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Eidogenesis of the Artificial: The Case of the Relationships between Models of the "Natural Image" and Cellular Automata †

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Abstract: The old concept of *eidos* summed up those of "form" and "image" of an object; this is the subject covered here, supporting a realistic theory of conception and design, as opposed to the anti-realism of the postmodern age and its media conception of "image". Nowadays it is believed that some ways of conceiving the form and image of the artefacts—according to the current tendency towards naturalisation in social science, which has followed the converging technological and scientific progress of the third industrial revolution—derive from particular morphogenetic (ontogenetic and phylogenetic) models developed in natural science. From this point of view, the subject of "natural images" has become a central issue, which can be interpreted in two considerably different meanings: (1) as perceptual characteristics of natural environments; (2) as a format of visions. The issue of "natural images" (by incorporating the meanings 1–2) is a morphological matter, which is highly relevant to both the natural (cognitive) and cultural (anthropologic) points of view in visual studies and theory of images. In other words, the topic allows some remarks on the ways the concepts of "form" and "image" equally concern *Naturalia* and *Artificialia.* This difference measures the complexity of the issue that we exemplify only in the case of cellular automata, but with a particular focus on the simultaneous new emerging meanings of the term "image". The different specific meanings of "image" articulate the themes of the essay: from the image interpreted as shape, *eidos* and *Bild*—i.e., as objective geometry (the shape of things)—to its definition in terms of *Gestalt*, i.e., as subjective geometry (format of perception).

Keywords: imagination; design theories; ideation; weak textualism; natural image; morphogenetic models; shaping; eidogenesis of artefacts; realistic theory of images; semiotics of artefacts; categorisation; self-organised matter; morphogenesis; semio-physics

1. (Only) Shape

In April 2005, among the characters of the 14th episode of the 16th series of "The Simpsons"—the popular US animated sitcom—we can see the Frank Gehry puppet arriving on the scene. The well-known architect opens the mailbox in front of his house in Santa Monica (1978) and, among the many bills addressed to him, he finds a letter commissioning to him a project of an auditorium for a small town. The puzzled starchitect ignores the proposal, literally: he crumples the paper and he throws it away. But—*eureka!*—by observing the crumpled paper on the ground, the architect sees in it the revelation of the model of the required work: he only needs to transpose the shape of the wrinkled paper in that of a "Gehryan-like" building, namely resembling the Walt Disney Concert Hall in Los Angeles (Figure 1).

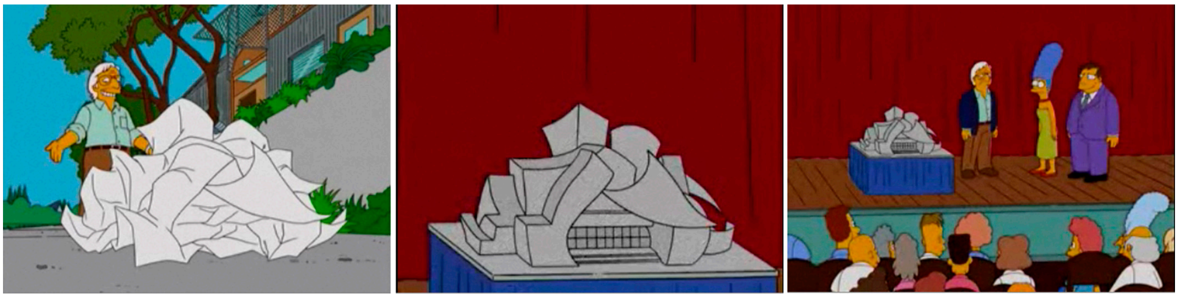


Figure 1. Scenes from the 14th episode of the 16th series of "The Simpsons".

The parody of Gehry in "The Simpsons" is really true to the figure of the Canadian architect. Gehry is indeed particularly famous for his mainly sculptural design process; by shaping a multi-material model, or a series of small objects, at an early stage, he assesses the apparent forms of those fragments of matter, extracted and composed in a gestural way, as one would do by crumpling a piece of paper. Then he measures the superficial shape of the model and he imposes that shape to a digital 3D model that represents the shells of a plausible building. In the end—after the structural engineering and marketing assessment—that shape is communicated to the very expensive construction site of a real building.

This way of making architecture—which has been called "deconstructivist"—requires high construction costs. It is a sort of sculpture on an architectural scale, intended to count mainly as "conveyance" of a free and powerful empathetic act into space. It aims to make the user participate in the same plastic hedonism and gestural freedom of the author. The author is therefore appreciated as "demiurge", able to find and freely impose a new shape to an inert matter. At least this is what appears according to the hylomorphic theory (the distinction between form and matter in the substance of things) through which our common sense naively considers—even today—the conception of artefacts having an aesthetic function.

Anyway, in the "Simpsons" cartoon, the demiurgic act of the Gehry puppet is debunked; his creation and his construction of the auditorium seem random acts, only useful to an unsuccessful—and anything but liberating—marketing operation.

