

Deleuze and the Use of the Genetic Algorithm in Architecture.

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The computer simulation of evolutionary processes is already a well established technique for the study of biological dynamics. One can unleash within a digital environment a population of virtual plants or animals and keep track of the way in which these creatures change as they mate and pass their virtual genetic materials to their offspring. The hard work goes into defining the relation between the virtual genes and the virtual bodily traits that they generate, everything else –keeping track of who mated with whom, assigning fitness values to each new form, determining how a gene spreads through a population over many generations– is a task performed automatically by certain computer programs collectively known as “genetic algorithms”. The study of the formal and functional properties of this type of software has now become a field in itself, quite separate from the applications in biological research which these simulations may have. In this essay I will deal neither with the computer science aspects of genetic algorithms (as a special case of “search algorithms”) nor with their use in biology, but focus instead on the applications which these techniques may have as aids in artistic design.

In a sense evolutionary simulations *replace design*, since artists can use this software *to breed new forms* rather than specifically design them. This is basically correct but, as I argue below, there is a part of the process in which deliberate design is still a crucial component. Although the software itself is relatively well known and easily available, so that users may get the impression that breeding new forms has become a matter of routine, the *space of possible designs* that the algorithm searches needs to be sufficiently rich for the evolutionary results to be truly surprising. As an aid in design these techniques would be quite useless if the designer could easily foresee what forms will be bred. Only if virtual evolution can be used to explore a space rich enough so that all the possibilities cannot be

considered in advance by the designer, only if what results shocks or at least surprises, can genetic algorithms be considered useful visualization tools. And in the task of designing rich search spaces certain philosophical ideas, which may be traced to the work of Gilles Deleuze, play a very important role. I will argue that the productive use of genetic algorithms implies the deployment of three forms of philosophical thinking (populational, intensive, and topological thinking) which were not invented by Deleuze but which he has brought together for the first time and made the basis for a brand new conception of the genesis of form.

To be able to apply the genetic algorithm at all, a particular field of art needs to first solve the problem of how to represent the final product (a painting, a song, a building) *in terms of the process that generated it*, and then, how to represent this process itself as a well-defined sequence of operations. It is this sequence, or rather, the computer code that specifies it, that becomes the “genetic material” of the painting, song, or building in question. In the case of architects using computer-aided design (CAD) this problem becomes greatly simplified given that a CAD model of an architectural structure is already given by a series of operations. A round column, for example, is produced by a series such as this: 1) draw a line defining the profile of the column; 2) rotate this line to yield a surface of revolution; 3) perform a few “Boolean subtractions” to carve out some detail in the body of the column. Some software packages store this sequence and may even make available the actual computer code corresponding to it, so that this code now becomes the “virtual DNA” of the column. (A similar procedure is followed to create each of the other structural and ornamental elements of a building.)

At this point we need to bring one of the philosophical resources I mentioned earlier to understand what happens next: population thinking. This style of reasoning was created in the 1930’s by the biologists who brought together Darwin’s and Mendel’s theories and synthesized the modern version of evolutionary theory. In a nut shell what characterizes this style may be phrased as “never think in terms of Adam and Eve but always in terms of larger reproductive communities”. More technically, the idea is that despite the fact that at any one time an evolved form is realized in individual organisms, the population not the individual is *the matrix for the*

production of form. A given animal or plant architecture evolves slowly as genes propagate in a population, at different rates and at different times, so that the new form is slowly synthesized within the larger reproductive community. (1) The lesson for computer design is simply that once the relationship between the virtual genes and the virtual bodily traits of a CAD building has been worked out, as I just described, an entire population of such buildings needs to be unleashed within the computer, not just a couple of them. The architect must add to the CAD sequence of operations points at which spontaneous mutations may occur (in the column example: the relative proportions of the initial line; the center of rotation; the shape with which the Boolean subtraction is performed) and then let these mutant instructions propagate and interact in a collectivity over many generations.

