ALTERNATIVES TO SYNTACTIC PARADIGMS IN CAAD: USING RANDOM NUMBERS IN LAYOUT GENERATION AND SPATIAL MODELING.

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Abstract:

The paper provides instances of graphic techniques using random numbers in layout generation and spatia1 modelling. Leaving aside more elaborate methods based on shape grammars and syntactically oriented schemes, direct graphic procedures useful in computer aided architectural design are discussed. Drawings presented show aleatory input can influence the appearance of computer generated forms.

1. The many uses of randomness.

It is said that Mozart gave instructions for the composition of waltzes based on 'diced' notes, and also that Vivaldi was inspired to create an entire composition from the sequence of notes resulting when his cat leaped unexpectedly upon a keyboard. These could be historical anecdotes, but somehow represent the introduction of randomness in music; a concept that has been fully explored in the XXth century by, composers like Cage, Stockhausen, and Boulez. All of them made use of aleatory notes in their works in various ways.

Xenakis, another musician who has played with randomly generated sounds, believes that dealing, with randomness in an requires a deep philosophical understanding of history.

Equivalent to both the notion of *work in progress* and random improvisation in music was the so called "automatic writing" practiced by James Joyce and a number of surrealist writers in the first decades of this century.

Also the kinetic works of Calder are sculptural objects which can adopt different spatial configurations at random -depending on meteorological forces that act upon them.

In the Middle Ages, Virgil had come to be regarded as a sage and magician. Virgil's poems were used in the type of divination called "sortes", in which the book was opened at random and a verse selected in the same manner as an answer to a problem or question.

Randomness, however, today seems reserved to scientists studying subjects like chaos, complexity, and turbulence. With the pervasiveness of computers, random numbers have turned into common places in physics, chemistry, mathematics, engineering, etc. They are currently, applied to matters as sophisticated as the study of long-term behavior of weather or the simulation of sociological phenomena [1].

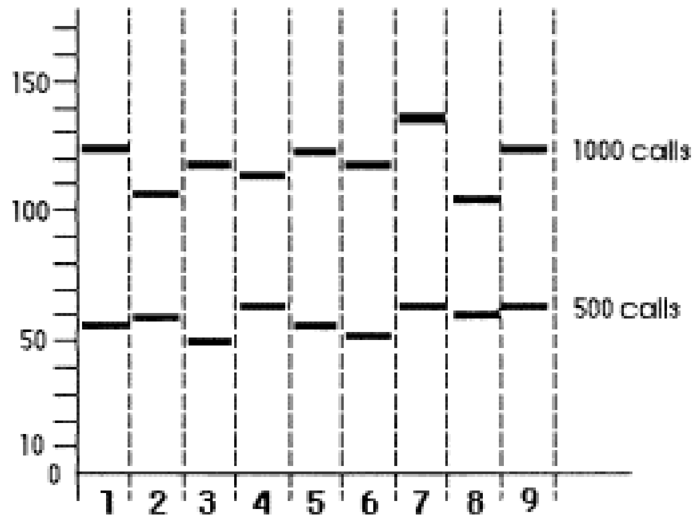
The Webster dictionary, though, defines randomness plainly as <<lacking a definite plan, purpose, or pattern>>, and also <<being or relating to a set or to an element of a set each of

whose elements has equal probability of occurrence>>. We think that this is an reasonable characterization, and with it plus a little of programming a meaningful use of random numbers can be achieved. Particularly, when directly applied to graphic primitives and sets of graphic elements in a computer screen, random numbers can provide a simple and interesting method to generate a vast number of unique shapes. Computer-assisted research on architectural morphology can benefit from applying such a method.

2. Random and pseudo-random.

To approach true or statistical randomness in a series of number, some procedure has to be devised in order to generate numbers whose occurrence offer no discernable pattern. One way to do this is through the computer timer. Most computers allow access to a variable which reflects the pulses of its internal clock and thus provides a series of digits changing periodically. These digits are usually manipulated to calculate the current date on the computer. A routine that picks up one of these digits at any given time can easily, be implemented in order to build a sequence of random numbers.

Most graphics presented in this paper were produced using a random number generator based on a microcomputer time. In order to detect possible regularities in the random sequences generated this way, it became necessary to check for value frequencies by means of the dynamic table shown in Figure 1. Potential deviations or biases in the values were appreciated on the table -which was drawn on the same CAD program as the examples were.



A rondom number generator routine was used to produce most graphics in this paper. Anytime it is invoked, the routine gives an integer between 1 and 9. Two or more digits are combined to form decimal numbers when needed. The table shows value frequencies after two runs of 500 and 1000 consecutive calls.

Figure 1

Sequences of numbers generated in this fashion cannot be called perfectly 'random' as they depend on the internal cycles of the computer. The fact is that pure randomness seems to be a difficult thing to achieve by this or any other means at all. Actually, a prevailing attitude in several scientific fields is that randomness sooner or later unveils a pattern, which in some studies is called *attractor.*

Current software offers anyway pseudo-random generators based either on the computer timer or in algorithms that employ a fixed string of random numbers as seeds to generate new ones. But we thought that writing a routine expressly for our purposes was appropriate this time. One reason for that was the convenience of programming both the random number generator and the graphic examples with the same Lisp interpreter. Additionally, inside the CAD program we used, communication between the random generator and the array of available graphic procedures was fast enough to produce results dynamically on the screen.

