We are currently witnessing the end of an artistic world. Artists of tomorrow will no longer produce works but something yet to be named. They will no longer create objects but rather types of microuniverses in perpetual evolution.

Abstract

These universes will be woven with uninterrupted changes, with mobile networks of lines, surfaces, forms, and forces in constant interaction, produced by the coupling of mathematics and calculators. From fractal dragons to cellular automata, from zooids to logic viruses, mathematical beings move and metamorphose in their symbolic spaces. They can change or alter the very laws by which they are constituted. They can provide the virtually autonomous substance of a new, intermediary art. The metaphor of the "symbolic bonsai" has been chosen to render the intermediary "life" of this intermediary art. Why intermediary art?

In an attempt to explain art using the words of language, even the greatest minds diverge to some extent. According to Plato, for example, art is the quest for "likelihood;" according to Hegel it aims to "reveal the truth."[1] Should art seek likelihood or truth? Is the artist a magician or a prophet? What, in fact, is truth? Plato said truth is a "divine vagabondage," which undoubtedly is why it remains beyond the reach of art, why he contends we must be satisfied with a "likely" imitation.

Since we are not gods, we cannot "vagabond;" we need laws. And this need applies to art. Thus, art must also be a science. As a product of human activity, art must obey rules inherent to the techniques used to create it. But art is also sensible representations, and as such refuses the domination of abstraction and laws. The best way to resist laws is to change them–constantly. Art itself must therefore be change–perpetual change.

1. G.W.F. Hegel, *Phénoménologie de l'Esprit*, Ed. Aubier, Paris, 1977

Bonsai

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The Bonsai: A Living Work of Art

Living but regulated, regulated but changing—such is the truth of a likely art, of the art of metamorphosis. This is the art for which the bonsai offers a plausible metaphor.

The notion of a living work of art is not new. Hegel placed such art somewhere between abstract and spiritual works. The archetype of the living art work is the "fete man offers himself in his own honor." The free, fluid movement of "torch bearers" becomes a kind of figure, itself an "animated, living art work, as beautiful as it is vigorous."[2]

Whether the living element is "the work" itself or the human agents is ultimately secondary. What is important is the fact that this notion of a living work is so prevalent. Aristotle draws a formal comparison between the living products of nature and those of art and maintains that form is the principle of all production. It is form that becomes manifest in morphogenesis and in artistic creation. The seed gives birth to the tree in the same way the painter gives birth to the canvas.

Bachelard takes this formal analogy to its limit by stating that the tree is "normally a work of art." Indeed, all life that is sufficiently whole "normally" can be considered a work of art. In terms of law, the integrity of the life divulges the presence of law. Thus, whereas life guarantees change in the laws it adopts, it cannot dispense with the laws. Living art must in turn obey certain laws, without which it is condemned to vagabondage and errancy. These laws govern the general development of the work, the procedures and their composition.

Fusion of Impression and Calculation

Pure sensibility and the unutterable impression must be based on a calculation. Once the law underlying work becomes known, it is as though disemboweled. Thus, on the one hand, without laws the artwork would remain

spineless. On the other hand, the work must not let its skeleton show.

To continue our tree analogy, the presence of a calculation for an art work is as necessary as that of a trunk for a tree. It is a support, a structure, and a course for the rising sap. Calculations, however, become tiresome and must be forgotten. Forces must be allowed to act and forms to react. The creative process is no longer a question of a time for analysis but of a time for fusion.

Technical reasoning must be founded in sensible expression; the idea must unite with the form. The precise moment of this union is more important than the art work itself. The work belongs to the real world. It breaks away from its creator and assumes autonomy as soon as it has emerged, becoming a mere trace of the creative act. The work is proof that fusion was one day possible, desired, and granted. Yet, in reality, the work is nothing more than an excrement of creative digestion.[3] Thus, the distinction between essential and secondary phenomena is capital. The creative act is essential, whereas the work thereby created is secondary. Artists who expect to sell their canvases are well aware of that distinction. Their works are neither their flesh nor their blood.

Artists will no longer produce works, but something that has yet to be named. They will no longer create objects, but kinds of microuniverses in perpetual evolution. These universes will be woven with uninterrupted changes, with mobile networks of lines, surfaces, forms, and forces in constant interaction. The art of metamorphoses of the universe will soon make its appearance in the world of metamorphoses of art. This art will live off the symbolic life of mathematical being.