In the cartoon, the recipients of the auditorium, not very keen on classical music, end up deciding to use it as a private jail, after providing its openings with suitable bars.

The Walt Disney Concert Hall actually built in Los Angeles did not suffer the same fate. Yet, even the existing building is a cartoon architecture; it is indeed made to be consumed as an image in a particular media context, but also conceived—as we said before—through a process of imitation and modification of images. It is an architecture that actually depends on a marketing project and on a very expensive building site that requires a prior structural engineering process through algorithms that don't depend on the original process of shape modelling. The shape is only an image issue, but how do we have to interpret, here, the term "image"?

The shape of the auditorium counts for its rhetorical effectiveness, not for structural or material reasons. After all, Gehry's deconstructivism is an extension of postmodern, i.e., of a deeply anti-realistic philosophy, that determines the value of architecture, design and arts especially in their media visibility and in their power to evoke media images.

In other words, the postmodern philosophy emphasises the fictional and imaginal, autobiographical, subjective dimension of design, until design is reduced to a genre of entertainment, in the age of the iconic turn.

There's no reality outside the analogical context of media images according to this philosophy that devaluates the whole concrete dimension of design and art interpreted as techniques, as productions of technical objects for aesthetic purposes.

By devaluing the technical dimension, the history of artefacts is reduced as well to an entangled congeries of genealogies—without accumulating knowledge and traditions—where every creator starts over day by day, beginning from its alleged freedom, "within the solitude of his own heart" [1].

The narcissistic neurosis is the best-known effect of these design forms supported by anti-realistic philosophies doomed to solipsism.

In contrast with these anti-realistic philosophies, the realistic and techno-aesthetic point of view considers every human art in the context of an anthropology of the techniques [2].

It acknowledges the full (uncorrectable) technical reality of artefacts, by firstly considering the artefacts as concretely designed "things" and their ideas—their essential models—as objective realities as well.

This is not, of course, a "realism of the ideas" in a Platonic sense: here, in fact, the term "idea" doesn't relate to a fixed, already given reality, but to an "ideal object" given *a posteriori*: a "social object", like the Pythagorean theorem, the combustion engine or Duchamp's Urinoir. Here, ideas are intended as socially shared models (empirical categories) continually adjusting and evolving almost like organisms.

In this sense—according to a "weak (and materialistic) textualism" [3]—we can interpret the design of the objects as an eidogenesis (speciation) of the artificial.

2. *Eidos* (Form and Matter)

The realistic point of view on conception primarily asserts itself with the strong criticism by Gilbert Simondon [4] of the hylomorphic conception through which the common sense considers the creation of artefacts. He dismantles the dualistic conception of the being that opposes form and matter, soul and body, showing that the expression "form of an object" only relates, in fact, to a useful abstraction (Figure 2).

But the more clearly we have an idea (conceptual image) of the different aspects of a given object, the more the notion of his form becomes tangible.

In the end, by knowing the actual individuality and the history of an artefact, one can conceive the material principles of its form and the formal principles of its matter, as well as the degree of technical evolution of that object.

As Simondon illustrates [4] (p. 54 et seq.), even a simple brick doesn't "take" the form of any possible geometric parallelepiped, but "is" that of a material parallelepiped whose dimensions suit a large number of technical requests: from its modularity as an element for various types of wall, its satisfying dimensions—given the chemical and physical characteristics of the clay—the technical specifications of production, …, to the visual (figurative) features enhanced in construction.

Thus, the (technical or artistic) invention of an object is always a project and never a random act of imposing a shape. It is always a (more or less adequate) mediation effort between two classes and scales of a single reality that we call—through an abstraction—form or matter.

Every constructed object has found—one way or another—a condition of compatibility between form and matter, i.e., between a macro (inter-elemental) and a micro (infra-elemental) geometry.

This is best shown in the case of natural objects; form and matter of natural species only indicate two opposite scales of the same reality, two aspects of the same ontogeny or entelechy. A biological phenomenon—as Paul Valéry said [5]—"doesn't separate its physics from its geometry". It is therefore usual to believe that the macroscopic natural forms—especially the symmetry of the organisms and the stochastic regularity of the superficial patterns—are explained by the material characteristics of the object, the medium and our receptive apparatus.

The physical reality of the object and the natural medium, as well as the biological reality of our perception, are parts of a single material system, even if it still remains unknown in detail. Thus, the models through which natural sciences try to explain the phenomenal principles of the bodies (as we experience them), somehow always tell us something about a (falsifiable) fragment of a single truth.

However this—at first sight—doesn't seem to apply to the forms of human artefacts, which are not considered as motivated as the natural ones.

The arbitrary shapes artificially created by a human being are considered abstract and separated from the matter of the objects—according to the hylomorphic scheme—distancing their geometry from their physics and physiognomy. Therefore—at first glance—we aren't led to believe that social sciences can explain the form of the artefacts the way natural sciences explain the development of a body.

