DYNAMIC LANDSCAPES

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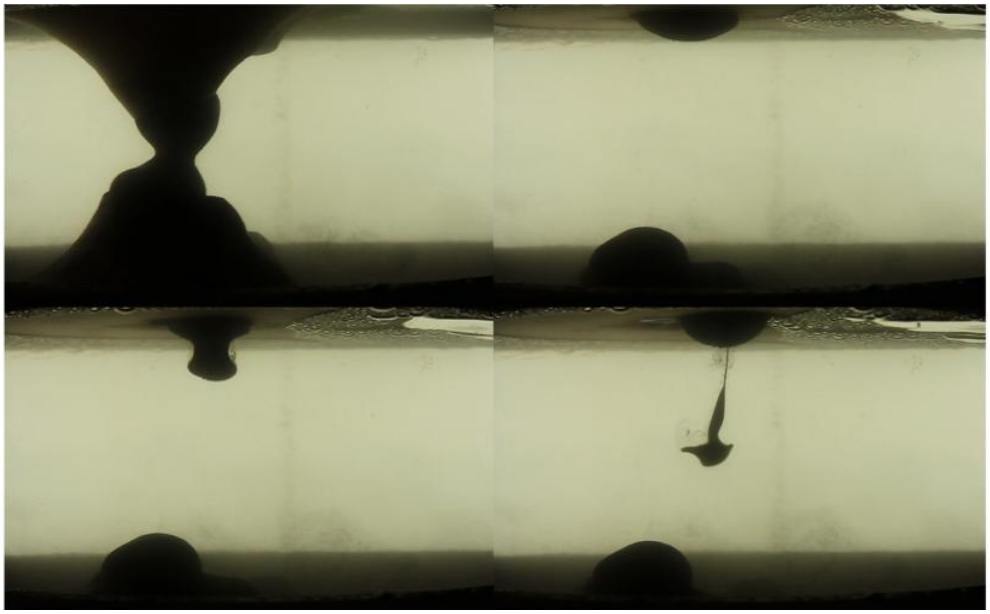
I will illustrate a performative design research program, based on a structural (albeit dynamical) interpretation of the figure of landscape in theoretical biology. We are interested in the dynamical properties of landscapes to be instantiated by the behaviour of designed devices: we are working on a pragmatics of landscapes.



"Paysage magnétique", february 2010, in the framework of the workshop "Dynamics of a Landscape", in collaboration with the research program Dynlan. Students: Maia d'Abboville & Ferdinand Dervieux. Copyright ENSAD.

Morphodynamic narratives

ONE. CHANNEL

On a tensed membrane presenting maxima and minima, balls of different size are falling down. Sometimes they stop in local minima of the membrane. A second tensed membrane lies under the first, and they are connected by a channel.

TWO. TECTONICS

Potentially interacting agents are irregularly distributed on a plan network, at rest. They attract each other whether their distance is equal or less then a critical value. This condition can be produced, for example, by an external perturbation. Their topological disposition may thus change, and the global form of the surface be modified, folds appear.

THREE. A NETWORK OF SINGULARITIES

Imagine a network of singularities, dispersed in the three-dimensional space. Local maxima, local minima. They are interconnected. This connection is materialized not by linear links, but by surfaces. As in a dance, each equilibrium is nothing but a frozen instant of a global morphodynamics. An equilibrium can be destabilized, following certain tendencies. A local maximum can become a local minimum, while other unstable and dynamic equilibria are deploying their connection surfaces. We assist to a – periodic – revolution of the mutual equilibria.

FOUR. FLUID SCENARII

Insistent attempt of an encounter. Pressure. Resistance. Crossing a threshold. Modification of the form. Explosion. Surge. Fall. Dispersion. Extinction. Agglutination. Da capo. (Fig. 1)

Each of these morphogenetic narratives is compatible with one of the prototypes that have been produced in the framework of workshops on performative design held in ENSAD, Paris, inspired by the figure of landscape in theoretical biology. Some details on the context of the teaching and research experience in which these workshops took place are given in. [1] The idea was to provide to applied art students an introduction to the figure of landscape in theoretical biology through the presentations of some researchers in the field. A brainstorming with the researchers and with some teachers of the ENSAD - also involved in the project - followed this introduction, in order to help students in formulating a project of prototype, to be realized in the following weeks. In which sense the figure of landscape can be connected with morphogenesis and morphodynamics? And how can it inspire an experience of performative design?

The figure of landscape in theoretical biology

In every day language the term “landscape” has several acceptations. The most obvious are perhaps the ones referring to landscape as an expanse of scenery that can be seen in a single view: a desert landscape, for example, or a picture, or an artistic representation depicting this expanse of scenery. In our research, however, we are referring to another acceptation of landscape – we will not consider a material landscape or its image, but an abstract one that, nevertheless, also concerns vision: the landscape considered here emerges from contemporary science practice, it is a mental picture offering a theoretical view on morphogenesis and morphodynamics in systems composed by interacting agents evolving in an environment.