According to Plato, mathematical things belong to an intermediary world. They occupy a position between material realities and pure ideas, between the domains of the sensible and of the intelligible. By coupling with calculators, mathematics has engendered curious beings, which people have called monsters. The principle behind the animal movement of fractal dragons and cellular automata is derived from recurrence. The iterative pulsation functions as a vital pulse, leaving the algorithm to evolve in the space of its area of application (phase space). The algorithm can modify or alter the very laws whereby it is constituted.

The Creative Act Versus the Work

We have been acknowledging the existence of the creative act as separate from the work itself. Now, we will discuss what those separate phenomena mean. In the conventional sense, art is defined above all as the production of a work. The work is created from a model, which may be an actual motif or a pretext. Emphasis is put on the originality of creation; even the most imitative works depart from their models. On the other hand, once a work comes to light, it must persevere in its being. The art object is lasting; it is a product frozen in time and one that endlessly copies itself. Whereas the artistic labor of

3. "Like excretion, the instinct to create plastic form is an act where the animal becomes as though external to itself." G.W.F. Hegel, *Philosophy of Nature*.

Despite being a tree, that is, a natural phenomenon, the bonsai epitomizes the cultural world. It is cultural in that it is physically cultivated and gardened and that it symbolizes the labor of will over chance.

begetting the work must be considered a living process, an epigenesis rich in surprises and metamorphoses, the finished work presents nothing more than a mingled mass of all the instants during which it was wrought. Although the work as a finished product clearly affirms its form, it thereby relinquishes the history of its advent. Forget-ting the genesis is a prerequisite to the completion. The project is thus obliterated by the object. The last stroke of the brush is also the rub of an eraser.

The end of the work is its limit. This point is crucial. Given that a work of art precludes our tracing the story of its creation, other than summarily, and given that the work offers a finished result rather than a process, we can conclude that something of the flash of insight inherent to the creative act remains eternally beyond reach. The work is more an object than a subject.

However dismal this prospect may seem, it is far from recent. The relationship between the artist and the work of art has not evolved for thousands of years. Plato condemns works of art and written works outright, noting they are nothing but dead productions, incapable of defending themselves. Socrates, speaking to Phaedra, does not mince words: "What is so terrible about writing is its resemblance to painting: do its offspring not present themselves as living beings, but remain majestically silent when questioned?"

The work is doomed to repetition and silence. By establishing itself in time, it copies itself indefinitely. I believe Plato's intermediary world—in other words, the mathematical-computer galaxy—is capable of proposing "works" endowed with properties that are in turn intermediary. These works are liable to elicit intermediary sensations and open up a world of intermediary art. The works in this world will be living rather than dead, voluble rather than tacit, evolutive rather than repetitive. In short, they will be more "automatic" insofar as this word (to automation = "self-moving," but also "chance") is, in Aristotle's philosophy, conventionally opposed to technical or artistic "production" (*Tekhne*).

Before proceeding further, consider that such intermediary arts have long existed. For example, we can adopt the art of the bonsai as a paradigm of an art of models. Despite being a tree, that is, a natural phenomenon, the bonsai epitomizes the cultural world. It is cultural in that it is physically cultivated and gardened and that it symbolizes the labor of will over chance. The artist's pruning provides a decisive response to the automatism of enzymatic and arborescent mechanisms. The bonsai is the victory of the mental over the vegetal realm. But if this is so, where is the omnipresent power of the creator?

There are two answers. First, the art of bonsai trees has simply been used here as a metaphorical example of a systematic competition between active principles of different natures. Ultimately, these active principles should be brought into play in a sym-

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bolic, intermediary world, where the sensible and the intelligible manifest consistency and performance different to those experienced in the material world. Indeed, the value of the undertaking resides in this very difference. Second, the Japanese gardener is not as directive as we might think. The struggle between the two wills, the mental and the vegetal, tends to be negotiated rather than cut short. The gardener must talk and even engage in a dialogue with the bonsai; he must persuade it to grow. In the course of generations of gardeners, the bonsai and gardener have maintained a constructive dialogue. The bonsai is itself the history of a conversation. The plant has learned to speak, and the human being has had to take root.

The Bonsai as Intermediary Art

The bonsai tree provides a good example with which to develop the concept of intermediary art. The tree is clearly one of the most ancient and deeply anchored archetypes. At the same time, it is endlessly adopted as a motif. From the beginnings of time to the present, the form of the tree has proved inexhaustible. Its symbolic resources have been well borne out by painting. Computer images are now tackling its representation. Hence, after so many successes, the tree provides us with a veritable test case: If the bonsai tree is a work of art, can an intermediary bonsai be grown on computers? In what respect do these symbolically cultivated trees open the way to an automatic art? Do these automatisms simply fulfill the wish expressed earlier this century by André Breton, or do they constitute the premises of a new aesthetic project?

