USE OF MORPHOLOGICAL OPERATORS TO ASSIST ARCHITECTURAL DESIGN IN EARLY STAGE

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ABSTRACT

In this paper, we make the assumption that a shape modelling process can rely on the application of a set of morphological operators to initial shapes. We refer to several researches which have attempted to identify such operators. We also attempt to validate this design approach through the analysis of some buildings. A design system based on the combination of these operators could enable the designer to quickly explore a great number of spatial solutions.

KEY WORDS

morphological operators, modifiers, shape modeling.

INTRODUCTION

Since the early 80's CAD tools have provided us with a new means of graphic representation in architecture. Contrary to the usual manner in which spatial forms are represented in a 2D "glance" [in sections, elevations and plans], using this 3D drawing software one is provided directly with a virtual 3D model "constructed" by the computer.

Admitting that graphic figuration plays a key role in architecture (Lebahar 1983) (Boudon et al. 1994) these recent developments constitute an important milestone in the practice of conceptualisation. In fact today's computer techniques provide architecture with a unique opportunity for "re-tooling" and "re-thinking" its methodologies just as happened with the arrival of perspectives and stereometric projections. 3D model software [Catia, Maya, etc.] are particularly applicable for conceiving enclosed spaces with complex morphologies. Such representations are well beyond the capacities of the conventional tools of the trade. The Guggenheim museum of F.O.Gehry is perhaps the most emblematic example of this novel approach.

From Ph. Boudon's postulation that "The process of conception is a diachronical one that implies a progressive transformation of what a project is" (Boudon et al. 1994), we can hypothesise that the procedures that lead to the production of forms issue from the application of semantic operators on "seed" elements that give rise to "goal" forms. In this article we will at first treat different works of research aimed at identifying these operators.

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In addition, in the analysis of early drafts of a range of "non-standard" architectural works we will show how such operators can help in the design of projects and open the way to innovative practices in the creation of forms.

Finally we will present a prototype of a form generator.

MORPHOLOGICAL OPERATORS IN ARCHITECTURE

Several works based on project documents have been conducted to try and analyse the various processes and changing phases of architectural projects.

In a study realized on a collection of drawings made for the design of a bungalow by the architect Neimann, Ellen Do et al. have demonstrated a classification of elements, transformations, localization and also colours of elements (Do et al. 1999). This classification led to the naming of the variations realized between each sketch. The authors were able to identify the transformations but these remain simple ones, of the order of rotation, translation or symmetry.

In his work, Philippe Boudon aimed at getting beyond mere geometric operators and to identify a whole range of transformations of state which appear during the design process (Boudon 1994). He thus proposes to describe through scales how the architect applies measures to an edifice through operations of conceptions. Although called operators, the scales say more about the pertinence of the design operations than indeed about the morphological operations themselves.

Dominique Raynaud in a study about architectural design (Raynaud 1998) has shown that when changes of the state result in the transformation of the actual structure of a morphological model , the description through scales belonging to the architecturology is barely obvious. Going back to one of the first hypotheses of Herbert A. Simon on the solving of problems (Simon 1966) he suggests that the description of these transformations calls for another class of operators. These could be schemes if one means the class of prototypical actions which can be expressed through basic verbs like to open, shut, cut, link, etc.

From an empirical analysis of a sample of 162 architectural projects representative of the history of architecture from antiquity to the present times, Raynaud describes the transition from a symbolic representation - which can be a text as well as an image or an idea - to the formal translation into a project . He thus defines 20 schemes which are: to contain, turn, go up, radiate, cover, go through, open, begin, cut, descend, wave , unite, enclose, go out, link, repeat, end, surround, diminish, cross, battle, grow up.

In his work on the development of a parametric model which permits to generate complex forms, Carlos Barrios (Barrios 2005) uses similar concepts. He enhances the existence of operators of forms such as "torsion" and "intersection". Working from the analysis of a column of the side-nave of the Sagrada Familia by the architect Antonio Gaudi, he also demonstrates the combination of those operators. This allows him to define a parametric model and to modelize this architectonic part of the cathedral.