3. Applying, numbers to shapes.

Numbers are different from shapes, and so are eventual carriers of numbers like notational signs. Although properties derived from a triangle can translate to numerical or geometric data, a triangle is just a triangle. Shapes are different from words either, as Christopher Alexander pointed out in his essay "Notes on the Synthesis of Form" [2]. Let's remind that Alexander had to resource, to sketches, or primary shapes, to help his analytical method solving the design problems discussed in his book. Underlining the delicate issues that arise when mapping words to objects, Alexander gave entrance to a question whose incidence in recent CAAD research has been determinant: the conflictive relation between shapes and verbal labels in formal languages. These relations are surprisingly not questioned in a great number of CAAD studies. Assigning numerical variables to physical properties of an object is one thing, but applying a verbal label to describe it and substitute it in a "shape algebra" is another. The former can be one of the legitimate uses of formal languages; the latter can represent an abuse of language in the sense that Wittgenstein gave to this matter. Wittgenstein said that functions of natural language cannot all be expressed by formal languages [3]. This seems particularly true when mapping, precise words or biuinivocal signs to shapes whose main problem is interpretation, as it happens in architecture.

Now more than ever, computers offer the possibility of linking notational languages to shapes through programs. Unfortunately, programming sometimes turns to be an alibi for logicians and linguists to explore a field which otherwise would be unattainable to them: the domain of form and meaningful form manipulation.

We have attempted to bypass the many problems that notational representation of architectural information poses. Our concern was, to apply numbers to shapes as purely as we could, taking advantage of several random techniques of easy explanation. Then morphological research is here the topic in focus. We would like our paper to be understood as a piece of *minimal art*, as it tries to give an immediate response to the question of how computers can be applied to architectural modelling.

4. Exercises on 2D

Our Proposal for using random numbers centers on primary graphic operations on the screen. Primary graphic operations can be considered void from representational content and include sketches, all sorts of scribbling, free painting, etc.

In computers, one way to relate random numbers to a 2D primitive like a straight line is defining its end points randomly. Figure 2 shows the results of applying this technique over different sets of straight line segments.

43 lines 90 lines 139 lines

Figure 2

Randomly defined points in a plane can link arcs and straight_lines also, as Figure 3 shows.

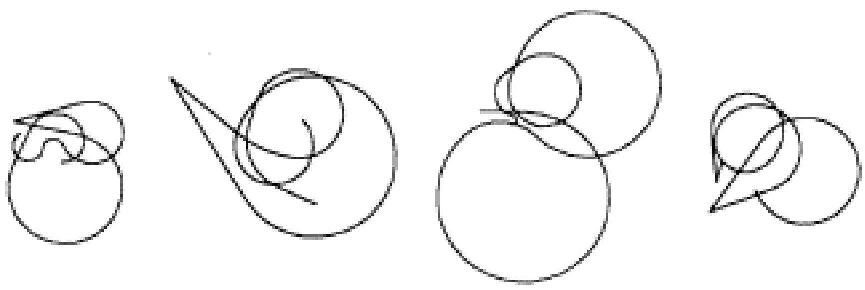


Figure 3

If end points of straight lines are connected, we obtain pictures similar to Figure 4. As in Figure 21, random points were constrained to appear into a square area.

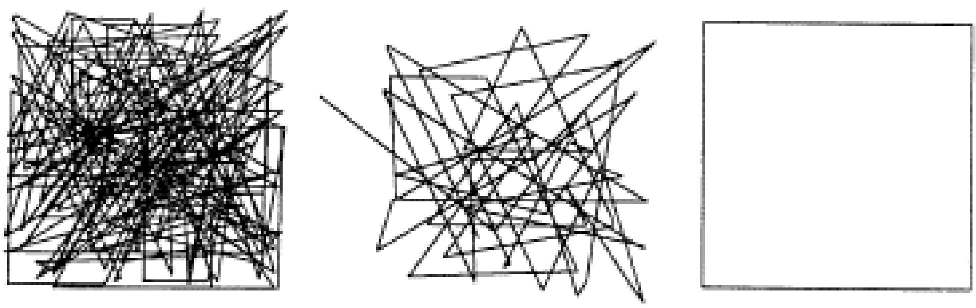
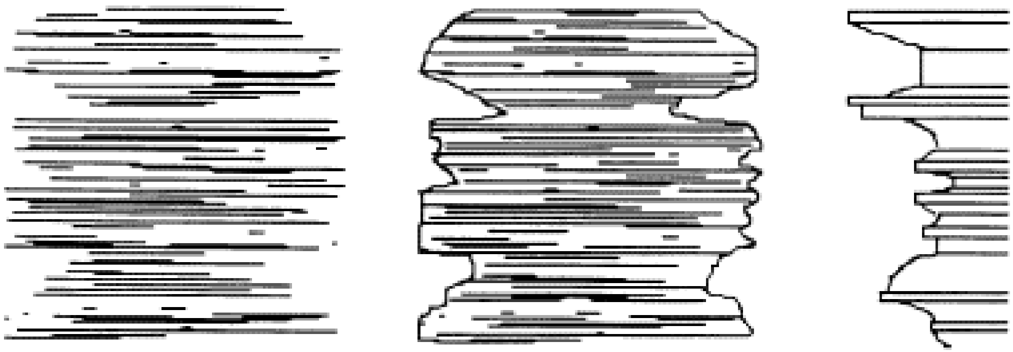


