METACONCEPTION

Evolutionary tooling of the creative design process

Philippe Marin[1], Jean-Claude Bignon[2], Hervé Lequay[1]

[1]*École Nationale Supérieure d'Architecture de Lyon*
[2]*École Nationale Supérieure d'Architecture de Nancy*

Introduction

We would like to characterise the creative design process in which genetic algorithm are used to drive the exploration. We focus our point of view on the initial phases of the process, moments during which the conceptual representations of the object under study are significant.

First of all, we consider the tooling as a virtualisation mechanism of the action and we highlight the notion of "Critical Points of Change" which are stimulated by the instrumentation. In a second time, we review the limitations of classical digital tools as efficient to support a creative activity. Then, we identify the advanced practices in the field of digital design and we replace the genetic algorithm in the category of algorithm process and evolutionary architecture. Lastly, we describe our experimental genetic tool, which leads us to identify three key concepts: a cognitive shift from an implicit thinking to an explicit one, the place of the chance and the significant indeterminacy and finally the notion of "Transform" and the emerging posture of the "Metaconception".

1 Instrumentation of the conception

1.1 Instrumentation and virtualisation of the cognitive activity.

We know from the history of techniques, that the materialisation of the action and gesture led to the emergence of tools during the history of mankind. What was subjective and internalized has been transformed, interpreted and externalised in an object. The virtualisation of the cognitive activity can be associated to the conception of a new tool. In this case the tool virtualises a cognitive function, a mental activity. In this case, the tool is a virtualisation of the action. Designing a tool allows us to climb at a higher level of an indeterminate group of situations, rather than focusing on the ongoing action. A constraint is transformed in a variable, the tool become a fulcrum for the resolution of a class of problems. *"But in turn the subject must learn gestures, develop reflexes, re-organise his mental and physical activities in order to use the tool "* (Lévy, 1998). Through the realisation and the use of the tool, the technique proceeds to the materialisation of the action and in return to the virtualisation of the action. Thus it re-organises the intellectual ecology and it modifies the cognitive function, which was initially supposed to be supported and underpinned. The perception is modified each time new tools allow us to reach a new reading level.

The fundamental component of the design is based on the intellectual qualities and abilities of the designer to perceive, imagine, invent and make sense. The designer leads his work through a dialogue with himself, through the multiple representations and figurations he makes. A continual interaction between the idea and its manifestation operates by the use of design tools. Ganshirt (Ganshirt, 2007) marks the close relationship between tools and design: the compass and the rule create their own geometry based on lines and circles; the perspective induces a certain conception of space. All design tools are used in order to figurate and they facilitate the perception. They are used to reduce the complexity of the object under study, to make it intelligible to the designer.

1.2 Stimulate the emergence of "Critical Points of Change"

Each mode of representation is used as a knowledge tool, facilitating the specification and the emergence of an understanding. But these representations are also gather their own properties. The representations have their own and specific "affordances[1]" which make the designer's action easier. Thus the choice of the representation mode determines or constrains the modalities of comprehension and expression.

The architects are now taking advantage of the wide range of tools and media available to them, each one revealing benefits and disadvantages and each one having to help the understanding of the object being designed. Parthenios (Parthenios, 2008) considers the ability to switch between different modes of representation as a process that can stimulate the emergence of Critical Points of Change (CPC). The Critical Points of Change are particular moments in the design process: they reveal a previously invisible component of the object under study, allowing a decision-making. For Parthenios, the tools of conceptual assistance must be characterized by: their ease to reveal CPC situations, their ability to induce CPC, their potential to encourage an exploration of design alternatives by offering different representation levels and complementary understanding, their capacity to organize the different assumptions and their ability to integrate different media and tools. But for the author, it is the capacity to assume the coexistence of digital and analogue tools that should be the most suitable for supporting and stimulating design.

2 The CAD emergence

Since several years the digital tool and the computer assistance have invested all fields of design and creation. These digital tools are used primarily for their ability to attend the virtual representation of an anticipated environment, for their ability to attend an analysis based on the evaluation of the performance and for their ability to help decision-making in implementation of expert system. Here we will identify constraints and limitations of these methods of use, especially when they are used in a creative design process associated with the initial phases of design work.