Finally we will refer to the research work by John Frazer about evolvable generative architecture which indicates the use of a genetic code to describe the themes of the project (Frazer 2002). According to an approach close to the one used with genetic algorithms, the project evolves along internal rules confronted to demands imposed by the architect. In this model of morphogenesis multiple mutations will arise, one or several stable phenotypes of the project. This principle of a genetic code in which the future mutations or transformations would be present draws nearer to our own hypothesis about the existence of a collection of shape operators in the architectural design.

We will keep in mind from this quick presentation of works about modelization of the architectural form that the existence of morphological operators is at the core of numerous theories which support our own hypothesis. In the following part of this article, we will attempt to verify this principle through the analysis of a few so called "non-standard" architectural projects.

MORPHOLOGICAL OPERATORS SEEN THROUGH A FEW EXAMPLES :

PETER EISENMAN

Peter Eisenman is a particularly interesting example for our analysis. Indeed, in several "de-constructivist" projects such as the Guardiola House or "Memory of Mak" he conceived a formal system the expression of which is based on materialized recording of conducted operations and on the track of the transformation process itself. It is then easy to detect step by step the morphological transformations in which a formal element replaces one or several others. For example, a volume is divided into faces, the parallel faces become a grid, the grid is turned over and so on. In later projects like "Max Reinhart House" or "Alteka Office Building", the notion of transformation gained an even more explicit character and allowed us to identify what could be related to schemes.

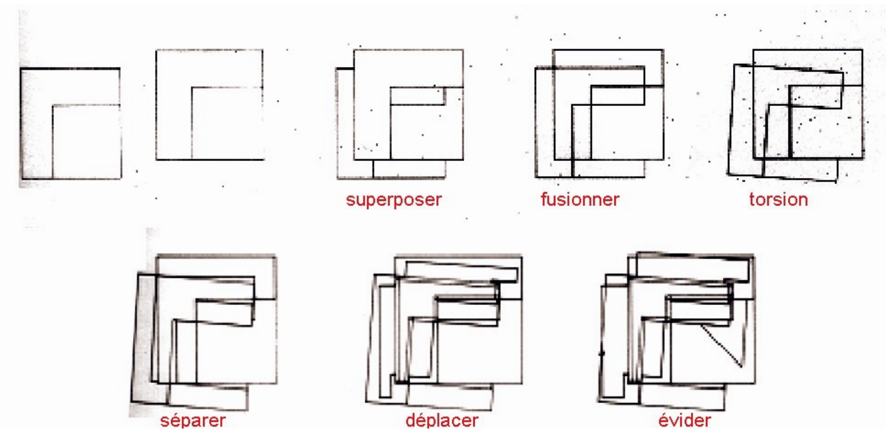

Figure 1. Example “Guardiola House”

It appears then that operators such as "superimpose", "blend" or "twist" are as many tools which assist the project process in its formal genesis.

As far as the meaning of forms is concerned, it is to be related to themes associated with the place of realization or the type of project. Thus, in the bungalow of a visual exposition in Holland, the zigzag of forms is supposed to derive from the paths that electronic beams follow in the display of a tube.

MARCOS NOVAK

Marcos Novak's work belongs to the field of visual architecture and cyberspace. By creating forms in virtual worlds, the designer gets rid of fetters of reality such as gravity, climate or constructibility. Novak develops the concept of liquid architecture, a fluid and imaginary environment where forms are described in 4 dimensions. They evolve in time and transform themselves through the influence of external factors such as sound-waves or also actions by the user. The forms turn, incurve, stretch, twist themselves …in a way they mutate.

It is this last aspect of Marcos Novak's work which is of great interest to us. We could imagine using similar transformations on architectural seed forms, not in reaction to a continuous phenomenon but as morphological operators being used consciously by the user.

FRANK GEHRY

Recent works by Frank Gehry [Los Angeles Walt Disney Concert Hall, Bilbao Guggenheim Museum, Seattle Experience Music project] show on the one hand the possibility to use new forms in architecture, based on curved surfaces which up to then were rather the privilege of fields such as furniture design, car and aeronautics. It is obvious that such forms would be hard to conceive without the help of a computer.