Figure 4

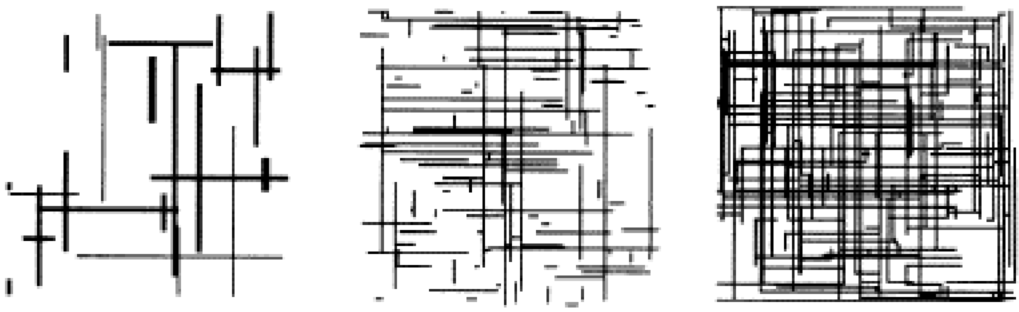
Next drawing comes from limiting direction of straight lines to one orthogonal axis (Figure 5, left)



(interpretation of the drawing on the left)

Figure 5

When combining lines in two perpendicular directions, we obtained pictures shown in Figure 6, which remind of works of Piet Mondrian. Drawings 6-*a* and 6-*b* are the result of mixing vertical and horizontal straight lines randomly. In drawing 6-*c* a constrain that lines be connected in "L" was added. Again, all drawing elements were forced to appear in a square area each time.



a b c

Figure 6

5. Random generation of layouts and facades.

The next series of exercises dwell on the possibility of directly sketching, layouts and facade prototypes on the screen. Some of the following drawings have a 'mondrianesque' flavor, and could be used to find parties when outlining architectural plants and elevations.

Since a computer screen is strictly ruled by logic and Cartesian coordinates, randomly produced drawings can overcome this rigidity, and approach more live pictorial actions. On watching these drawings, it becomes apparent that sophisticated techniques are not necessary to turn a computer into something 'Intelligent'. Random numbers allow for a kind of computer-usage different from that of a mere drawing machine. By producing a large variety, of potential solutions, the computer is able to design decisions at the outset of the creative process.

5. 1. Random divisions in a square (Figure 7). Compositional ideas for facades could be obtained from these graphics, as well as general distributions for a plant. Created to work with any rectangular figure, the routine for dividing the squares starts with two opposite corners and then asks for the number of partitions desired in X and Y directions.

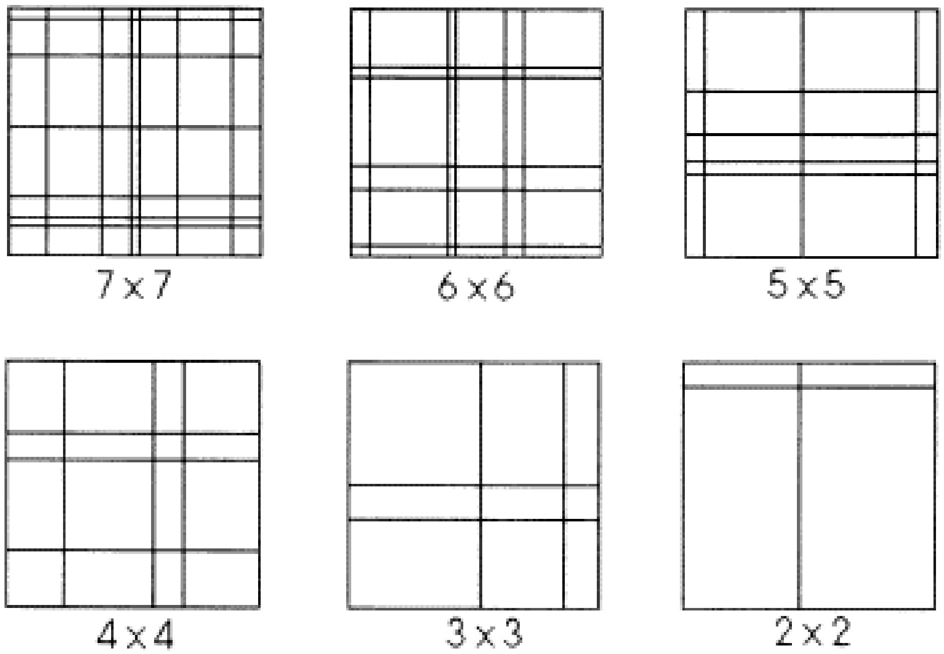


Figure 7

5.2. Random edged divisions in a square (Figure 8). Similarly to the previous example, compositional ideas for facades could be obtained from these drawings . Wall partitions in a plant could be studied with this routine too. Created to work within any rectangular shape, the routine starts with two opposite corners given graphically by the operator and then asks for the number of partitions desired in X and Y directions (5 in the example). There is a prompt for entering the edge width also.