[1] Le mot *affordance* est un néologisme forgé à partir du verbe anglais *to afford* qui signifie « permettre, donner les moyens, accorder, offrir, le mot *affordance* désigne les opportunités d'action que nous procure notre environnement, en vertu des informations que nous percevons. Il est à rapprocher des notions d'écologie de la perception proposées par James Gibson. (Ganascia, 2006)

2.1 A transformational model

Françoise Darses (Darses, 1994) reminds that the systematic evaluation of CAD tools in the creative design process reveals that they introduce requirements that affect the creative part of the design work: the user awareness is focused on accurate content and the execution of the drawing takes precedence over the problem analysis. CAD systems reinforce a hierarchical solving of the problem by imposing to follow predetermined resolution steps, they make impossible the implementation of strategies and manipulation of uncertain and undefined objects, such as drafts, sketches or graphic overloads. This cascade model establishes a phasing sequence from abstract to concrete. But this "transformational model" is not adapted to the characteristics of a creative process.

2.2 Contextual and cognitive limits

Pierre Leclerq (Leclerq, 2005) illustrates this inadequacy. The 3D rendering with an animation will assess the quality of forms and spaces or verify some dimensional constraints; the modelling of the supporting structure will validate the stability of the building; the thermodynamic modelling of the locals and walls will allow the evaluation of the energetic needs of the building; formal grammar rules, or fractal formulas may facilitate the development of a complex geometry. These encodings are nevertheless long and daunting, they require a high degree of expertise and at the same time the explicit full model description. They are therefore involved in most cases after the preliminary design or they only deal with a small fraction of the number of parameters. It is therefore an expert input, distributed between sectoral players in a linear process of division of responsibilities.

We note two types of inadequacy particularly pressing in a creative process associated with the initial phases of the design (Huot, 2005) :

- Contextual inadequacy: the digital tool theoretically gives an immediate access to various assessments, yet these forms of interaction impose heavy operating constraints. Mental workload required to complete the model affects the attention on the object of design. The amount of indirect interactions, via buttons, menus and dialog boxes, plays a distractor and the designer focuses on irrelevant details.

- Cognitive inadequacy: graphical objects must be defined; they need to be concrete, precise, detailed and comprehensive to answer the digital system. The computer requires a univocal description from the first phases of the process, and it implies an ability to foresee all eventualities to ensure the possibility of appropriate subsequent changes. Moreover, the iterative and evolutionary process, which allows the exploration of the solutions space through combining assumptions and which leads to the emergence of a new proposal, is incompatible with the rigor imposed by the geometric description. Through a digital instrumentation, modelling based on a unique solution, it is necessary to have the right solution at once, upon pain of having to question the whole structure of the object description. Cancellation and back functions allow for versioning, but they do not facilitate the emergence and generation of new solutions.

2.3 Ergonomics features:

Studies in cognitive psychology have led to the identification of ergonomic principles which have to be used for the development of digital tools dedicated to the early phases of design {Flemming, 1997, Design Studies, 18}: facilitating data entry by hand movements, allowing imprecise data entry, allowing different levels and types of representation, assisting the comparison between different concepts of solution, making suggestions and helping evaluate the choices.

Many studies and recent developments in software tools attempt to address these ergonomic principles by improving the functionality of the human-being/computer interaction: multi-view handling of the geometric model, "altered" or evocative representation by taking over conventional graphic codes.

However it appears here that the extension of hand drawings techniques in the field of digital does not admit a transposition of creative qualities of sketches. Based on this inventory, we will see which digital advanced practices can be more efficient to attend a design and to stimulate creativity.

3 Digital architectural design

In this chapter we wish to identify the advanced practices in digital architectural design. We'll first deal with the process categorization before noting the importance of the hybridization of devices.

3.1 Maturation of CAD

The implementation of digital tools both for the architecture design and for the production of its elements, creates a continuous but heterogeneous information flow. These operating procedures have already transformed all fields of architectural production {Migayrou, 2003, Architectures non standard, Préface}. Since a few years, the use of advanced digital tools in the architectural design process is illustrated by the practice of many agencies. It generates an innovative approach and the renewal of the architectural practice theory. Based on practices and experiments conducted over the past twenty years, the digital tool can now reveal its potential and attend a creative and innovative design.