To population thinking Deleuze adds another cognitive style which in its present form is derived from thermodynamics, but which as he realizes has roots as far back as late medieval philosophy: intensive thinking. The modern definition of an *intensive quantity* is given by contrast with its opposite, an *extensive quantity*. The latter refers to the magnitudes with which architects are most familiar with, lengths, areas, volumes. These are defined as magnitudes which can be *spatially subdivided*: if one takes a volume of water, for example, and divides it in two halves, one ends up with two half volumes. The term “intensive” on the other hand, refers to quantities like temperature, pressure or speed, which cannot be so subdivided: if one divides in two halves a volume of water at ninety degrees of temperature one does not end up with two half volumes at forty five degrees of temperature, but with two halves at the original ninety degrees. Although for Deleuze this lack of divisibility is important, he also stresses another feature of intensive quantities: *a difference of intensity* spontaneously tends to cancel itself out and in the process, it drives fluxes of matter and energy. In other words, differences of intensity are *productive differences* since they drive processes in which the diversity of actual forms is produced. (2) For example, the process of embryogenesis, which produces a human body out of a fertilized egg, is a process driven by differences of intensity (differences of chemical concentration, of density, of surface tension).

What does this mean for the architect? That unless one brings

into a CAD model the intensive elements of structural engineering, basically, *distributions of stress*, a virtual building will not evolve as a *building*. In other words, if the column I described above is not linked to the rest of the building as a *load-bearing* element, by the third or fourth generation this column may be placed in such a way that it cannot perform its function of carrying loads in compression anymore. The only way of making sure that structural elements do not lose their function, and hence that the overall building does not lose *viability as a stable structure*, is to somehow represent the distribution of stresses, as well as what type of concentrations of stress endanger a structure's integrity, as part of the process which translates virtual genes into bodies. In the case of real organisms, if a developing embryo becomes structurally unviable it won't even get to reproductive age to be sorted out by natural selection. It gets selected out prior to that. A similar process would have to be simulated in the computer to make sure that the products of virtual evolution are viable in terms of structural engineering prior to being selected by the designer in terms of their "aesthetic fitness".

Now, let's assume that these requirements have indeed been met, perhaps by an architect-hacker who takes existing software (a CAD package and a structural engineering package) and writes some code to bring the two together. If he or she now sets out to use virtual evolution as a design tool the fact that the only role left for a human is to be the judge of aesthetic fitness in every generation (that is, to let die buildings that do not look esthetically promising and let mate those that do) may be disappointing. The role of design has now been transformed into (some would say degraded down to) the equivalent of a prize-dog or a race-horse breeder. There clearly is an aesthetic component in the latter two activities, one is in a way, "sculpting" dogs or horses, but hardly the kind of creativity that one identifies with the development of a personal artistic style. Although today slogans about the "death of the author" and attitudes against the "romantic view of the genius" are in vogue, I expect this to be fad and questions of personal style to return to the spotlight. Will these future authors be satisfied with the role of breeders of virtual forms? Not that the process so far is routine in any sense. After all, the original CAD model must be endowed with mutation points at just the right places (and this involves design decisions) and much creativity will need to be exercised to link ornamental and structural elements in

just the right way. But still this seems a far cry from a design process where one can develop a unique style.

There is, however, another part of the process where stylistic questions are still crucial, although in a different sense than in ordinary design. Explaining this involves bringing in the third element in Deleuze's philosophy of the genesis of form: topological thinking. One way to introduce this other style of thinking is by contrasting the results which artists have so far obtained with the genetic algorithm and those achieved by biological evolution. When one looks at current artistic results the most striking fact is that, once a few interesting forms have been generated, the evolutionary process seems to run out of possibilities. New forms do continue to emerge but they seem too close to the original ones, as if the space of possible designs which the process explores had been exhausted. (3) This is in sharp contrast with the incredible *combinatorial productivity* of natural forms, like the thousands of original architectural "designs" exhibited by vertebrate or insect bodies. Although biologists do not have a full explanation of this fact, one possible way of approaching the question is through the notion of a "body plan".

As vertebrates, the architecture of our bodies (which combines bones bearing loads in compression and muscles bearing then in tension) makes us part of the phylum "chordata". The term "phylum" refers to a branch in the evolutionary tree (the first bifurcation after animal and plant "kingdoms") but it also carries the idea of a shared body-plan, a kind of "abstract vertebrate" which, if folded and curled in particular sequences during embryogenesis, yields an elephant, twisted and stretched in another sequence yields a giraffe, and in yet other sequences of intensive operations yields snakes, eagles, sharks and humans. To put this differently, there are "abstract vertebrate" design elements, such as the tetrapod limb, which may be realized in structures as different as as the single digit limb of a horse, the wing of a bird, or the hand with opposing thumb of a human. Given that the proportions of each of these limbs, as well as the number and shape of digits, is variable, their common body plan cannot include any of these details. In other words, while the form of the final product (an actual horse, bird or human) does have specific lengths, areas and volumes, the body-plan cannot possibly be defined in these terms but must be abstract enough to be compatible

with a myriad combination of these extensive quantities. Deleuze uses the term “abstract diagram” (or “virtual multiplicity”) to refer to entities like the vertebrate body plan, but his concept also includes the “body plans” of non-organic entities like clouds or mountains. (4)

