Deleuze and the Use of the Genetic Algorithm in Architecture

Manuel DeLanda exploits organisational processes in order to understand the possibilities contained within the computer programs known as 'genetic algorithms' – evolutionary simulations that replace normative design methods and aid in the breeding of new forms. This technique should be understood as a result of a complex feedback loop that exists between technology and culture. DeLanda uses the genetic algorithm to replace determinist notions of causality with non-linear, bottom-up, systemic process-driven techniques, which produce fertile spaces that are 'rich enough' for the evolutionary results to be exceptional, and sufficiently open-ended to make it impossible for the designer to consider all possible configurations in advance. These create emergent organisations of several variations instead of singular static objects.

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 lies in defining the relation between the virtual genes and the virtual bodily traits that they generate. The remaining tasks – 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 – are performed automatically by computer programs 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 not deal with the computer science aspects of genetic algorithms, or with their use in biology, but will 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 to merely design them. However, as I argue below, there remains a part of the process in which deliberate design is still a crucial component. Since the software itself is relatively well known, and easily available, users may get the impression that breeding new forms has become a matter of routine. But it must also be noted that the space of possible designs in which the algorithm searches must be sufficiently rich for the evolutionary results to be truly exceptional. As an aid to design, these techniques would be rather useless if the designer could easily predict which forms would be bred.

Genetic algorithms will only serve as useful visualisation tools if virtual evolution can be used to explore a space in which it is impossible for the designer to consider all potential configurations in advance, and only if what results shocks, or at least surprises. In the task of designing fertile search spaces, certain philosophical ideas, traced to the work of Gilles Deleuze, play a crucial role. I would argue that the productive use of genetic algorithms necessitates the deployment of three philosophical forms of thought: populational, intensive and topological. Deleuze did not invent these but he brought them together for the first time, and made this the basis for a new concept of the genesis of form.

In order to utilise genetic algorithms, a particular field of art must first be used to solve the problem of representation in the final product in terms of the process that generated it. Then one must figure out 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 object in question. This problem can be simplified through the use of computer-aided design, given that a CAD model of an architectural structure is already defined by a series of operations. For example, a round column is produced with the following directions:

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 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. In this case, the code itself 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.)

In order to understand the next step in the process, one must apprehend the basic tenets of 'population thinking'. This method of reasoning was employed in the 1930s by the biologists who synthesised the theories of Darwin and Mendel, thereby creating the modern version of evolutionary theory. This method of thinking can be encapsulated in the brief phrase, 'never think in terms of Adam and Eve, but always in terms of larger reproductive communities'. That is to say, although at any time an evolved form is realised in individual organisms, the population, not the individual, is the matrix for the production of form. Any given animal or plant architecture evolves slowly as genes propagate in a population – at different rates and at different times – so that a new form is slowly synthesised 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 articulated above, an entire population – not just a 'couple' – of such buildings must be unleashed within the computer. The architect should add points at which spontaneous mutations may occur to the CAD sequence of operations. For example, in the case of a column, one should take: the relative proportions of the initial line; the centre of rotation; and the shape with which the Boolean subtraction is performed; and allow these mutant instructions to propagate and interact collectively over many generations.

To population thinking Deleuze adds another cognitive style, 'intensive thinking', which, in its present form, is derived from thermodynamics but has roots as far back as late medieval philosophy. The modern definition of an intensive quantity becomes clear when contrasted with its opposite, extensive quantity, which includes familiar magnitudes such as length, area and volume. These are defined as magnitudes that can be spatially subdivided, that is, a volume of water divided in half comprises two half volumes. The term 'intensive' on the other hand, refers to quantities like temperature, pressure or speed, which cannot be subdivided as such; that is, two halves of a volume of water at 90 degrees of temperature do not become two half volumes at 45 degrees of temperature, but rather two halves at the original 90 degrees. Although for Deleuze this lack of divisibility is important, he also stresses another feature of intensive quantities: a difference of intensity, which spontaneously tends to cancel itself out and, in the process, 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 fertilised 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? It means that unless one brings to 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 can no longer perform its function of carrying loads in compression. The only way to ensure that structural elements do not lose their function, and hence that the overall building does not lose viability as a stable structure, is to attempt to represent the distribution of stresses. One must show which types of concentrations, during the process that translates virtual genes into bodies, will endanger the structure's integrity. For example, in the case of real organisms if a developing embryo becomes structurally unviable it won't even reach reproductive age where it would be subject to the process of 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 us 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) in order to write a code that brings the two together. If the individual now sets out to use virtual evolution as a design tool, he or she may be disappointed by the fact that the only role left for a human is to be the judge of aesthetic fitness. The role of design has now been transformed into (some would say downgraded to) the equivalent of a racehorse breeder. There remains, clearly, an aesthetic component, 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 a fad and that questions of personal style will return to the spotlight. Will these future authors be content in the role of virtual form breeders? Not that the process, thus far, is routine in any sense. After all, the original CAD model must be endowed with mutation points at just the right places. This involves design decisions and much creativity will still be needed to link ornamental and structural elements in just the right way. Nevertheless, this remains far from a design process by which one develops 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 style of thinking is to contrast the results artists have so far obtained with the genetic algorithm to 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 stands in sharp contrast to 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 for this, 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 them 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. By this I mean an 'abstract vertebrate' which, if folded and curled in particular sequences during embryogenesis, yields, for example, an elephant that, when 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 realised in structures as different as the single digit limb of a horse, the wing of a bird or the hand with an opposing thumb of a human. Given that the proportion 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, the form of the final product (an actual horse, bird or human) does have specific lengths, areas and volumes. But the body plan cannot possibly be defined in these terms and must be abstract enough to be compatible with many different combinations of these extensive quantities. Deleuze uses the term 'abstract diagram', or 'virtual multiplicity', to refer to entities akin to the vertebrate body plan, but his concept also includes the 'body plans' of nonorganic entities like clouds or mountains.[4]

What kind of theoretical resources do we need in order to analyse these abstract diagrams? In mathematics, those spaces in which terms like 'length' or 'area' constitute fundamental notions are called 'metric spaces'. The familiar Euclidean geometry is one example of this class, whereas non-Euclidean geometries, using curved instead of flat spaces, are also metric. On the other hand, there are geometries

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where these notions are not basic, since these geometries possess operations that do not preserve lengths or areas unchanged. Architects are familiar with at least one of these, projective geometry, as in the use of perspective projections. In this case, the operation 'to project' may extend 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 abstract invariant properties. These topological invariants – such as the dimensionality of a space, or its connectivity – are precisely the elements we need in order to begin thinking 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 precisely what kind of design methodology will be necessary when one cannot use fixed lengths or even fixed proportions as aesthetic elements, but must rely instead on pure connectivities (and other topological invariants). But it is clear that without this the space of possibilities in which virtual evolution blindly searches will be too impoverished to be of any use. Thus, architects wishing to use the new tool of genetic algorithms 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. AD

Notes

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, p 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, p 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.' Deleuze and Guattari, op cit, p 141.