Mortamais and Magerand (Mortamais & Magerand, 2005) assume that the digital tools can greatly increase the conception possibilities by the processing power, by the diversity and the specificity of representations, by the universe of inspiration they imply. The new features of the tool can be exploited, they allow new expression means, they develop new working methods and new ways of perception. They lead to a renewal of the design, at the same time in the sources of inspiration, processes, methods and results. As the perspective representation had brought its own perceptual changes, the digital encourages new perceptions by revealing unexpected aspects of the reality. These new perceptions are identified: reading and writing complexity (treatment of the infinitely small and infinitely large and their interaction), statistical reasoning, genetic evolving of the project, the immediacy and the heterogeneity of perceptions.

It is crucial that the digital support systems offer tangible representations of the intermediate solutions ongoing from the initial phases of the design (Darses, 2005). These representations will have to report of intermediate solutions, incompletely specified, in order to be used as basis for mental simulation. They will have to be part of the "visual conversation" between the designer and his production. Their function is not to represent a completed object but rather to be the support of a cognitive simulation and to participate in the dialogue between the designer and himself.

Here we will illustrate this renewal of methods and these perceptual changes by considering the non-compositional strategies and the approaches that convoke the continuum between digital design and digital fabrication.

3.2 Non-compositional strategies

Lucan (Lucan, 2003) analyzes the works of major architects from the early century and describes their non-compositional strategies. Architects like Koolhaas and Herzog & de Meuron consider the form as "a whole". Thus, when Koolhaas presents the three steps of the project for the Y2K house, he explains the process of morphogenesis by the definition of a “capable volume”: the first step consists of the assemblage, the mixed agglutination, of the secondary functions of the house around a parallelepiped empty space that represents the living room. The second step is the definition of a “serving thickness” wrapping the “served space”. The third step represents a sculpture activity, through tessellation and hollowing out operations. The “capable volume” becomes an irregular polyhedral monolith shape. Herzog & De Meuron propose the notion of “searching form” in order to describe the unitary and monolithic configurations of their projects (Ricola Building in Laufen, building of offices and housing in Solothurn, Pharmacy of the Kantonsspital in Basel, Prada store in Tokyo). These irregular configurations comply with context features. The building is shaped from the outside according to the program and site features. The architects proceed by subtraction of material, by successive approximations or radical decisions and they always consider the form as a whole. The description of the project is complicated and requires new modes of representation: unfolded façades or successive sections are some examples. This unit forms, rather than harmonious, are described as harsh or crude; they do not express the functions they host, but rather evoke some found objects. There are neither proportional understandable system nor intelligible geometric principles. The conventional compositional habits are rejected. The stakes would be based more on the selection of a process than on the choice of a composition. Here the method of the design is not based on known rules but rather on the actions associated with a process, which do not allow an a priori understanding of the result.

Even if the above examples do not call specifically digital tools, they help to formulate a new theoretical view on the principles of morphogenesis. It is probably the question of the process that best characterizes these different modalities. This implies a non-choice of the form from the author, and refers the definition of the form to an emergent property of the process. We gather here the digital methods used in terms of morphogenesis, based on the Kolarevic's classification (Kolarevic, 2000).

- Isomorphic and topological architecture: Gregg Lynn is one of the forerunners in the misappropriation of digital technology. He used the functions and properties of the isomorphic surfaces, generally called "metaballs", as a method of formal exploration.

- Metamorphic architecture: it includes animation techniques by key-frames, "morphing" and section extrusion along a trajectory.

- Dynamic data: "Animate architecture", represents the modelling methods that exploit the capabilities of IK, dynamic animation and particles emission. "Datascape" is a concept proposed by MVRD (Maas, 1999) that induces a quantification and statistical modelling of contextual constraints and allows a time projection as well as the simulation of the decisions impact.

- Performance modelling: digital technologies are used to simulate the qualitative and quantitative performances of the building: structural analysis, thermal or acoustic analysis. Optimizing the performance of the building is used as a driving force of the design process.

Algorithmic processes gather three approaches.

- Parametric architecture: the parametric design process focuses on defining a set of parameters that influences the shape. The shape is induced. Changing the parameter values generates not only one object, but a set of variations. The process is not simply based on metric values but rather on the overall relationships between the objects that make the form. A modification of an element causes a transformation of the entire system. The parametric model consists of a set of relationships between geometric entities, whose parameters are manipulated.