Then again, what is a tree? Matisse says "A tree is a leaf." That is, a tree is recurrence: It weaves its difference by repetition. It grows upward and downward. It burgeons and flowers. It is both base and foundation. It is master of its own form. It uses its strength. The oak and the alder, the hornbeam and the elm, the willow and the beech, the pine and the spruce make up its various essences.

But what is the essence of the tree? To say the tree is a form is too expedient. A tree does not have a form. Rather, it *is* form in that it breathes and transpires. The sun and the rain, the day and the night accompany its incessant metamorphoses. It never rests. The boughs reveal sustenance procured by the roots. And as the tree ramifies, it affirms its mastery of new spaces. It abandons bleak three-dimensional geometries to explore fractional dimensions, fractal shapes.

The form of the tree has conquered the world. Everything that flows is a tree. A river and lungs, an arterial network, and a nervous system are all trees. The universality of the tree is due to the fact that it is, a priori, a form of the flow of time in space. It draws the form of time and the force of space and results from the sum of their constraints. The tree

is a living force. The tree and the forest are living with an incessant life.

Language cannot apprehend what is pure fluency by nature. So if language fails in its attempt to render nature, what hope is there for the image? How are we to grasp the colors without forms and the forms without end? What is a tree?

Pictorial Representation

The painted tree hides the wood of real trees. Thus, pictorial art needs to take up the challenge to convey their tufted confusion, the intertwining of form and space by means of relatively simple tools—the canvas and the brush. The history of painting abounds in trees dreamed up or rethought, trees that are delirious, opulent, luxuriant, teeming, lavish, prolific. Their forms are muscular or full blown, meticulous or ascetic. Painters seek their architectural truth or give them theatrical postures.

All graphic metaphors are mobilized to "render" a given aspect: Leonardo da Vinci creates braids and interlacing forms. Théodore Rousseau paints plantlike fronds of hair. Claude Monet simulates the rippling sea in his foliage. Van Gogh draws trees of flame. Cézanne rediscovers his favorite geometric shapes. Where is the truth of the trees?

The Chinese painter-poet Su Tung-p'o (1036-1101) wrote, "Trees, bamboo and a few other plants possess a constant characteristic form (*Hsing*) and, moreover, have a fundamental expression (*Li*), which can be very seriously transgressed. If the painter does not attain this quality with precision, his error is far greater than if he had failed to grasp the external form adequately."

The quest for this "fundamental expression" is not only a technical quest. It requires a certain view, a systemic approach. Tchen Jen, a Chinese monk in the eleventh century, devoted an entire work to the apple tree in blossom. He attributed sensitivity to deeply imbedded structures, to latent models, to obscure forces at work: "In the apple tree there is a hierarchical system such that its branches never grow on all sides: nor do the flowers bud by chance, but each has its own predetermined place."

The tree is first and foremost growth, movement, and vital impulse. Van Gogh said trees must be made to "grimace." Clearly, there is a substantial distance between the "representation" of the tree and the "simulation" of its vital energy. In short, even for those who have abandoned all hopes of bringing alive the twisting and pain of self begotten trunks, the problem of graphic representation remains a formidable one. The trunk grows staunchly upright, affirming its strength and its expression, but all those countless, invertebrate leaves, fluctuating and luminous, must also be dealt with. The leaf is the last boundary of representation.

Computer Images

Having thus measured the limits of pictorial representation, what can we expect from models and algorithms?

Where can computer images lead us when even the most penetrating gaze is incapable of analyzing the profusion of verdant crowns? Gaston Bachelard has warned us of the danger of misused calculations: "Applying the mechanical to the living may be comical, but applying geometry to the vegetal is the ultimate in ridicule."[4] At the risk of ridicule, I shall present several tree "models" applied to image synthesis.

Jules Bloomenthal from the New York Institute of Technology (NYIT) was one of the first people to attempt a "realistic" representation of the tree. He emphasized the efficiency of calculations at the expense of a rather elementary analysis.

Bloomenthal defines his model as follows: "The branches of a tree can be described simply as a list of points in a three dimensional space, and as a list of connections (the branches) between these points." For variation, he called on random number generators. Parameters such as the number of the branches are calculated in an aleatory manner, starting from average values. The geometry of the trunk and branches is rendered by a simple "generalized cylinder." The leaves are likewise digitized from photographic sources, then cut into three sections to allow them to be bent by the wind.