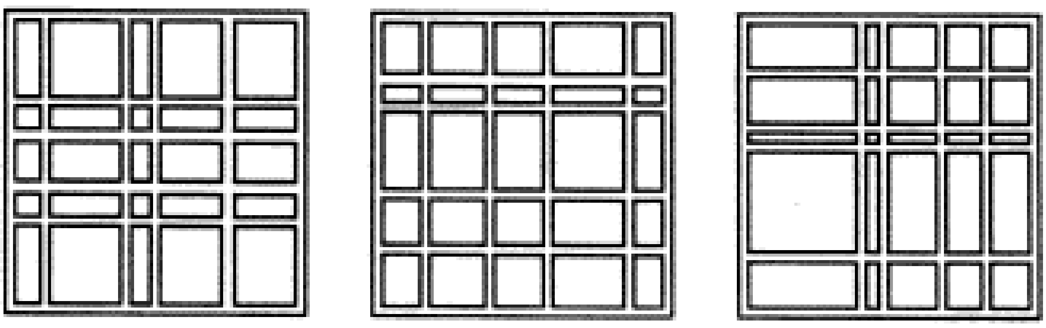


Figure 8

5.3. The following are randomly, composed facade prototypes that can be of interest in urban projects (Figure 9). A number of aleatory adjacent rectangles is stipulated, and then an array of windows is automatically produced for each 'building'. Maximum and minimum values for all rectangular entitles, affecting both width and height, can be limited by specific coefficients introduced in the routine.

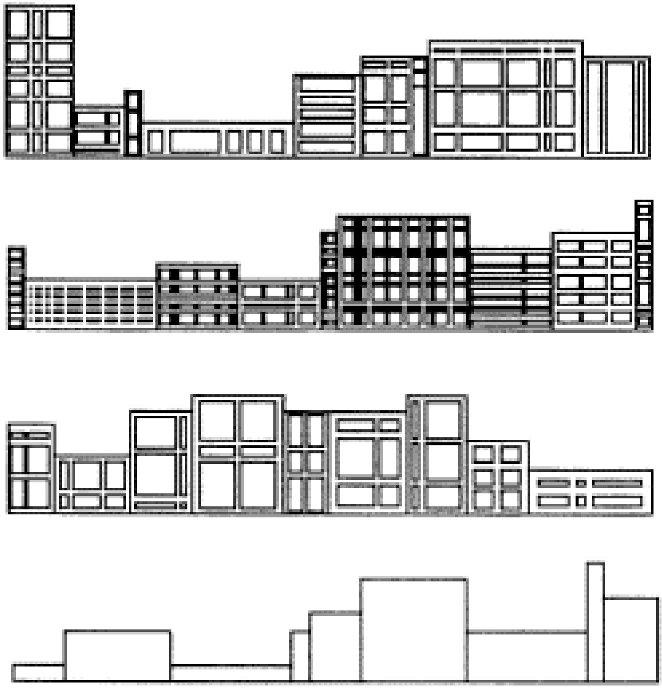


Figure 9

6. Random numbers and 3D shape generation.

An easy but effective way of using random numbers in 3D space is to start with a block having specific geometric characteristics, and then randomly change them throughout the drawing. By repeating the same basis block in different positions and with varying sizes and angles, unexpected spatial relations begin to emerge. (our first 3D routines were then not truly generating procedures, as they were devised to modify objects which already existed)

We used an array of 10 x 10 cubes to do our first experiments (Figure 10)

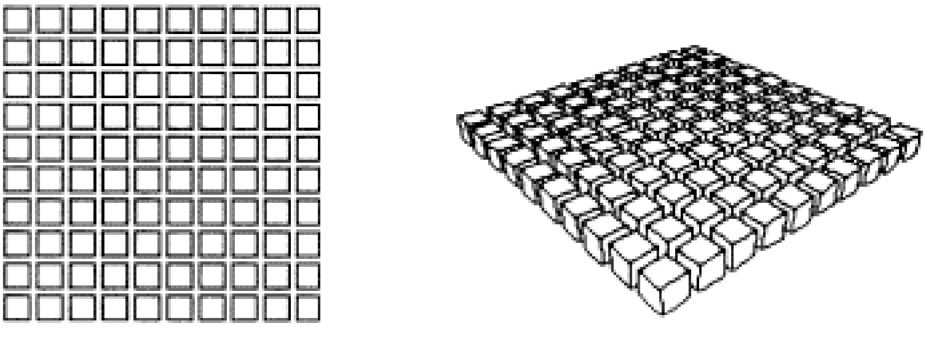


Figure 10

When a random number generator was applied to height only, results were as in Figure 11. Maximum and minimum values for height could be predetermined.

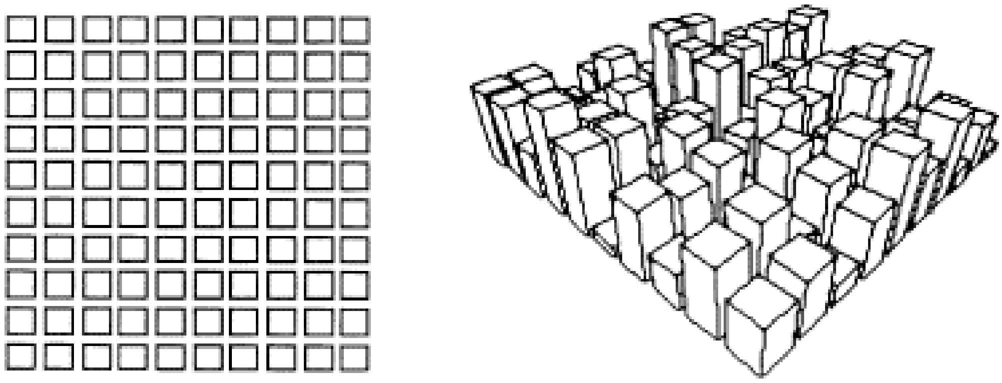


Figure 11

The insertion angle for each individual cube can he given randomly. By doing, so the initial array of cubes transforms into something, like Figure 12.