From the theory of evolution to embryology and statistical physics, the “landscape” metaphor - qualified as “adaptive”, “epigenetic”, or “energetic”, depending on the domains under consideration – presents a characteristic shape defined by peaks, pits, and cols. An example of recent interdisciplinary research in theoretical biology dealing with landscapes is given in Armando et al. [2] These figures played and play an important role in the development of biology, from population genetics and evolutionary theory to embryology and epigenetics, since they entrance on the scientific scene during the 1930s. On one side, the adaptive landscape, introduced in 1932 by Sewall Wright, one of the founders of modern synthesis, is described by this author, as a

“diagrammatic representation of the field of gene combinations in two dimensions [...]. Dotted lines represent contours with respect adaptiveness.” (from the original caption) [3]

In this representation the dynamics of mendelian populations on this surface is expected to go towards local maxima of fitness. On the other side, the epigenetic landscape introduced by Conrad Hal Waddington is qualified by Waddington himself as a mental image, a representation by a diagram of the developmental system of an embryo:

“Although the epigenetic landscape only provides a rough and ready picture of the developing embryo, and cannot be interpreted rigorously, it has certain merits for those who, like myself, find it comforting to have some mental picture, however vague, for what they are trying to think about.” [4]

From a morphological point of view, the common shape of these landscapes (hilly surfaces) could suggest an analogy with the images of potential or energy landscapes for dissipative systems in mathematical and physical literature. However, Wright himself affirmed years later the introduction of his landscapes, that he did not meant to give them this mathematical connotation. He was indeed interested in suggesting a visual metaphor and in using its rhetorical power in order to render his own theory more understandable and to promote it in the wide community of not mathematics trained biologists. If in the case of Sewall Wright’s landscapes images served manifestly to visually illustrate his already mathematized theory, I argue that the epigenetic landscape plays, with respect the theory it should represent (on embryo development), an inverse role: it is not an illustration of a theory, but in some respects an anticipation – an anticipation of its expression in mathematical terms. As a composite metaphor, involving variables at different spatio-temporal scales, it contains a call for mathematization of developmental processes. This interpretation of the figure of the epigenetic landscape, with all the potentialities it offers, lead my choice to build a teaching and research program at ENSAD on morphogenesis in an art-science perspective (see also papers by Jonas Ranft and Jiang Bin & Sara Franceschelli in this conference).

How to say mathematics with images

In Waddington’s 1957 version of the epigenetic landscape a ball, lying on the top of an undulated surface, is ready to move along one of the paths opened in front of it. This image is completed by a “hidden” part, underlying the undulated surface: a network of pegs fixed in the ground, interconnected, often in a redundant way, by guy-ropes and strings. Tension on the links (guy-ropes and strings) is finally assured by the fact that some of them are connected to the inferior side of the surface (imagined here of non-zero thickness). The form of the undulated surface is thus seen as the emergent effect of this complex set of relationships. This suggests that a change in the tension of a link (that could be provoked by a variety of factors, for example an external perturbation, a modified tension between two or more pegs, or other…) could modify the form of the undulated surface, thus creating a new path, a new possibility for the balls to be chosen. On another side, one can also imagine that some tension modifications could be balanced by other modified tensions, so as to leave unmodified the global tension game on the undulating surface. This would imply that the paths offered by the undulations of the surface to the balls routes would not change, despite the underlying local modifications. And this could be seen as the guaranty of a certain form of robustness for the dynamics of the balls. Now, what could this image represent? Waddington states it explicitly: The undulated surface represents the fertilized egg. The path followed by the ball represents the developmental history of a particular part of the egg. As far as the underlying part, the epigenetic landscape turns out to be a composite metaphor, offering an explicit and mysterious at a time interpretation of the constitution of the surface itself:

"the complex system of interaction underlying the epigenetic landscape. The pegs in the ground of the figure represent genes; the strings leading from them the chemical tendencies which the genes produce. The modeling of the epigenetic landscape […] is controlled by the pull of these numerous guy-ropes which are ultimately anchored to the genes." (from the original caption) [4]

This figure points out at least two aspects of Conrad Hal Waddington vision of embryology:

- the development of the embryo is canalized along defined pathways
- the undulating surface on which pathways, or channels, are defined, is moulded by the underlying network of genes interactions.

Waddington's non reductionist position vis-à-vis single gene action is explicitly stated:

"it is not necessary, in fact, to await a full understanding of the chemistry of single genes before trying to form some theoretical picture of how gene-systems produce integrated patterns of developmental change." [4]

Moreover, Waddington compares the genetic actions on the whole to the geological structure moulding the valleys of the landscape: beyond the field of embryo development, structural and morphological thinking is inscribed in Waddington's images. And this is the aspect that our research stresses.

What do landscapes do?