Peter Oppenheimer has used a similar model at NYIT. His trees do not try to be an exact arborescent structure but a surface realism. Although the matter the trunks are made of is acceptable, his trees are oddly reminiscent of vermicelli.

William Reeves has developed another essentially aleatory model called a "particle system." A particle system is not a static entity. The position, orientation, attributes, and dynamics of each particle are defined by a sum of aleatory functions subject to constraint. This allows the creation of numerous variations. The parameters are interdependent without being bound in a linear relation. The breadth and height of the tree and the length and thickness of the branches vary together. The "twigs" are recursively generated by the "branches," which endow them with their own parameters. The other parameters are adapted to the given height. This recursive generation algorithm produces regular structures. Hence, Reeves proposes a posteriori processing to simulate real conditions: the effects of gravity, dominant winds, and sunlight.

Bloomenthal's and Reeves' models are basically aleatory; they do not involve strict botanical analysis. Others have chosen to exploit the knowledge of plant anatomy acquired by botanists. Their approach gives rise to a totally different philosophy, one where the tree is seen as a complex organism in search of an incessantly disrupted equilibrium.

In this second approach, discrete models have been used to account for plant morphogenesis. Chaetomorpha, the green seaweed, was described by Lindenmayer's L parallel rewriting system as early as 1968. L systems are presented as sequences of states that may, for example, represent the cells of the given organism. State transitions are simultaneous and depend on a gram-

4. G. Bachelard, *L'air et les songes*, Ed. Jaié Corti, Paris, 1943, p. 235.

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mar G = A, R, x, where A is the finite set of symbols of possible states, called the alphabet, R represents the sum of the transition rules, and x stands for the initial state. If the longevity of a cell depends not only on its position with regard to neighboring cells but also on its mother cell, in other words, if the grammar allows the preceding generation to be memorized, growth is qualified as a "temporal interaction" process. If state transition is likewise dependent on neighboring cell status (diffusion mechanisms), "local interaction" systems are involved. The interaction speed across the filiation (time) can be modelized, as can local propagation between neighboring cells (space). Finally some systems undergo "erosion" during development, in other words, they are systems whose grammar can modify itself.

Other research has shown the possibility of generating the structure of various trees without using a generative grammar, using a combinatory growth motor instead. Ramifications are made to increase by recurrence. The following ramification is obtained by randomly drawing a branch from the preceding ramification and by drawing a direction in space. A new twig thus sprouts on this branch in the chosen direction. Above all the combinatory method allows effective control of overall parameters (such as the Strahler number), which impose shape-related constraints on the tree. Whereas the chance factor involved in random drawing allows wide variety of individuals to be obtained, they remain strictly within the framework of a given tree "species," summarized by geometric parameters derived from botany, such as the ratio of branch length to branch diameter and the angle between "mother" and "daughter" branches.

Philippe de Reffye[5] has analyzed a mathematical model of the coffee tree based on experimental growth curves. His model places considerable emphasis on stochastic processes and aleatory developments capable of creating structural irregularities. It also takes into account weight and resistance of materials for the bending of the bough, the buckling of vertical shoots, or phenomena related to breakage. Finally, he ascribes substantial importance to the four parameters characteristic of tree growth: activity, viability, ramification, and number of axillary buds.

The CIRAD team in Montpellier used this method to simulate numerous trees (coffee tree, cotton tree, palm, frangipani, poplar, spruce, beech, litchi) as well as plants and flowers (daffodil, tulip, lilaceous and araceous species, vine, fern). Anticipated developments concern calculating the gene for the branches within a given tree or among different trees. Evaluation of the luminous flux at any moment is likewise envisioned.

The CIRAD simulation method has numerous applications in botany, agronomy, forestry, and landscape design. One of its most interesting perspectives is the possibility of simulating fossil trees. Indeed, it provides

5. P. de Reffye, "Modelisation de l'architecture des arbres par processus stochastiques," Doctorat d'Etat, Paris, 1979. Also see M. Jaeger, "Representation et simulation de croissance des vegetaux," doctoral thesis, Strasbourg, 1987.