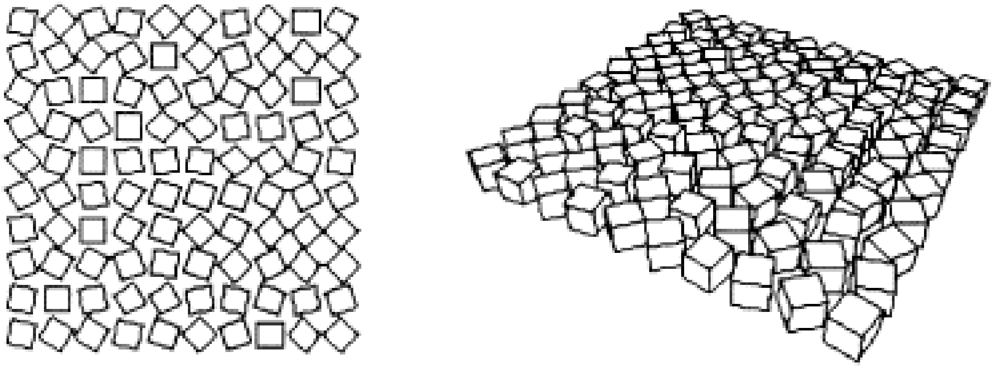


Figure 12

Next drawing shows the results varying heights randomly when using a truncated prism instead of the initial block (Figure 13).

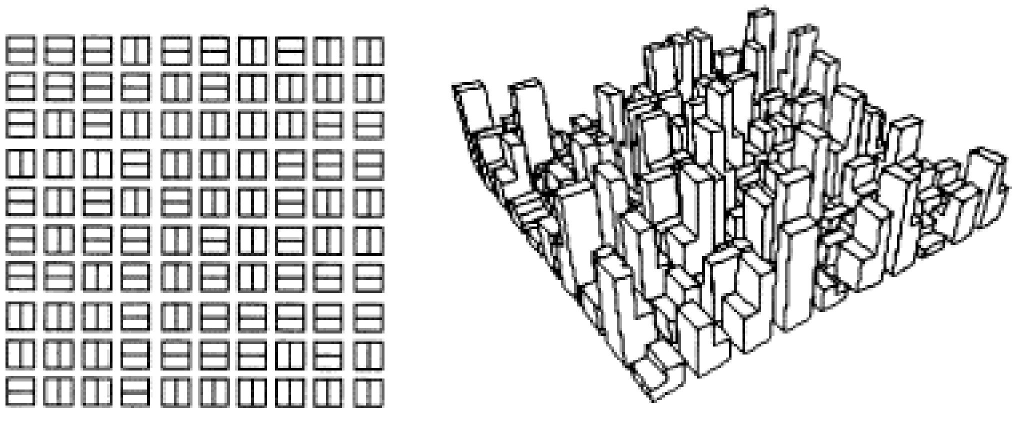


Figure 13

Last but not least, we applied a random deformation to the cubes in two axis, but maintained the same height over the entire array (Figure 13).

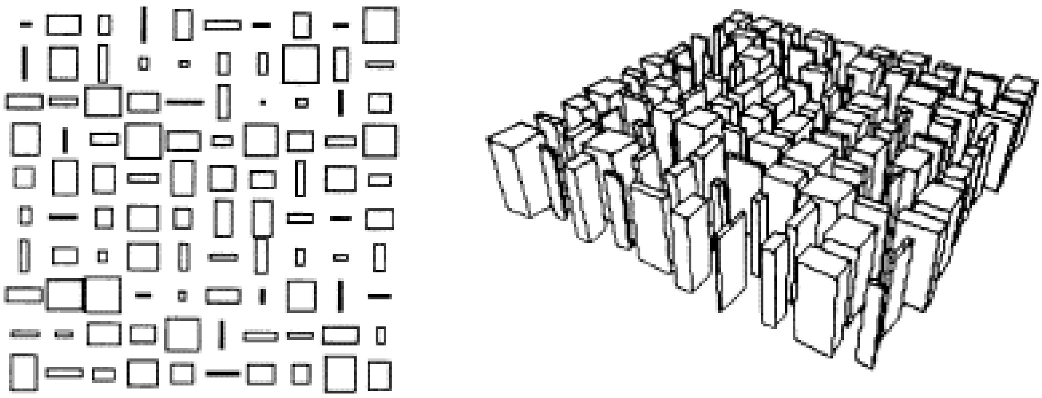


Figure 13

Another set of 3D shapes was produced extending, the scope of the previous routines. The new ones can generate their own array each time they are called. Thus the operator, can determine the number of items to appear in both X and Y axis, and fix interstices between objects in each direction (Figure 14).