Yet, the realistic point of view that we support is based on three essential facts:

1. We examine "real objects" (either *naturalia* or *artificialia*) through "ideal" and "social objects", which are their socially shared models;
2. These "models" depend on us (intersubjectivity), but they may turn out to be more or less adequate to the reality of things, which exists regardless of us;
3. Among these "models" there are also the "ideas" on which the conception of the artefacts (genealogically) works. They are not only internalised images, subjectively experienced by the designer; they are cultural realities, empirical intersubjective categories, witnessed by their actual products; they are contents, which are documented and recorded in that set of texts that—using Eco's term—we would call the Encyclopaedia of a given culture [6–8].

Seen in this light, the concept of *eidos* sums up those of "image" and "form", but it doesn't (ontologically) distinguish between "form" and "matter".

Following Simondon [4], we believe that the distinction between form and matter is only referred to two opposite scales and aspects of the same reality of an object (Figure 2):

1. On the one hand (referring to "form") the most inter-elemental, holistic, evolutionary aspect of the object, we would call it "phylogenetic";
2. On the other hand (referring to "matter") the most infra-elemental, physicalist aspect, we would call it "ontogenetic".

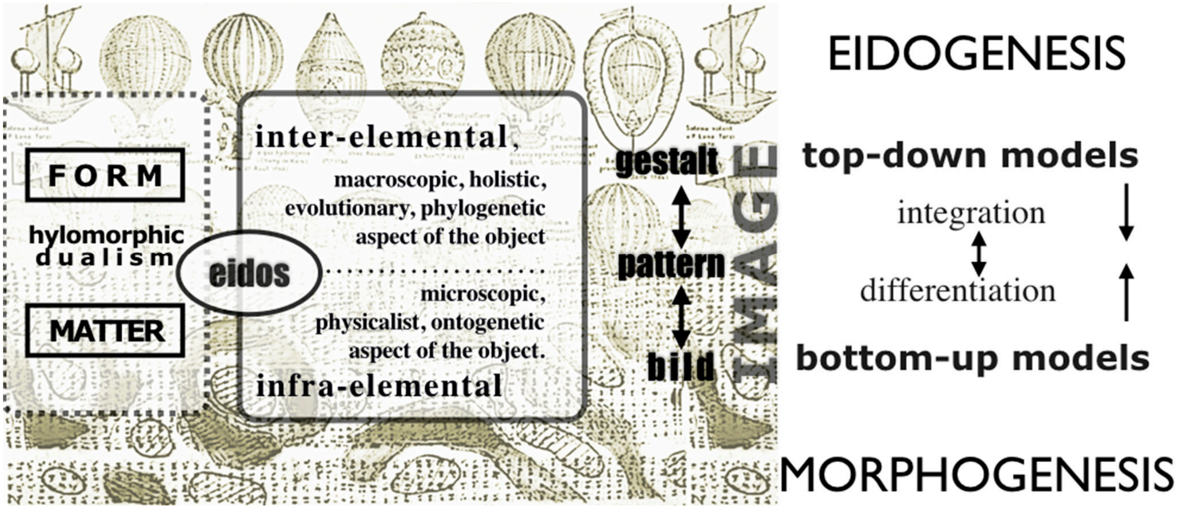


Figure 2. Alternative scheme of the hylomorphic argument—cfr. [4].

Consequently, from this realistic point of view, the shape of a brick is not more arbitrary or deterministic than the shape of a shell or a mineral. The difference lies in our idea of their morphogenesis (ontogeny and phylogeny), an idea that can be more or less adequate to a (single) reality that we can analyse from a physical, biological, social, …, point of view.

Even if it's not possible to keep together (translating between them) these different (physical, biological, social) aspects of the reality of artefacts, it is to be hoped—for the future of design studies—that it will be partially done, exploring some important analogies.

Simondon's encyclopaedic realism [7] and René Thom's semiophysics [9] are two of the approaches that look very promising in relation to the design studies.

However, these philosophical texts may seem still today too far from the topics and concerns of the technical, historical and methodological design literature.

This gap can be reduced if we consider the influences, in the design studies, of the morphogenetic models generated by the social sciences throughout the last century, especially during the third industrial revolution. That was the time when the convergence of science and technology took place, leading to a radical change in the concepts of form and "natural image".