Far from being an arrogant, barbarian art object, mathematics is a transcendental tool of knowledge. Intermediary art is an art of manner, a neomannerist art, concerned not so much with nature as such or its deformation as with its transformations.

a magnificent example of creating intermediary art: Such models allow us to shape at will, in the same way as one cares for a bonsai year after year, generation after generation. It is no longer a question of a tree or a model but of artistic simulation of a nature. Finally we would like to cite the most developed simulation model of living vegetable environments. It consists of creating a model that translates not only plant growth but genetic evolution of the species itself. Hypotheses are formulated on the factors likely to reinforce a given species in its struggle against the pressure of selection. It then becomes possible to induce a "mutation" in a given characteristic and to evaluate the performance of this mutation. Numerous reiterations of such a procedure are possible.

Minor modifications encouraged or inhibited by the selective pressure of the "environment" lead to a reinforcement or dying out of the "species." A priori criteria are used, such as the aptitude to capture light, the resistance structures manifest to their own weight, and the efficiency of seed dissemination. These are "genetic" parameters that are the object of "mutations" in the course of successive generations. A mutation occurs when the efficiency of growth characteristics is maximized according to one or several of the adopted criteria. For example, it is possible to seek out the evolutionary trajectory whereby seed dissemination capacity or the ability to capture light is optimized. Simulation becomes extremely valuable when it allows the confrontation of several "plants." The "selective pressure" of the "environment" is highly interactive in this situation, as the environment is itself made up of species struggling for supremacy. This veritable "plant war" ultimately yields results similar to those obtained by nature insofar as can be seen from paleontological analysis of fossil plants.[6]

The Simulated Tree

Armed with these various models, it is clear that the simulation of intermediary trees is another art that leaves painting behind. It is a systemic art. The simulated tree is not a painted tree because it evolves from a complete interactive system, including the represented individuals, the species' characteristics, and the environment. Symbolic calculations grow trees that are no longer illusory appearances but are entities in a state of permanent metamorphosis. Nature was already known to be an artist, as was the fact that "a blade of grass no more resembles another blade of grass than a Raphael resembles a Rembrandt" (Bergson). Now that we have managed to tame the very procedure of inventive flowering and budding repetition, we must show we are capable of subduing this prolific matter by making it express that without which art does not exist: emotion that can be shared.

The lesson is fully contained in the end: The seed and the bud are

6. See K. Niklas, "Computer-simulated plant evolution," *Scientific American*, May 1986.

but moments, and ever refuted moments at that. An art content to present no more than seeds, be they large or small, would fall short of its initial objective. As Hegel stated, "When we wish to see an oak in the sturdiness of its trunk, the expansion of its boughs and the masses of its foliage, we are dissatisfied if, in place of the oak, we are shown an acorn."[7] It is a matter of establishing the bases of a veritable intermediary art, an art capable of providing us with real enjoyment of this world, situated at the crossroads between the domains of the sensible and the intelligible.

This world is the site of mathematical beings. Mathematics is a necessary point of transition. For Plato, it is the intermediary images of ideas. For Aristotle, it is beings involved in matter. For Pythagoras, it comprises both the models and the substance of things. Leaving aside the nuances of interpretation, the essential point is clear: Mathematical things are bound to sensible things, thus to art.

What function can be ascribed to this intermediary art, of which mathematics constitutes the matter? As was hinted earlier, intermediary art is above all an art of metamorphosis, first, in that it uses a material destined to metamorphose constantly and, second, in that metamorphosis constitutes a novel function that cannot be fulfilled by the classical arts of the sensible world.

Far from being an arrogant, barbarian art object, mathematics is a transcendental tool of knowledge. Intermediary art is an art of manner, a neomannerist art, concerned not so much with nature as such or its deformation as with its transformations. These subtle metamorphoses that the eye does not follow can only be enjoyed thanks to mathematical beings, the intelligible version of such metamorphoses.

The "intermediary artist" so urgently demanded in our age of reason has already existed. Leonardo Da Vinci has shown us the way. He was not "intermediary" by virtue of his dual culture but because he allowed that culture to rove between heaven and earth. "He is the master of visages, of anatomies, of machines. He knows what a smile is made of; he can put it on the frontage of a house, in the curves of a garden: he untangles and freezes filaments of the waters, tongues of fire ..."[8]

It is up to art to trace the unpredictable path of forms in our universe caught in the throes of fusion. At the bend of the rustling forests, art alone allows us to share the countless smiles of forms.

7. G.W.F. Hegel, *Phenomenology of Mind*, op. cit.

8. P. Valery, *Introduction à la Methode de Leonard de Vinci*, Ed. Gallimard, Paris, 1960.