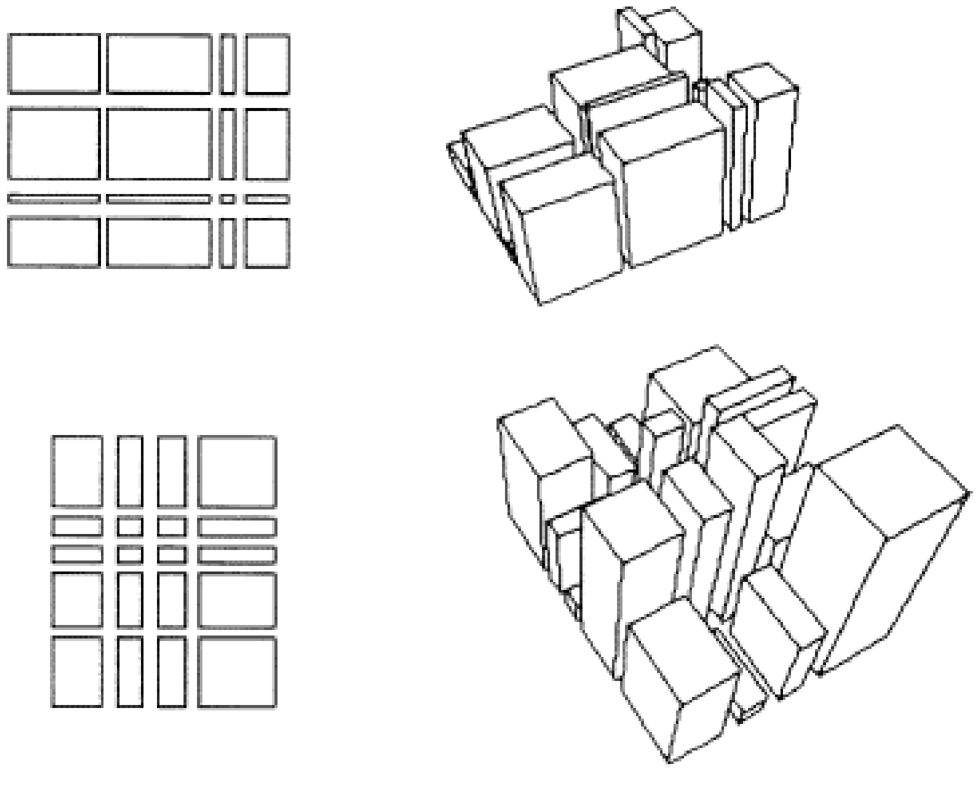


Figure 14

Combining different shapes is an easy method to get unpredictable 3D output also. The following images show what. can be obtained from assembling a parallelepiped and a bevelled prism on the top. The new unit was randomly, repeated over a rectangular area, in the same fashion as the precedent examples (Figure 15).

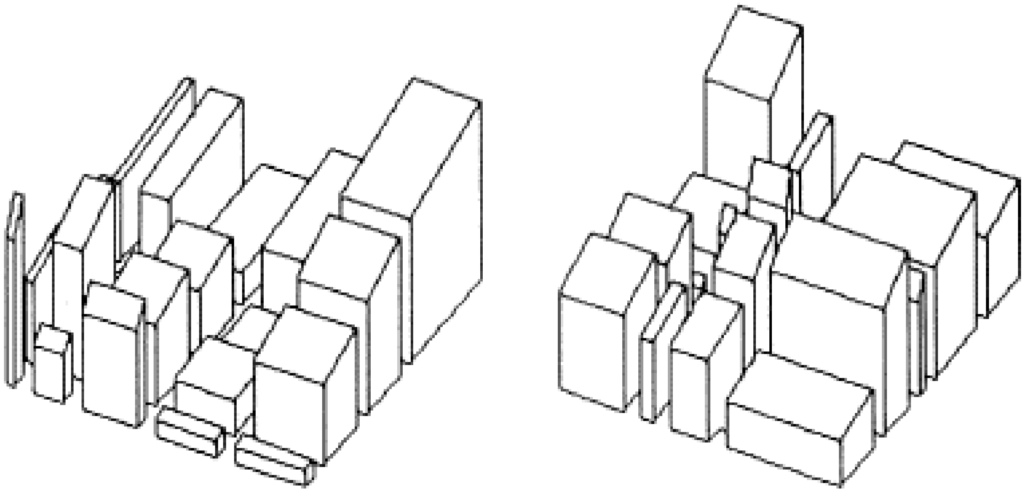


Figure 15

A flat-shading based rendering of a similar assembly is shown next (Figure 16)