3. Gestalt vs. Bild

A distinction can be made between the morphological models and the image conception in natural sciences, according to their tendency towards the "matter" or towards the "form". If we think that form and matter are—as we said before—aspects and scales of a single reality, then the morphological models can be divided into:

1. On the one hand, the matter-oriented models, e.g., the genealogy of morphogenetic models similar to the one formulated by Alan Turing in his seminal paper *The Chemical Basis of Morphogenesis* (1952) [10];
2. On the other hand, the form-oriented models, e.g., the theory of perception developed by the *Gestaltpsychologie* (von Ehrenfels, Wertheimer, Köhler, Koffka, Goldstein, Lewin …), or (in evolutionary biology) the theories related to the functions of the phenomenal self-image of the organisms [11], such as the evolutionary interpretation of phenomena like camouflage, crypsis, mimicry, aposematism, (Poulton, Bates, Portmann …) and other phenomena related to zoosemiotics (Uexküll, Sebeok, Simondon …) [12,13].

Thus, on the one hand (1) we can find the paradigms tending to be reductionist, physicalist, differential and ontogenic; on the other hand (2) the paradigms tending to be holistic, integral and phylogenetic.

3.1. Bild (Physicalist Models of Morphogenesis)

The models coming from a reductionist and differential conception of morphogenesis explain the shape of a body and its image (*Bild*) according to a drastic physicalist hypothesis, starting from the infra-elemental properties of the system.

Unlike the holistic models, they describe a bottom-up building (*Bildung*) process of the form (*Bild*), from local to global, from the microscopic to the macroscopic, from every single cell—unanimously (through self-organisation)—to the whole organism.

According to the physicalist hypothesis studied in biology, the elementary matter (chemically) generates the forms of the bodies, without either receiving instructions from an intangible model or containing *in nuce* its own "material representation" (preformationism).

Today the "gradient hypothesis" is dominant in the field of embryology, where it accounts for the gradual differentiation of tissues and organs on the basis of the information that is locally provided by some proteins (morphogens) in relation to their local or regional concentration thresholds, since these proteins are differently distributed (depending on a gradient) and spread over the embryo from the production site.

Nowadays we know that the morphogens are gene transcription factors, i.e., they specify the embryonic place in which they activate (or inhibit the activation of) two or three particular genes, thus guiding the process of spatial arrangement of the organism during the ontogeny. However, long before any molecular genetic explanation, the "gradient hypothesis" was already part of the sciences of complexity, especially through the mathematical model that Alan Turing conceived in 1952 in his seminal paper *The Chemical Basis of Morphogenesis* [10].

This model describes the most abstract and general situation in which forms can emerge from a material substratum as a result of mere chemical kinetics, that is, through the variations in the concentration of the reagents and products in space and time, corresponding to the reaction rates. Turing had the brilliant idea of describing that dynamic situation in terms of coexistence of two opposite processes, originated by the interplay of two opposite agents: two morphogens which constitute (in different concentrations) the substratum and interact with each other by means of autocatalytic reactions.

The two coexistent processes—which are mathematically expressed by the combination of two differential equations dealing with chemical kinetics—are:

1. A reaction process—i.e., a tendency towards the local differentiation of the substratum—expressed by means of reaction equations between molecules inside the same cell;
2. A diffusion process—i.e., a tendency towards the homogenisation of the whole substratum—expressed by means of equations describing the spatial transport of the reaction products towards adjacent cells.

The interaction between the two morphogens in the two processes describes the dynamic of a complex system: "forms" (in space) emerge as "states" (in time) of the system whose destiny can go through different kinds of balance and critical thresholds.

Starting from a homogeneous state and by means of small fluctuations in the concentration of the two substances, indeed, we can see the appearance, time after time, of concentration patterns made of spots, stripes, or even oscillatory states or states that tend to return to homogeneity.

Thus, by means of this formulation—a system of coupled differential equations—Turing first revealed how the emergence of forms is bound to the forms of instability of a dynamic system.

Considered just as one of the ways through which nature generates its variety of forms [14], Turing's model can be associated with the "emergent" complex systems [15] in which the different agents interact with each other following local rules rather than top-down instructions.

According to Turing's equations, the concentration of the two substances, at any point of the system and at any given time, depends on the detected concentration of the same substances in close proximity to it. As a result, though, we can see a recognisable global behaviour, typical of self-organised systems.

3.2. Gestalt (Natural Image)

The holistic, anti-atomistic, ecological, … models explain the form (*Gestalt*) and image of the bodies by assuming a clearly systemic point of view.

They mainly study the global properties that turn out to be phenomena of "emergence" and "supervenience" only referring to an integral wholeness level of the system (organism, community, species, ecological niche, …), not to single parts of this wholeness. They seek to explain the emergence of the forms as a top-down process, from global to local, from the whole to its parts, or from the external environment towards the organism. For instance, the Gestalt laws of grouping—Proximity, Similarity, Continuity, Closure, Connectedness, *Pregnanz*—are properties of the proximal image taken as a whole instead of considering only a portion of it.

The holistic and reductionist conceptions are two complementary notions—not contradictory between them—of form and image. This complementarity of the concepts of form and image is expressed in German using the terms "*Gestalt*" and "*Bild*". The two types of paradigms (holistic and reductionist) are not generally and technically translatable between them, but—from a realistic point of view—they are correlated.