- Generative architecture: the development of the *scripting* has facilitated the algorithmic conception. This allows the emergence of complex forms through the iterative functions instantiation. This method of design facilitates the interactivity and allows the designer to explore the notions of emergence and complexity. Its non-linear dimension characterizes this approach. The reached solutions are initially unpredictable situations. The project is not formal anymore, but becomes procedural. The characteristic of these approaches is based on the fact that the designer does not manipulate the object being designed, but the generative system. Fischer (Fischer & Herr, 2001) identifies three benefits of such mechanisms. They enable the automatic exploration of a large number of solutions. They are supposed to stimulate the designer's creativity. Selection mechanisms should help to identify the right solutions. However, an automatic evaluation based on subjective criteria, whether aesthetic or plastic, is difficult.

- Evolutionary architecture: here the form generation process is based on species natural selection and evolution principles. A genetic algorithm is inspired by Darwin's formulation of the natural selection process. Architectural concepts are expressed as rules and their evolution can be tested quickly. A numerical model is transformed from successive crossovers and it is evaluated according to predefined objectives and constraints.

We characterize this design process by the fact that the role of the designer shifts to that of a meta designer. With the advent of digital technologies in the field of design, the designer's role has changed. From a designer creator of a work and a single solution, we now witness the emergence of a meta designer, a creator of an expanded set of solutions (Soddu, 1998). The designer no longer works to develop an exclusive item, but rather to design a family of forms, whose the chosen solution represents a significant condition in this set of potentials. As quoted by Levy (Lévy, 1992), the designer no longer draws an object but a system of possible objects, a machine to explore the potentialities. The area of expertise jumps up a logic notch; an objectivization of realities is necessary for shaping logically the intellectual operations.

The procedural implementation implies a form of "letting go" from the designer. He accepts to share decisions with the tool. The emergence of new or surprising solutions results from the process. There is no *a priori* certainty of the final result. The designer establishes the conditions for the generation of solutions, but he does not operate the realization of a unique solution, he makes choices from all possible solutions offered to him.

These practices induce a reflection on the tool influence and its ability to amplify cognition. It is not just the automation of repetitive tasks, or the realisation of complex calculations. The question is more about the changes of our understanding, our ability to know, our memory and conceptualization faculties.

Thus for Asut (Asut, 2008), the designers must build a critical point of view on software features and they should be able to develop and customize their own design tools. The increasing of "scripting" and "open source" practices illustrates practices of sharing and cooperative development of custom tools, exceeding the embedded functionalities of the market software. Sevaldson (Sevaldson, 2005) talks about the creative ways of using digital tools. He emphasizes the scripting potential as a help to an exploratory process, and he notes that the moment of the creation has shifted from the production of a visual material towards the definition of a process creating visual configurations and towards their evaluation.

3.3 Generative fabrication

Understanding the close relationship between design, manufacturing and generation appears to be a priority today. The concept of generative manufacturing has been proposed at the seminar SIGGRAPH2009. It goes beyond the concept of automation to deal with two main areas of investigation: the generative design on the one hand and the digital manufacturing on the other hand. We have previously defined the generative design concept, characterized by algorithmic processes, iterative loops, bio-inspired mechanisms, non-linear and emergent processes, based on analysis and optimization performance. All these design features allow the exploration of a possibilities universe, without asking the form as an *a priori* phenomenon but rather as a result. Geometries from these processes are often complex: it is the principles associated with digital manufacturing that enable a reinterpretation, a materialization and a constructive implementation of these proto-forms.

The digital fabrication imposes its own production strategies through the exploitation of machinery and materials opportunities and constraints. The manufacturing logic is thus integrated to the design strategies, while avoiding traditional building processes mimicry, and rather seeking innovation through the creation of new processes, exploiting the digital machines qualities, tools modelling and design-fabrication continuum features. A new architecture thus emerges: its construction cannot be conducted with traditional methods. For Bonwetsch (Bonwetsch, Gramazio, & Kohler, 2007), automated manufacturing methods will be used by the construction industry when digital made components will demonstrate their capital gains, in terms of aesthetic, economic and practical. Moreover, incorporating their principles during the architectural design phases will develop these techniques.

4 Experiment and evaluation of a Genetic Algorithm

We have experimented an evolutionary tool and we have evaluated its potential to support a creative design. These evaluation and characterization of the tool were conducted through students' experiments.