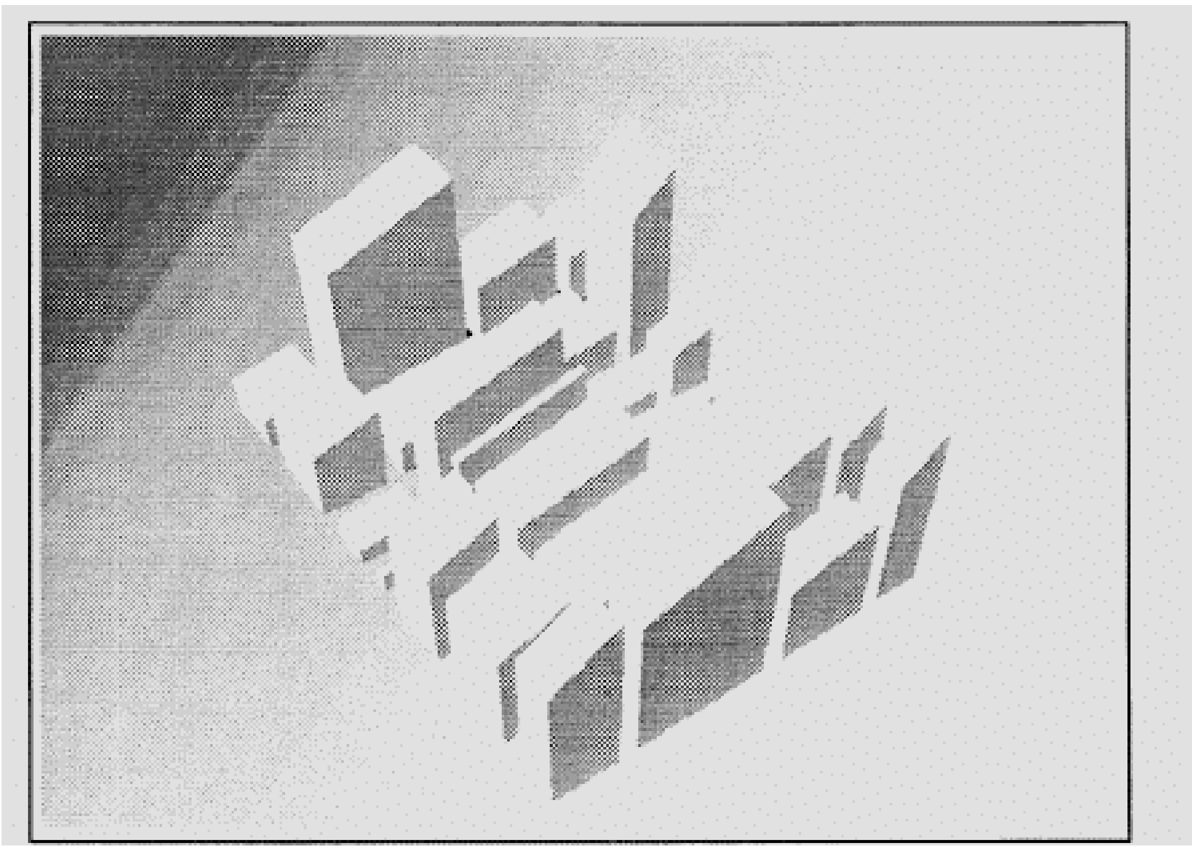


Figure 16

A routine that draws a single parallelepiped and then randomly 'slices" it in X, Y, and Z directions was tried next (Figure 17). The operator is asked to enter two opposite comers for the base, then the prism's height, and finally the desired number of cuts in each direction as well as their width. Divisions appear randomly after that. (The examples are based on cubes)

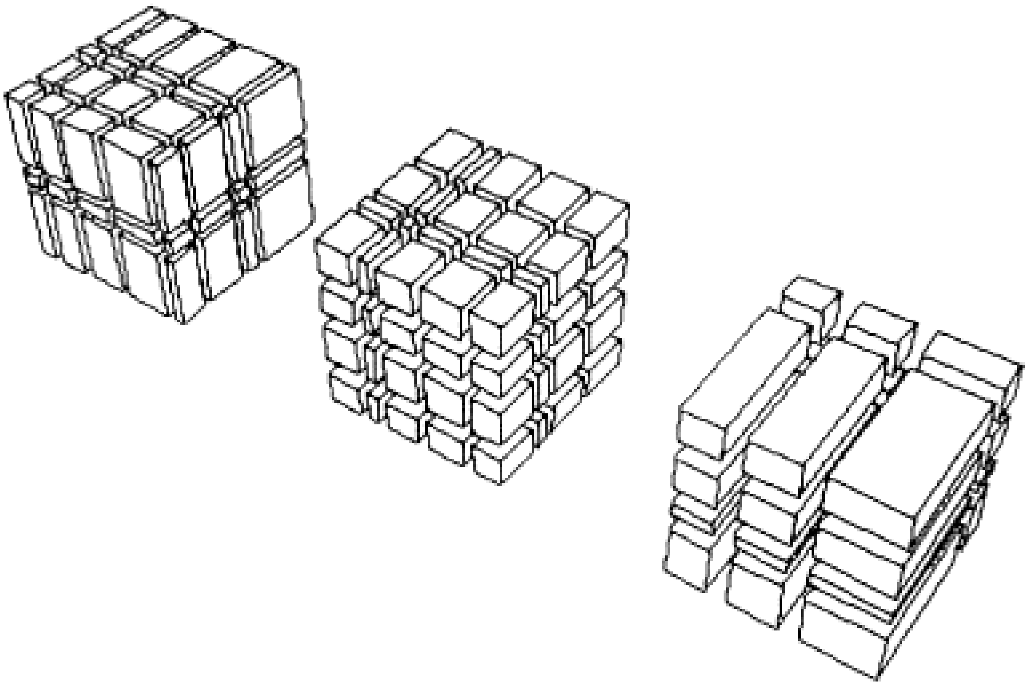


Figure 17

7. "Parameterization" of an architectural type

If a computer model of an architectural type is divided into different parts (blocks), then random scalar factors can be used when re-assembling, these parts. By doing so, completely new objects can emerge. Topology, is not changed in any of them, but the outcome can be quite diverse from applying parametric variations to a model, which usually is performed after evaluating precise dimensional constraints and relations between parts. Parametric design was first developed for mechanical design problems, and later extended to the automation of repetitive components of architectural construction such as fire stairs. By means of parametrics a final design may be derived by refining, but not fundamentally changing the prototype, in the sense that all pieces retain the same general form. Parametrics shouldn't imply significant modifications of the formal aspect of the object being parameterized. The main purpose of industrial parametric programs is helping production of versions of the same object, rather than injuring what meaningful shapes could be discovered along the process.