What kind of theoretical resources do we need to think about these abstract diagrams?. In mathematics the kind of spaces in which terms like “length” or “area” are fundamental notions are called “metric spaces”, the familiar Euclidean geometry being one example of this class. (Non-Euclidean geometries, using curved instead of flat spaces, are also metric). On the other hand, there are geometries where these notions are not basic, since these geometries possess operations which do not preserve lengths or areas unchanged. Architects are familiar with at least one of these geometries, projective geometry (as in perspective projections). In this case the operation “to project” may lengthen or shrink lengths and areas so these cannot be basic notions. In turn, those properties which do remain fixed under projections may not be preserved under yet other forms of geometry, such as differential geometry or topology. The operations allowed in the latter, such as stretching without tearing, and folding without gluing, preserve only a set of very abstract properties invariant. These topological invariants (such as the dimensionality of a space, or its connectivity) are precisely the elements we need to think about body plans (or more generally, abstract diagrams.) It is clear that the kind of spatial structure defining a body plan cannot be metric since embryological operations can produce a large variety of finished bodies, each with a different metric structure. Therefore body plans must be topological.

To return to the genetic algorithm, if evolved architectural structures are to enjoy the same degree of combinatorial productivity as biological ones they must also begin with an adequate diagram, an “abstract building” corresponding to the “abstract vertebrate”. And it is at this point that design goes beyond mere breeding, with different artists designing different topological diagrams bearing their signature. The design process, however, will be quite different from the traditional one which operates within metric spaces. It is indeed too early to say just what kind of design methodologies will be necessary when one cannot use fixed lengths or even fixed proportions as aesthetic elements and must instead rely on pure

connectivities (and other topological invariants). But what it is clear is that without this the space of possibilities which virtual evolution blindly searches will be too impoverished to be of any use. Thus, architects wishing to use this new tool must not only become hackers (so that they can create the code needed to bring extensive and intensive aspects together) but also be able “to hack” biology, thermodynamics, mathematics, and other areas of science to tap into the necessary resources. As fascinating as the idea of breeding buildings inside a computer may be, it is clear that mere digital technology without populational, intensive and topological thinking will never be enough.

REFERENCES:

(1) “First....the forms do not preexist the population, they are more

like statistical results. The more a population assumes divergent forms, the more its multiplicity divides into multiplicities of a different nature....the more efficiently it distributes itself in the milieu, or divides up the milieu....Second, simultaneously and under the same conditions....degrees are no longer measured in terms of increasing perfection....but in terms of differential relations and coefficients such as selection pressure, catalytic action, speed of propagation, rate of growth, evolution, mutation....Darwinism's two fundamental contributions move in the direction of a science of multiplicities: the substitution of populations for types, and the substitution of rates or differential relations for degrees."

Gilles Deleuze and Felix Guattari. *A Thousand Plateaus*. (University of Minnesota Press, Minneapolis, 1987). Page 48.

(2) "Difference is not diversity. Diversity is given, but difference is that by which the given is given...Difference is not phenomenon but the nuomenon closest to the phenomenon...Every phenomenon refers to an inequality by which it is conditioned...Everything which happens and everything which appears is correlated with orders of differences: differences of level, temperature, pressure, tension, potential, difference of intensity".

Gilles Deleuze. *Difference and Repetition*. (Columbia University Press, New York, 1994). Page 222.

(3) See for example:

Stephen Todd and William Latham. *Evolutionary Art and Computers*. (Academic Press, New York, 1992).

(4) "An abstract machine in itself is not physical or corporeal, any more than it is semiotic; it is *diagrammatic* (it knows nothing of the distinctions between the artificial and the natural either). It operates by *matter*, not by substance; by *function*, not by form...The abstract machine is pure Matter-Function -a diagram independent of the forms and substances, expressions and contents it will distribute."

Gilles Deleuze and Felix Guattari. *A Thousand Plateaus*. Op. Cit. Page 141