A precise description of the tool is presented in the publications (Marin, 2010) and (Marin, Bignon, & Lequay, 2009): we note here the main elements. This tool is intended for initial design phases and it aims to stimulate creative and innovative activity. The function of evaluation is based on passive solar qualities of the object under study. The architect is here searching solutions that meet given environmental constraints. This first exploration should allow him to go further in his design work. A phase of initialization corresponds to the specification of the global algorithm parameters and environmental conditions. The generative engine initializes the process by generating a random population that evolves through the evolutionary process. The evaluation engine determines the energetic qualities of each individual. The morphogenetic engine allows the phenotypic derivation and the material engine ensures the physical properties assignment at each facet. Mechanisms of crossover and mutation allow the building of successive generations. Each individual is evaluated in function of its adaptation to energy constraints. The morphological exploration is based on a metamorphosis transformation (Ching, 2007). A series of morphological operators is used to drive the deformation. The end of the evolutionary process marks the start of an interaction phase with the user. The designer thus may know the best individuals in the population. Starting from the analogon provided by the algorithm, the designer reaches all model geometric features and he can manipulate them in order to extend his design work.

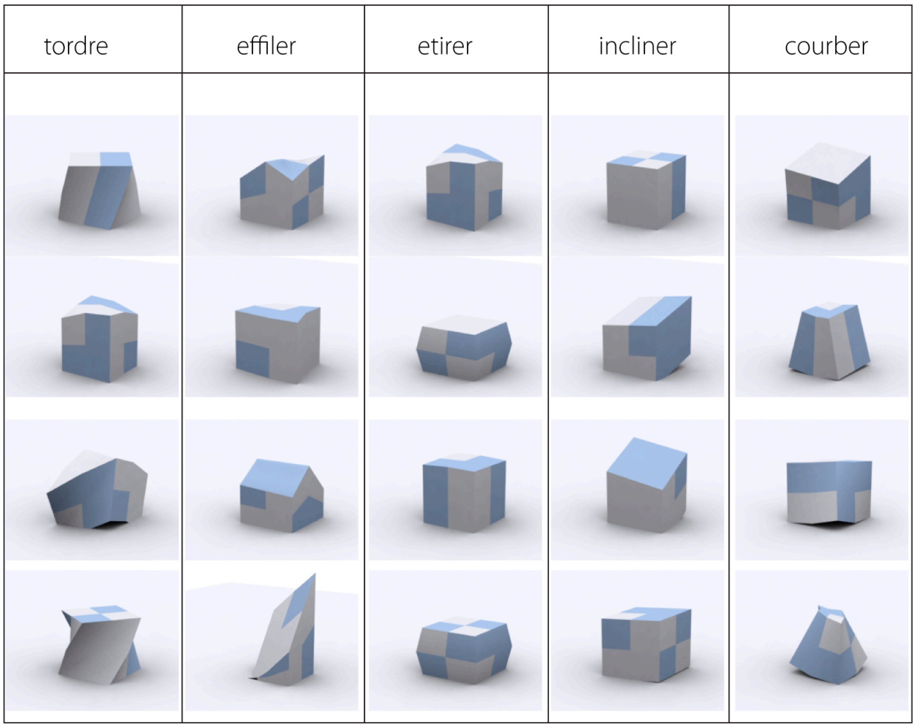

Figure 1. Representation of the population elites for five morphologic operators.

The following illustration shows a population of individuals. In this example, four elites are preserved over generations. The population is composed of twenty individuals who evolve through twenty-two generations.