Their complementarity is clear—to give a useful example—if we consider the phenomenal image of an organism and how it appears to the other forms of life that surround it.

If we take the well-known example of the zebra stripes, we can explain it from both an ontogenetic (Section 3.1) and an evolutionary (Section 3.2) point of view:

1. From an ontogenetic point of view, the pigmentation pattern of the animal coat is explained as a physiochemical result that today we can simulate with an image (*Bild*) through an algorithm derived from Turing's morphogenetic model;
2. From a phylogenetic point of view, the form (*Gestalt*) of that pattern is generally explained based on the evolutionary advantage given to zebras, thanks to the fact that their phenomenal image in the predators' eyes (lions and hyenas) has an effect of disruptive patterning (confusing and breaking up the body outline);

Therefore: on the one hand (a) biology and developmental psychology [16] and, on the other hand (b) ontogenetic biochemistry try to explain—in the same genetic context—a single phenomenal reality, even if their models are not technically translatable one to another.

There is a common horizon between them, which is more inclusive—although still far—and would integrate Evolutionary biology (a) and Developmental biology (b) [17]. Moreover, it has been possible for some time now to simulate through computation (§ 4) some aspects of the pattern's morphogenetic process, by artificially recreating aspects of the natural image.

The current use of morphogenetic models in the field of design—morphogenetic design—seems to suggest that what we have observed for the zebra pattern may apply—*mutatis mutandis*—even to the study of the image of artefacts with an aesthetic purpose, from fashion design to architecture.

Unfortunately, nowadays, the use of morphogenetic models in the field of design is mostly limited to the mimesis—using other materials—of generally biomorphic shapes; it hasn't become an actual tool for the design of "artificial organisms" yet, at least compared to the opportunities revealed by the current Industry 4.0. In other words, the natural image (in its biological model) technologically appears to be more efficient and advanced than its artificial imitations.

Yet, it is exactly in the terms of "morphogenetic models" that the issue of the "natural image" is related to the so-called "sciences of the artificial" [18] and the design studies as well.

The third industrial revolution in the 1950 and 1960 is marked by the extraordinary convergence between natural sciences and technics, particularly thanks to the development of the so-called "sciences of complexity"—von Neumann, McCulloch, Pitts, Wiener, …—with the advent of information technologies and theories, neural networks, cellular automata, self-organised and self-regulated systems, biocybernetics, …

These new tools are part of a shift in the way of shaping the issue of form in theoretical biology and, by extension, in a technical and aesthetic context, particularly through the topic of "natural image" and its computational implications.

But what do we mean by "natural image" today? We have outlined the case—although trivial—of the morphological models to describe the zebra stripes, because it gives a good example of the deep and dual reality of the natural image. As every kind of "image", the phenomenal image of the zebra coat is two-fold: there is a distal and objective image—on the zebra coats—and a subjective one, which lies in the perception of lions and hyenas.

The term "natural image" precisely indicates two intertwining facts:

1. The image of the environments and of the "natural" objects that a receptive apparatus perceives, referring to objective properties of natural forms, that are phenomenally experienced in that precise way;
2. The format of the image, transduced by the receptive apparatus, referring to the properties of the subjective perception apparatus; this is a topic that is going through a period of rapid development in neuroscience. It is important—among others—the example of the discipline called by Jean Petitot [19] "Neurogeometry", meaning the study of the (mathematical) models of the functional geometry referring to the human perceptive apparatus for the low-level vision (from the retina to area V1).

By integrating these two meanings, the term "natural image" labels nowadays a heterogeneous area of studies in visual psychology, which primarily adopts towards it a computational approach.

A correlation between the neural format of vision and the forms of natural display has been established in this framework through an evolutionary hypothesis (e.g., [20]). If the natural environments—distal stimulus of perception—have statistically specific and lasting optical features, understanding its peculiarities would help deduce which processing economy has shaped the evolution towards the efficiency of the visual apparatus.

Therefore, some studies on the visual perception based on the computational paradigm [21,22] have tried to infer features of the neural processing of the optical images starting from specific statistic features—stochastic regularities—of the natural environments appearing to us. The object of these studies is not so much the *Bild* or the *Gestalt*, but the pattern. The concept of pattern suggests indeed the possibility of integrating a top-down (form-oriented) point of view and a bottom-up (matter-oriented) one, as in the case of the process of conception of the artefacts (Section 2).

But in what terms is the integration of the matter-oriented (based on local laws) and form-oriented points of view related to the artificial image from the Industrial Revolution on? The best example is provided by the case of cellular automata (CA).

4. (Natural and Artificial Implementation) Patterns (through CA)

Introduced by Stanislaw Ulam and John Von Neumann in the late 1940s—almost at the same time as Turing's model—cellular automata are algorithms that describe the evolution of a system made of a group of cells which, starting from a definite initial arrangement and a predetermined rule, can take a finite number of states.