The process of formal research with Gehry is based on an iterative approach on various supports. After the first sketches, the materialization of form is tackled on preliminary models, then refined with the help of the informatics tool (Catia, Dassault Systèmes) before being tested in models of verification on a bigger scale.

Thus the process of formalization is conducted by Gehry mainly through the model. It starts with a first spacialization based on primitive geometrical forms which take into account the functional needs. It then goes through a whole range of morphological operations: to blend, press, stretch, smooth, etc.

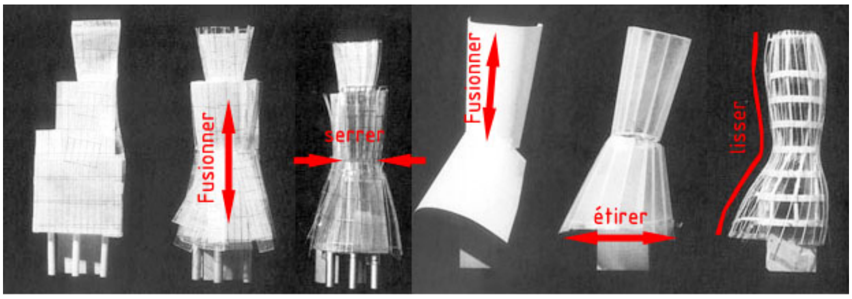

Figure 2. Nationale Nederlanden Building, Praha

The use of a 3D modeller in a second phase, allows a more rigorous and exact definition of the volumes, and the preservation of the various creative stages, as well as the taping of geometrical parameters for a transfer to a CAD-CAM process.

Such an approach shows us that it would be particularly interesting to model the process of morphological transformation so that it could be implemented with the help of the computer and no longer with real models.

GREG LYNN

Greg Lynn has largely used the ability of 3D modellers to create innovative forms in the design of furniture, interior architecture or buildings. Through his realizations and in his numerous projects for contests, Greg Lynn bases his creative activity on the use of the properties of surfaces and particularly the topological "events" they can generate. Those patterns named folds, knots, buckles, flowers, etc. become elements of a vocabulary which translates itself in architectural terms to become spaces, limits, openings and other spatial elements.

The second characteristic of Greg Lynn's work is his recourse to computer programmes in order to give life to the initial forms. The volumes are modified under the appliance of forces which transform their geometry. Animation is used here as a means to reveal the volume even better and to suggest variants which may be were not even obvious to the designer.

The example of the embryonic house (figure 3) shows the various stages of a morphogenesis and underlines the use of morphological modifiers in a conceptual approach.

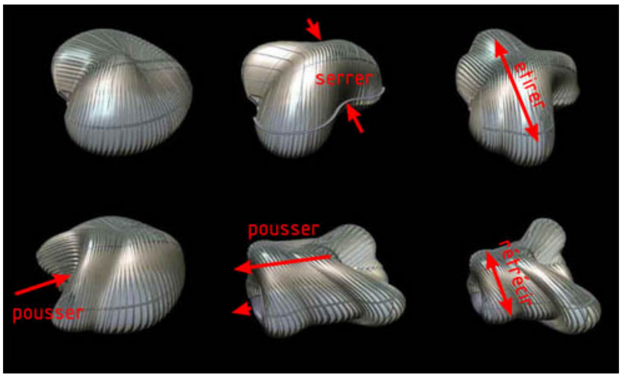

Figure 3. Embryonic house

INTERPRETATION AND INSTALLATION OF A MODEL

MODEL

The use of morphological operators or "structural modifiers" (Porada 2005) appears omnipresent in the process of formal design.

These schemes/operators can differ from the geometrical functions of a modeller because of the architectural meaning they carry. Thus, each transformation is motivated by the research for a spatial effect on a volume or a space, the user being the outside observer of a spatial composition, or navigating in a 3-dimensional space. A morphological operator can be the combination of several geometrical transformations.