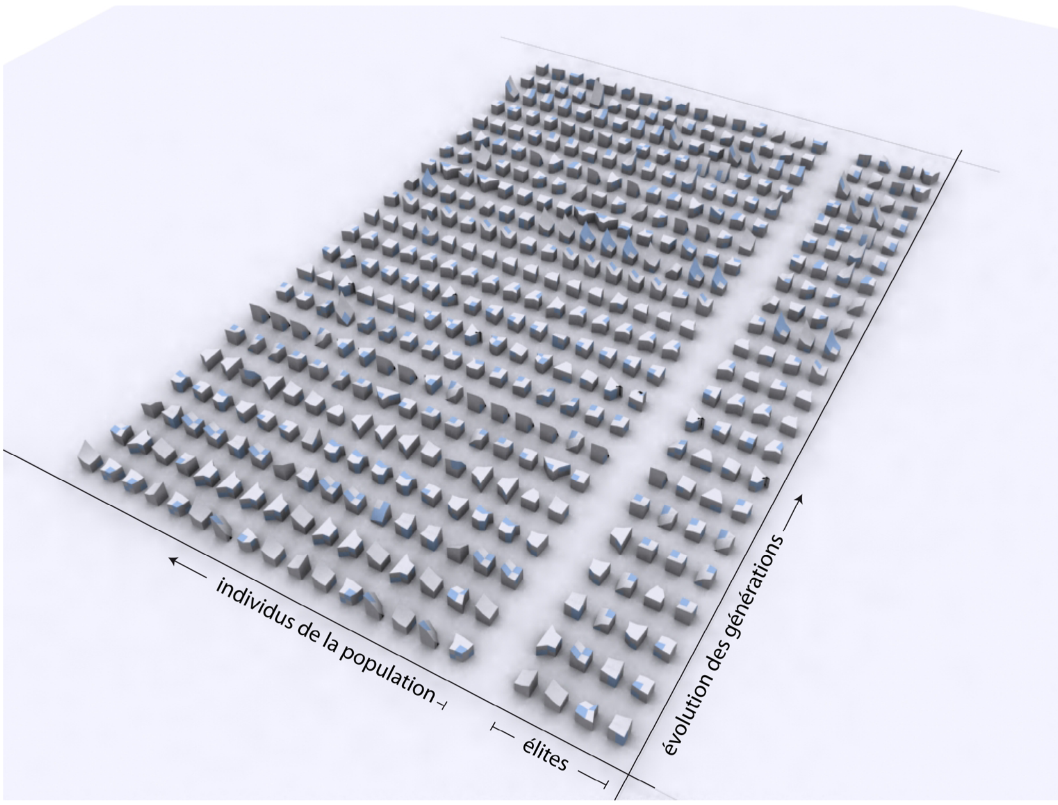

Figure 2. Population example.

5 Conclusion

5.1 Cognitive shift: explicit thinking versus implicit thinking

We believe that the implementation of a digital tool cannot bear a holistic approach in itself. The media is necessarily limited in its representation; it leads to certain kinds of understanding and expression, but it cannot afford completeness. Thus the quality of the designer lies in his ability to identify the right tool at the right time. Similarly, a generative tool cannot take into account all project variables: it inevitably operates on a limited number of parameters. The designer's skill is based on the relevance of his choices. Generative tools don't provide an answer to the whole problem; they are only a mode of expression providing a partial understanding of the design question.

However, their operating procedures are characterized by the explicit expression of a process that facilitates a subsequent visual interaction. Drawing and sketching are the expression of an implicit thinking; they arise through a gesture interaction. The common use of computers, based on a translation of hands drawing techniques, alters the creative design work. We saw the limits of the "transformational model" as well as the "contextual and cognitive inadequacies" of digital analysis tools. On the contrary, generative tools are based on an explicit thinking, resulting from the algorithm implementation. But here, it is not the geometric model that is defined but rather the conditions of its emergence and its limits behaviour. Thus the realization of the process, previously verbalized, generates in a second time a visual interaction that seems more conducive to fostering creativity.

5.2 The place of the chance: significant indeterminacy

A design attitude is based on the perception acuity activated during the different representations that are constructed or, in our case, generated. The objective is to search occurrences from the evolutionary fluctuations that could support speculation and imagination. We know the importance of the interpretative glance, its ability to capture the object occurrences and to transform them in an architectural component. This attitude opened to design opportunities is not specific to digital tools. However, software must maintain and stimulate this behaviour.

The "proto-architectures" generated by our evolutionary process must be considered as receptacles of potentialities awaiting for updating. They embody a figurative or metaphorical value. Generative devices should therefore support this speculative function, in the terminology of Estevez, or in the words of Deleuze: this suggestive function. However the software autonomy induces a feeling of control loss. The "letting go" designer attitude does not just happen. Therefore the question is how can we specify the conditions of emerging surprising facts. In other words, in which way a tool can encourage "serendipity".