The rule applied for each point of the system and for many iterations, depends on the current state of each cell and the state of the cells in its initially defined neighbourhood.

We can find these features, for example, in the Game of Life by John Conway, a two-dimensional cellular automaton whose evolution is only determined by its initial state, following three rules [23], which decide upon the survival of a counter for each step of the simulation.

Thus, depending on the initial position of the counters, we can obtain different schemes leading to a stable state, an oscillatory state, the disappearing of all the counters or even an apparently chaotic growth.

These different kinds of evolution largely correspond to those classified in the 1980s by Stephen Wolfram, who, in the same period, introduced the concept of "elementary cellular automata" [24]. These are one-dimensional systems evolving through time and represented by a series of cells arranged in grids whose rows correspond to the different stages of the automaton's evolution: each one of them is generated by the previous one following a few rules. The simplest example of elementary cellular automaton takes into account only two possible states for each cell and a neighbourhood of three cells: the considered one and the two adjacent to it in the same row. Thus, for each neighbourhood, there are $2^3 = 8$ possible arrangements. The possible rules—considering that each one of the eight arrangements can lead, at the following stage, to one of the two allowed states—are $2^8 = 256$. This proves that even the most elementary case can lead to a wide range of configurations (Figure 3).

As a consequence, cellular automata are suitable to represent and simulate the global evolution of phenomena that only depend on local laws, as for example the evolution of a population or an ecosystem, even if we cannot obviously reduce the complexity of nature to a simplified algorithm.

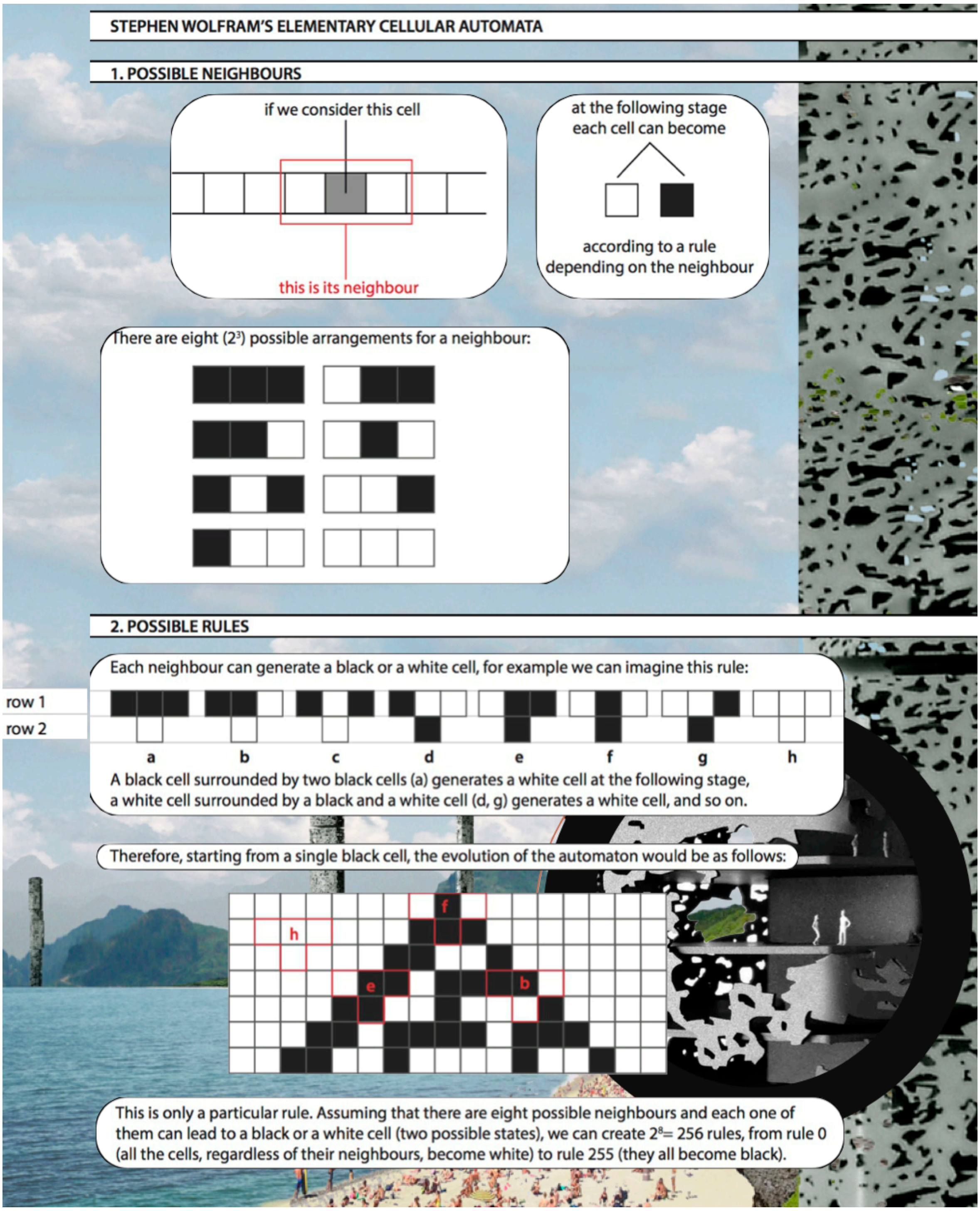
Such an example is provided by Wa-Tor [25], a model that is based on the predator-prey dynamic studied by Alfred Lotka and Vito Volterra in the 1920s. This cycle, a delicate balance that, if maintained, leads to periods of prosperity for both species alternating to periods in which one of the species is threatened with extinction, is represented in Wa-Tor introducing the spatial dimension: the survival of the two different species—fish and sharks—depends on the occupation of the surrounding areas.