In order to instrument those operators, we have first modelled the identification of operator classes and action parameters.

CLASSES

The work by Francis DK Ching (Ching 1996) on architectural shapes allows us to identify two main strategies of form productions and, potentially, two main operator classes.

The first strategy is metaphorically represented by a lobster and consists in creating forms through adjustment and combination. The seed form is made of unitary forms that we are going, for example, to add, juxtapose, superimpose. We will refer to this as "transformation by composition"

In the second strategy identified by a slug , the seed form will undergo morphological but not topological modifications with operators such as twist, stretch or pinch. We will refer to this as "transformation through metamorphosis". Of note is that some buildings are more concerned by one or other of these strategies but that the 2 production methods are not antagonistic and can be used simultaneously.

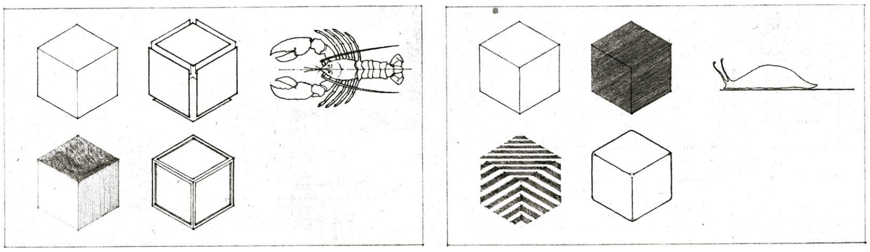

Figure 4. The lobster and the slug

PARAMETERS

The use of a morphological operator demands a definition of parameters by the user. We have identified a first family of parameters, linked not to a specific operator but to the way it applies itself to the geometry: the field of application, the intensity, the propagation type, etc. On the other hand, we have detected other complementary parameters which are specific to some operators: vector of direction, angle of inclination, angle of torsion, etc.

APPROACH

From this first work, we can propose an approach for a possible formal creation structured in 3 main phases:

- define a first scene from the seed forms chosen among a range of geometric primitives. We have seen from the above examples that the seeds could be geometric primitives as well as organic forms.
- apply an iterative process of transformation by using n-nary and/or unary operators. This process can be mastered step by step by the designer or inscribed in algorithms.
- build the final scene as a result of the process of transformation in which the seed forms, the operators, but also the very order of application of these operators have their importance.

The conjunction of these 3 factors provides many possibilities which justify the role of the computer as "an accelerator for the exploration of solutions" (Frazer 2002).

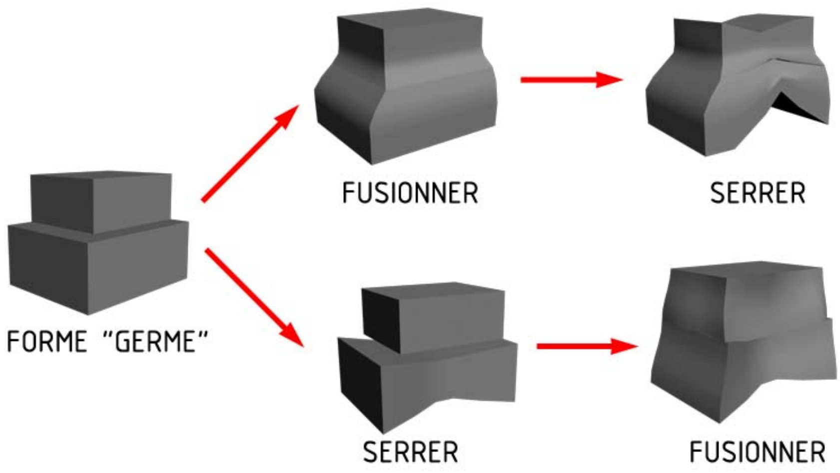

Figure 5. Successive application of the operators "squeeze" and "blend" applied in a different order to the same geometric components.