5.3 The "trans-form" notion

The above considerations require a re-conceptualization of the architectural object, in particular as far as its morphogenesis is concerned. Thus the form is no longer determined a priori, but it is part of a continuum by variation. Deleuze suggests the concept of "objectile" and of invariant by variation, a temporal modulation of the shape induced by modern production methods. The concepts of "searching form ", "strong form" or "capable volume" represent what Lucan called non-compositional processes. Here we expand these notions with the "evolving form" generated by an evolutionary process.

However, these concepts do not differ according to their instrumentation mode: they can be associated indiscriminately to appropriate physical or digital tools. We suggest to gather all these ideas behind the concept of "trans-form." A "trans-form" would represent the "meta-form." It is the description of the shaping conditions through the limits behaviour parameterization and the emergence conditions. The shape is not fixed, but it is informed and associated with a thinking of the multiplicity: it allows to integrate the diversity of realities.

Bibliography

Andel, P. V., & Bourcier, D. (2008). De la sérendipité dans la science, la technique, l'art et le droit : Leçons de l'inattendu. L'Act Mem.

Asut, S. (2008). Rethinking the Creative Architectural Design in the Digital Culture. Paper presented at the First International Conference on Critical Digital, Harvard University Graduate School of Design, Cambridge (USA).

Bonwetsch, T., Gramazio, F., & Kohler, M. (2007). Digitally Fabricating Non-Standardised Brick Wall. Paper presented at the ManuBuild, Rotterdam.

Ching, F. D. (2007). Architecture: Form, Space, & Order. Wiley.

Darses, F. F., P (1994). La conception collective : une approche de l'ergonomie cognitive. Paper presented at the Communication au GDR-CNRS FROG « Coopération et Conception », Toulouse.

Darses, F. (2005). Contribution de l'ergonomie cognitive à la construction d'un modèle d'expertise des activités de conception de produits. In Ingénierie des connaissances (1Cédérom). Editions L'Harmattan.

Fischer, T., & Herr, C. (2001). Teaching Generative Design. Paper presented at the GenerativeArt, Milan.

Flemming, U., Bhavnani, S.K. and John, B.E. (1997). Mismatched Metaphor: User vs. System Model in Computer-Aided Drafting,. Design Studies, 18.

Ganascia, J.-G. (2006). Les Sciences cognitives. Editions le Pommier.

Ganshirt, C. (2007). Tools for Ideas: Introduction to Architectural Design. Birkhauser Verlag AG.

Huot, S. (2005). Une nouvelle approche pour la conception créative : De l'interprétation du dessin à main levée au prototypage d'interactions non-standard. Université de Nantes, Nantes.

Kolarevic, b. (2000). Digital morhogenesis and computational architectures. Paper presented at the Sigradi 2000, Rio de Janeiro.

Leclerq, P. (2005). Le concept d'esquisse augmentée. Paper presented at the Séminaire de Conception Architecturale Numérique, Paris.

Lévy, P. (1992). La machine univers. Création et culture informatique. Seuil.

Lévy, P. (1998). Qu'est ce que le virtuel ? La Découverte.

Lucan, J. (2003). On en veut à la composition (2). Matières : Ouvrir les horizons : actualité de la critique architecturale, 6, 68-79.

Maas, W. (1999). MVRDV - Metacity Datatown. 010 Uitgeverij.

Marin, P. (2010). Exploration des Mécanismes Evolutionnaires appliqués à la conception architecturale. Institut National Polytechnique de Lorraine (INPL), Nancy.

Marin, P., Bignon, J.-C., & Lequay, H. (2009). Paramètres environnementaux et mécanismes de conception évolutionnaire. Paper presented at the SCAN'09 - Séminaire de Conception Architecturale Numérique, Nancy, France.

Migayrou, F. (2003). Préface. In Architectures non standard. Editions du Centre Pompidou.

Mortamais, E., & Magerand, J. (2005). La spécificité des outils numériques dans l'Esquisse comme explorateur de la pensée complexe. Paper presented at the SCAN, Paris.

Parthenios, P. (2008). Analog vs. Digital: why bother? Paper presented at the First International Conference on Critical Digital: Harvard University Graduate School of Design, Cambridge (USA).

Sevaldson, B. (2005). Developing Digital Design Techniques. Investigations on Creative Design Computing.

Soddu, C. (1998). Argenia, a Natural Generative Design. Paper presented at the Generative Art, Milan.