More precisely, fish can move randomly and occupy free cells. They are also associated with a reproduction time: they can generate new fish during a certain period if there is an available adjacent cell. They are potentially eternal, but they die if sharks occupy their cells.

Sharks can move randomly like fish and their life is determined by energy units: for each movement from a cell to another, they lose a unit, but they can gain energy by eating fish and occupying their cells. If they reach a certain energy threshold, they can generate a new shark, whereas, if their energy drops to zero, they die.

These rules lead to three possible scenarios: a perfect balance of the two species, the disappearing of sharks or the disappearing of both species.

Similarly, in 1968 Aristid Lindenmayer, biologist and botanist at Utrecht University, introduced the L-systems (Lindenmayer systems) to study the growth of algae, bacteria and plants [26]. This work was then broadened by Christopher Langton, who, in 1986, classified under the name "artificial life (a-life)" all these examples created to reproduce biological systems "from the molecular to the population level" capable of replication in artificial—or even virtual—spaces [27].



There are eight (2^3) possible arrangements for a neighbour:

Each neighbour can generate a black or a white cell, for example we can imagine this rule:

A black cell surrounded by two black cells (a) generates a white cell at the following stage, a white cell surrounded by a black and a white cell (d, g) generates a white cell, and so on.

Therefore, starting from a single black cell, the evolution of the automaton would be as follows:

This is only a particular rule. Assuming that there are eight possible neighbours and each one of them can lead to a black or a white cell (two possible states), we can create $2^8 = 256$ rules, from rule 0 (all the cells, regardless of their neighbours, become white) to rule 255 (they all become black).

Figure 3. Stephen Wolfram's elementary cellular automata. In the background, an example of morphogenetic (mimetic) architecture.

5. Conclusions (Categorising the Artificial Organism)

The Lindenmayer systems, together with other sets of algorithms—fractals, Voronoi diagrams, parametric equations, evolutionary (genetics) algorithms, Generative Modelling Language …—are, by now, part of the computational geometry and can be regarded as possible IT resources for the procedural modelling suites employed in the so-called "procedural digital modelling": i.e., the modelling of complex 3D shapes used in different fields of design, especially in some trends called "parametric" and "morphogenetic design" [28–32].

In relation to these trends, the use of procedural modelling is—in almost all currently known cases—limited to styling; it is a shaping tool and it doesn't deal with all the aspects of the artefact design. It is referred to software for parametric 3D modelling that is used—in the context of morphogenetic design—to generate biomorphic effects and articulations similar to natural patterns.

In short, the morphogenetic models developed in natural sciences are generally used as a drawing tool for design in that context of styling that—as we saw in § 1—separates form and matter, shaping and engineering.

Thus, morphogenetic design hardly seems "morphogenetic" in a scientific sense, since we have seen that the morphogenetic models in natural sciences don't separate physics and geometry: they are processes of mathematical physics applied to the organisational complexity of the material systems.

We believe that, in order to imagine an analogous morphogenesis referred to artefacts, it would be useful to conceive the material reality of the techniques and the human environment, by considering the artefacts as "artificial organisms" rather than artificial copies of natural organisms [33]. The term "artificial organism" has two meanings for us: (1) an actually evolutionary feature of technical objects and (2) a feature of the models used to simulate the complex artefacts.

1. In the first instance, by using the term "artificial organism", we refer to Gilbert Simondon's theory [7], which identifies the main evolutionary line in the conception of technical objects in the tendency of increasingly conceiving them as "quasi-organisms" in symbiosis with their environments, i.e., as "hybrid environments" able to amplify human aesthesis;
2. In the second instance, we refer to the evolution—in the era of Industry 4.0—of simulation models used in the design and building process of complex artefacts.

Let us take the example of the Building Information Modelling (BIM) software, which, dealing with the properties of building components (manufacturers' details, functional interconnection and interaction, life-cycle stages, …), could provide more comprehensive models, including many aspects of an artefact seen as an "artificial organism". The BIM models could be integrated with software for the simulation of aspects of the physical behaviour of artefacts—structural mechanics, the optical appearance (rendering) of the objects and their energy exchanges with the environment—and become (gathering together all these aspects) tools for shaping, physical simulation and computation of the components.