On the basis of these two main strategies we have identified two main operator classes:

- binary or n-nary operators, already mentioned as composition operators which are related to Boolean operations, and among which can be included actions such as merge, intersect, link, juxtapose, etc.
- unary operations which operate on one single form at a time. Among them are all the common geometric transformations [shifting, rotation, homothety, symetry] but also the operators we aim at , such as stretch, compress, dilate, squeeze, bulge, hollow, smooth, roll, split, open, shut, etc. These operators should be – as in Dominique Raynaud's schemes – the transposition of symbolical concepts.

CONCLUSION

In this paper, we have attempted to demonstrate the pertinence of the concept of morphological operators and its role in the process of formal research. A first model has been sketched. The installation of a precise experimental process should enable us to define more accurately these operators and to model a defined range.

This step will allow us to reach the definition of an intuitive 3D modelling environment which will enable the architect/designer to explore a number of formal solutions by using combinations of morphological operators.

REFERENCES

Aoki, Y. and Inage M. (2000). “Linguistic Operation System for Design of Architectural Form”, Timmermans, Harry (Ed.), Fifth Design and Decision Support Systems in

Architecture and Urban Planning - Part one: Architecture Proceedings (Nijkerk, the Netherlands).

Asimow, W. (1962). *Introduction to Design*, Ed. Prentice-Hall, Englewood Cliffs, New Jersey.

Barrios, C. (2005). (Department of Architecture, Massachusetts Institute of Technology, USA), "Transformations on Parametric Design Models", Computer Aided Architectural Design Futures 2005, Vienna (Austria) 20–22 June 2005, pp. 393-400.

Boudon, Ph., Deshayes P. , Pousin F. , and Schatz F. , 1994, *Enseigner la conception architecturale*, Edition la Villette, Paris.

Ceccarini, P. (2003). *Catastrophisme architectural : l'architecture comme sémio-physique de l'espace social*, L'Harmattan, Paris.

Ching, F.D. (1996). *Architecture : From, Space & Order*, Van Nostrand Reinholds, New-York.

Do E.Y. (1996). "Drawing as an interface to knowledge based design aids", ACADIA, University of Arizona, Tucson, p191-199.

Do E.Y., Gross M.D. , and Nieman B. (1999). "Sketches and their functions in early design – A retrospective analyses of a Pavillion House", Sundance Lab, University of Colorado, Boulder, pp255-266.

Engeli M., Jessurun A.J., and de Vries B. (2000). "Development of intuitive 3D Sketching Tool", Proceedings of the 5th Conference on Design and Descision Support Systems in Architecture and Urban Planning, Nijkerk, The Netherlands, 22-25 August.

Estevez D. (2001). *Dessin d'architecture et infographie. L'évolution contemporaine des pratiques graphiques*, CNRS Editions, Paris.

Frazer, J., Liu X. , Tang M., and Janssen P. (2002a). "Generative and Evolutionary Techniques for Building Envelope Design", International Conference on Generative Art, Milan.

Frazer, J., Liu X. , Tang M., and Janssen P. (2002b). "A generative design system based on evolutionary and mathematical functions", International Conference on Generative Art, Milan.

Jacobs J. (1961). *The Death and Life of Great American Cities*, Random House, New York.

Jencks C. (1979). *Le langage de la architecture post-moderne*, Academy editions, Londres.

Laseau P. (2001). *Graphic thinking for architects and designers*, Wiley, New York.

Lebahar JC. (1983). *Le dessin d'architecte - simulation graphique et réduction d'incertitude*, Collection architecture outils. Editions Parenthèses, Paris.

Porada S. (2005). "L'instrumentation de la création architecturale », Conférence SCAN '05, Paris.

Pranovich S. (2004). "Structural sketcher : a tool for supporting architects in early design", PhD Thesis, Technische Universiteit Eindhoven, Eindhoven.

Raynaud D. (1998). *Architectures comparées : Essai sur la dynamique des formes*, Editions Parenthèses, Marseille.

Rossi A. (1981). *L'architecture de la ville*, L'equerre, Paris.

Xenakis I. (1971). *Musique Architecture*, Casterman, Paris.