We are aware then that 'parametrics' is perhaps not the best word to refer to the experiment presented next, in which a prototypic computer model of the dome of Saint Peter in Rome was built (Figure 18). We use it to try some of the techniques shown previously. The idea behind this exercise was again very, simple. We cut the model of the dome vertically in several parts, so that we could apply aleatory numbers to height in each of them. A routine was written to gather the randomly modified parts into a new dome. After a few runs, we found that the routine have delivered not only all sorts of deformable domes, but also what can be defined as new architectural 'types', which was not expected at all. For instance, it became clear that feasible rotundas could be obtained from the geometry of a classic dome manipulated this way. Also, towers with a 'gaudinian' style were easily obtained when first results of the random number generator were increased by a factor of two or three. Objects reminiscent of some oriental architectures were found too.

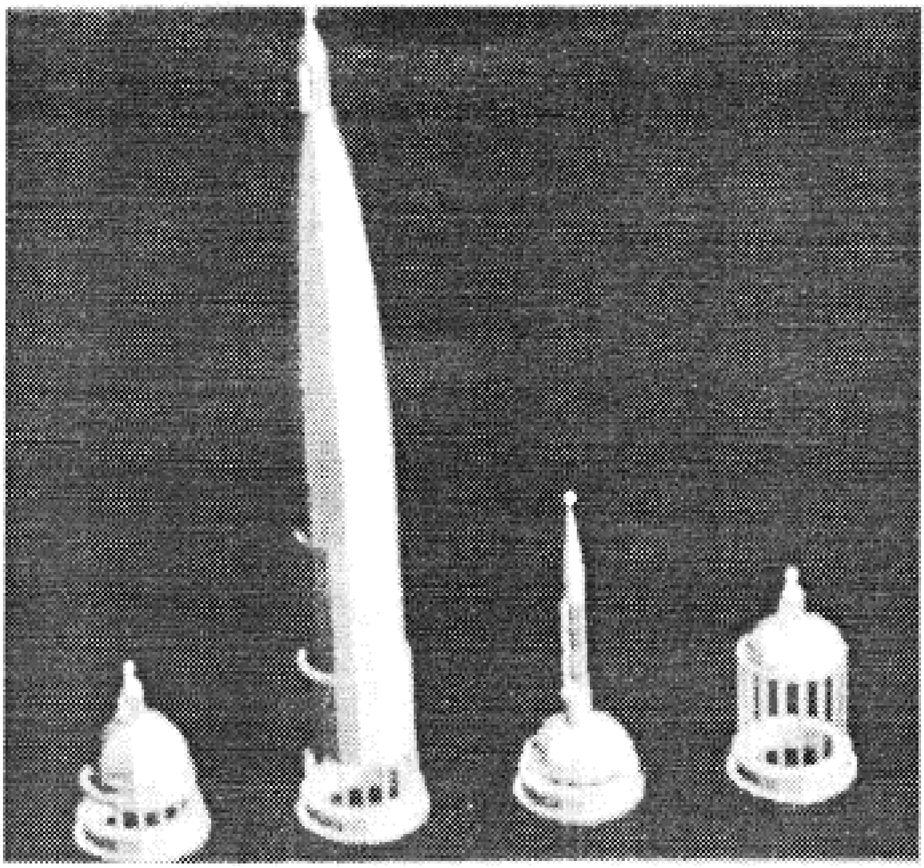


Figure 18

Conclusions.

Georges Braque used to say, that he would never begin a painting if he had the picture for it clearly on his mind. Creativity, in his own words, was "a surprise that the artist reserves to himself". In the CAAD field, routine design and procedural modelling -parametrics, variational geometry, shape grammars, etc. - give limited surprises, although they are appropriate modelling techniques where we want to rapidly generate alternatives according to a formula worked out previously. When the goal is emulating real design situations, procedural modelling seems less useful because we usually don't want to determine in advance which properties of a design we will be using at any given time.

Random generating techniques can lead to valuable feedback inside the rather unstructured flow of work of architects. From the point of view of shape creation and compositional work, implementation of random graphic routines offers a great deal of advantages in the design process. In the first stages of design, for example, it's a fact that graphic routines of purely aleatory forms can be defined and modified more easily than procedural oriented artifacts. Besides, primary graphic operations seem suitable for a random treatment and often show a minimum architectural content.

Random form generation is an open door to the "generate and test" method in architectural design, specially within a CAD program rich in graphic resources. Accidental juxtapositions of design elements can be examined for valid and possibly, unsuspected alternatives. Isolated components and absurd combinations can quickly be discarded, as well as repetitions of the same objects, etc. By combining and erasing different 2D or 3D entities at random, a variety of adjacencies can appear. Some may become familiar, others will make surprising sense or may suggest further possibilities.

[1] James Gleick: *Chaos. Making a New Science*. Penguin Books, 1988.
[2] Christopher Alexander: *Notes on the Synthesis of Form*. Harvard University Press, 1964.
[3] F. Waismann: *Ludwig Witigenstein und der Wiener Kreis*. Basil Blackwell, 1967.