However, we must not in any way confuse these two instances; that is, we must separate the reality of physical objects (a) and the reality of models (b) used for their conception.

Models are a particular category of technical objects representing (categorising) a necessarily partial aspect of a phenomenal and anthropologic reality.

In the use designers make of it, these morphogenetic models count for their explanatory value, rather than for their predictive value: they can indicate which categories (in the designer's opinion) are more appropriate and relevant to interpret a given phenomenal aspect. Thus, from the designer's point of view, the morphogenetic models of (natural or artificial) objects have no more than a heuristic value, which is, only partially, simulating (predictive). They are tools that allow the exploration of particular material organisational structures, which are so complex that they exceed the individual possibility of calculation and imagination, but which would not have any aesthetic value (for us) outside the human imagination.

This is what we have tried to illustrate by discussing the complexity of the issue of natural images in cognitive sciences. In this field, the study of the emergence of patterns and forms is related, on the one hand, to particular material systems, on the other hand, to less physical systems, like the categorisation and learning processes.

This is the case of conception: it is actually made of both objects and ideas; but a morphogenesis of the artificial would not be understandable without its own eidogenesis (in the sense that Simondon gave to conception in his theory of images). The "Eidogenesis of the artificial" is a fact. The veritable (philosophical, anthropological, semiotical and practical) question is: How adequate are our models in relation to the reality of eidogenesis (Figure 4)?

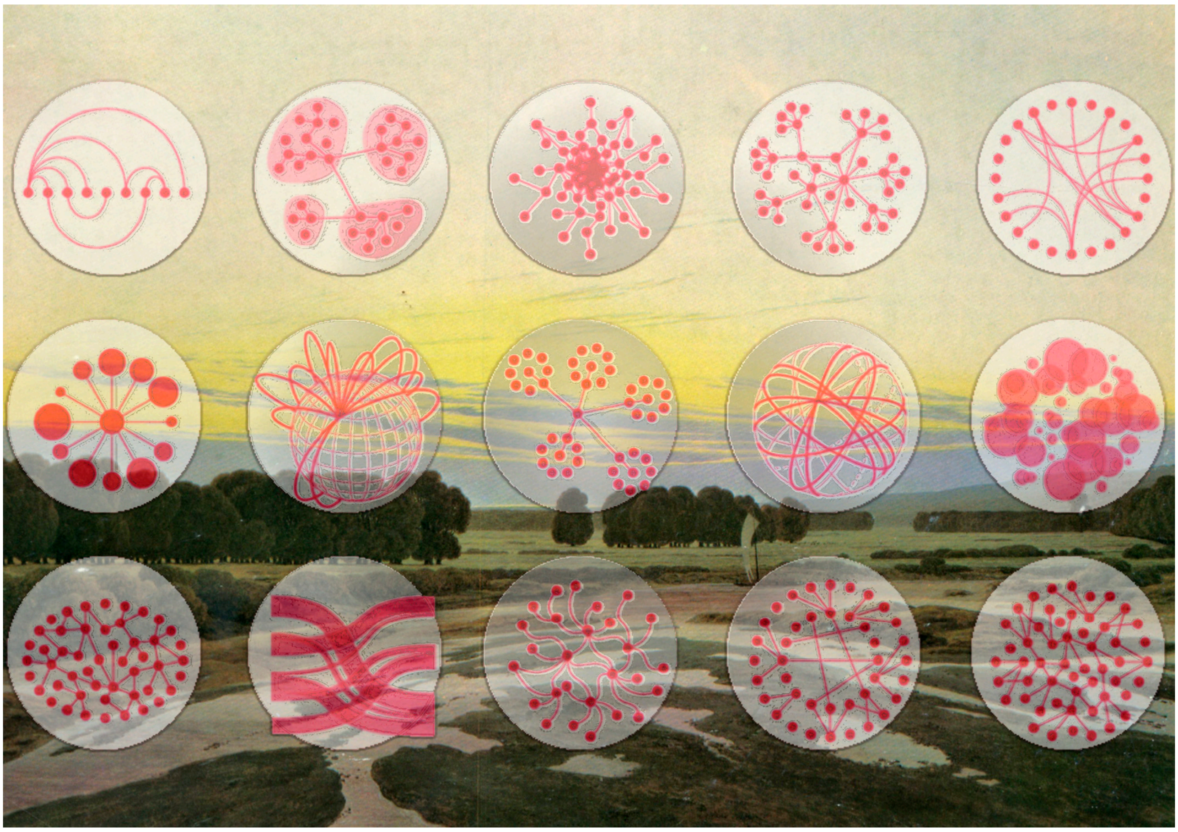


Figure 4. The category of an object is a network of information; these are 15 types of network visualisation.

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