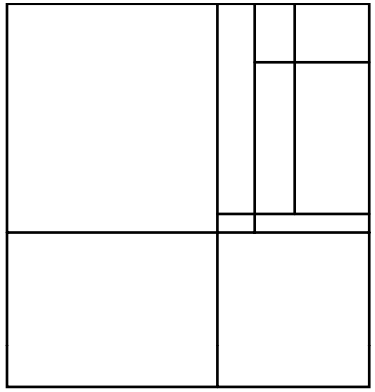
rules

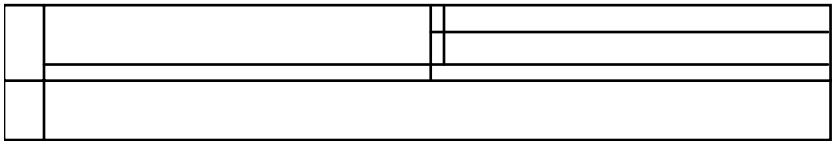
DERIVATION

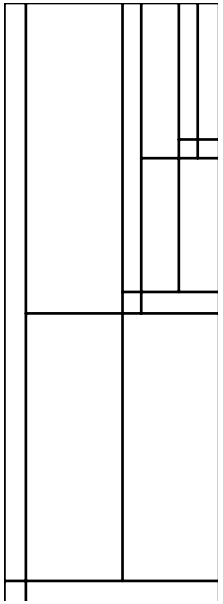


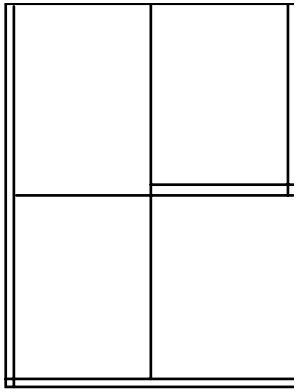


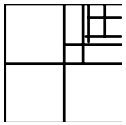




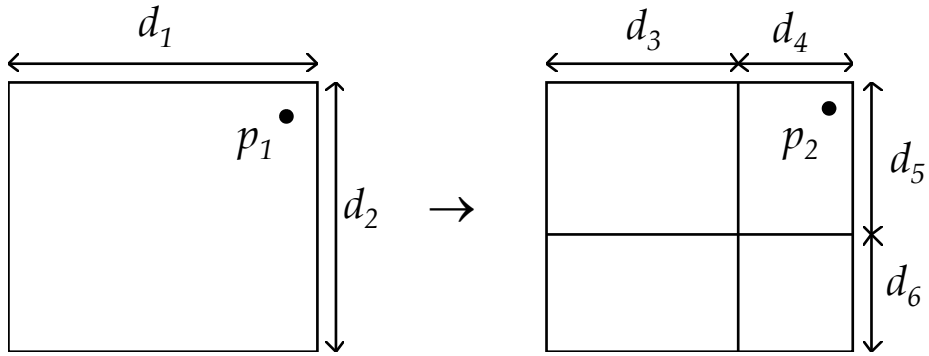








rule schema



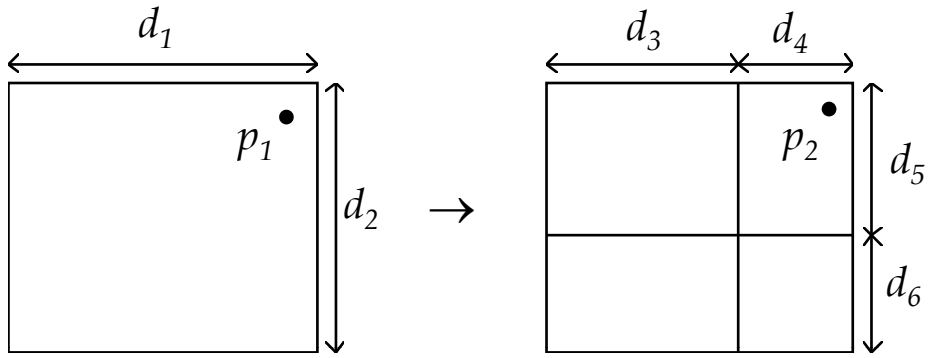
variables in rule schema:

dimensions d_1 , d_2 , d_3 , d_4 , d_5 , d_6
points p_1, p_2

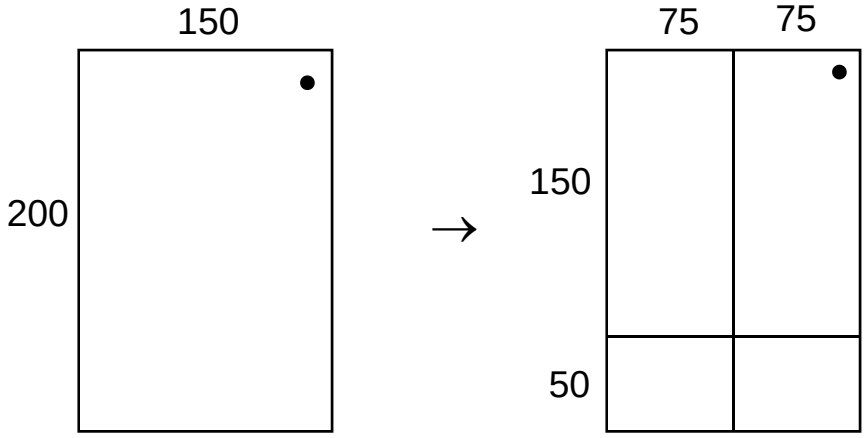
conditions on variables:

d_1 and d_2 are the sides of a rectangle
d_1 , d_2 > 0
d_3 + d_4 = d_1 d_3 , d_4 > 0
d_5 + d_6 = d_2 d_5 , d_6 > 0
p_1 is at the top right quadrant of the rectangle with sides d_1 and d_2
p_2 is at the top right quadrant of the rectangle with sides d_4 and d_5

rule schema



rule



Shape rule schema: A $\rightarrow$ B

Design

Define a standard shape rule from the rule schema:
with an assignment *g* of values to all the variables in A and B.
g (A) $\rightarrow$ *g* (B)

The shape rule *g* (A) $\rightarrow$ *g* (B) applies to a Design in the usual way:
whenever there is a transformation *t* that makes the left-side *g* (A)
a part of the Design.

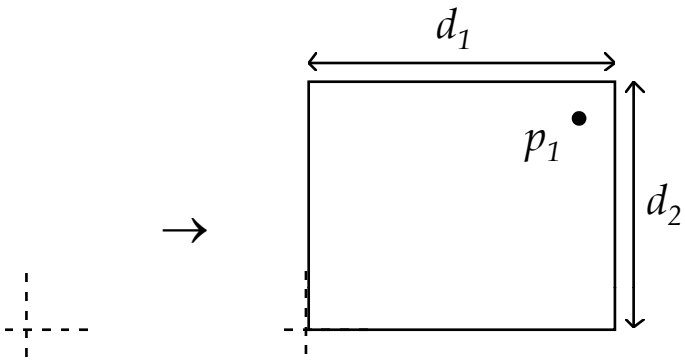
To apply the rule *g* (A) $\rightarrow$ *g* (B):
first subtract the transformation *t* of the left-side *g* (A) from the Design,
and then add the same transformation *t* of the right-side *g* (B) to the Design.

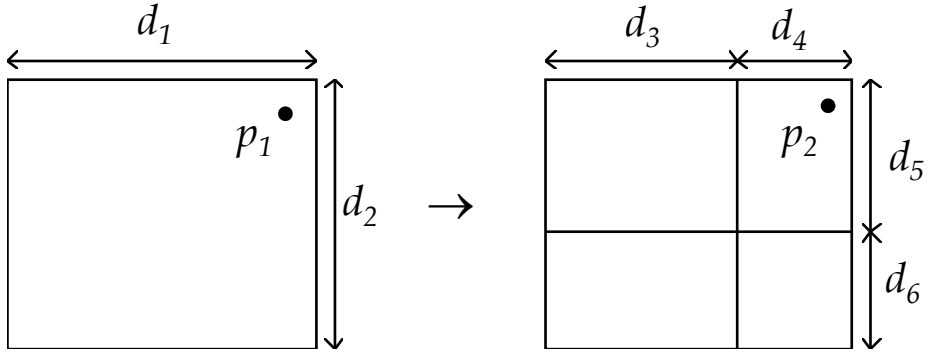
The result of applying the rule is a New Design:
New Design = [Design - *t* (*g* (A))] + *t* (*g* (B))

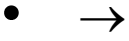
SHAPE GRAMMAR

initial shape

rules







DERIVATION