I argue that they call for a mathematization, setting the agenda of what a good mathematization of development should take into account. They also suggest the ingredients (non-linear dynamics, sensitivity to initial conditions, networks…) that could be at work. The mathematician René Thom, father of the catastrophes theory, inspired himself from embryology, and from these images, to create his mathematical theory. Catastrophe theory is a general theory of morphogenesis, intended as the creation or the destruction of forms, without regarding nor the substrate, nor the nature of the forces that determinate it. Waddington and Thom have been involved in a long correspondence, about a possible mathematization of the epigenetic landscape in terms of catastrophe theory. The correspondence shows some misunderstandings both on the theoretical notions associated to the landscape and on the mathematical notions that could describe them. [5] Despite these misunderstandings, and even more because of the questioning they open, I argue that the image of landscape, if interpreted in a structural, albeit dynamical sense, is a call for mathematization. It inserts itself in the history of the use of dynamical systems theory in biology, use conveyed also by cybernetics (the relevance of dynamical systems theory for cybernetics was not unknown to Waddington). Thus, if we look at the images of epigenetic landscape not as referring to objects, but to processes, possibly grasped by a dynamic systems approach, what becomes interesting is their performative power, more than their representational status. If the term landscape has, in its most general acceptation, the peculiarity of designating both the thing and the image of the thing – the signified and signifier - in our research program we are interested in the dynamical properties of landscapes to be instantiated by the behavior of designed devices. In other words, we are working on a pragmatics of landscapes. The challenge for students working with us on performative design is to conceive prototypes which instantiate some of the dynamic properties of landscapes.

What is performative in performative design?

The idea is that the morphological properties of landscapes, in their dynamic evolution, defines narratives that one could try and produce through designed devices. These narratives - thus shared by images of landscape (thought as processes) and material devices - can be supposed to be interesting on the basis of their genericity. Therefore one can work on pragmatics, with the idea in mind to eventually come back to semantics, carrying out questions and insights from the observed dynamic behaviors. If we consider the morphodynamics narratives we began with, each compatible with the behavior of a designed material device, several questions emerged from observations.

As far as the first narrative, “Channel”, inspired by the dynamics of canalization on a landscape, a possible question to explore is: Can the balls pass from the superior membrane to the inferior one, and how?

For the second narrative, “Tectonics”, which has been realized in the framework of the workshop “Dynamics of a landscape”, the questions we tried and ask to the functioning of the device were of the kind: Which are the properties of stability and of robustness of the folded surface - globally and locally? How does the device resist to external stresses?

The third narrative “A network of singularities” is associated to a device that has been realized by a group of first year students of ENSAD in 2008, in the framework of the workshop “Paysages sensibles et dynamiques” (co-directed by the ENSAD colleague and architect Yves Mahieu and myself), which has been inspired by the notion of deployment arising from the analysis of the Waddington-Thom correspondence ([6], see also [1]). Here we took the notion of singularity as the dynamic unit around which a complex deploying surface has been designed. We worked on the calibration of the parameters of the dynamics to obtain a periodic deployment of the surface itself. In order to go further and to work on a possible interactivity of the device, questions arise, such as: How could an agent evolve on this surface deployment? Will there be any interdictions? Any ruptures? Any holes? What else – who else could take part to this dance? Interactive potentialities of this device are to be explored.

Interactivity perspective has been further explored in relation with the fourth narrative, “Fluid scenarii”. This is associated to a device, “Paysage magnétique” (realized by two students, Ferdinand Dervieux and Maia d’Abboville in the framework of the workshop “Dynamics of a landscape”, Fig. 1), that has been conceived following the idea that, in a generic landscape, the ball, coming from the image of the epigenetic landscape, could be a modifiable element, too. The behavior of the conceived device, in response to user stimuli, raised the following questions: Are there recurrent morphologies in function of external stresses? Can we recognize recurrent histories? And try and obtain them again? Here, thanks to the exploration of the responsive dynamics of this device, under the effect of external stresses, we found pertinent the use of the notion of “scenario”, coming from the study of dynamic/complex systems transition to chaos.

In the study of dynamical systems from a mathematical point of view, as soon as non-linearity is implied, and there are more than three degrees of freedom - as it is well known since Poincaré’s work on the three bodies problem - predictive power of equations in not guaranteed. In order to make some predictions on the dynamics of this kind of systems, the question of establishing a good representation of the phenomena thanks to the equations is not enough: one needs to know the history of the system, its behavior under the effect of the variation of some control parameters: what does the system perform spontaneously in time, and under the effect of its parameters variations? Are there generic scenarios,

defined by generic series of bifurcations, that on can recognize? Our experience of performative design allowed us to explore this set of questions by observing the dynamic behavior of the “Paysage magnétique”, in response to the user actions.

Discussion

Without explicitly writing any equation, these performative design experiences lead us at the heart of the questioning about dynamic and complex systems behaviors, that the figure of landscape synthetically grasps. We followed the idea of not designing objects, but processes generating families of objects. From a practical point of view this has been translated in designing parameter controlled devices. We worked on mechanical, analogical devices without using the digital as a source of morphogenetic research. We worked on a qualitative basis, but theoretically there is no opposition with digital, morphogenetic research flourishing in architectural and design research, as for exemple in the work of Mark Burry, Hachim Menges, Michael Hensel, Aliza Andrasek... The tension analogical/digital, that we will explore in our further research, is not but a reactualization of one of the founding debates at the core of cybernetics, and still of great pertinence.

References and Notes:

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