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# From nature to manufacture

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## Abstract:

This paper reports on a work carried out during a one-week workshop with students of the architecture school of Nancy in France. Based on the advancements of CAD/CAM technologies, this exercise explores the link between two stages of the process of creation of an architectural object; geometric modelling and respective manufacturing preparations. The main idea is to deal with the continuum of the form creation, from the first idea (designer's mental image), through the geometric description, to the final physical model.

## 1 Introduction:

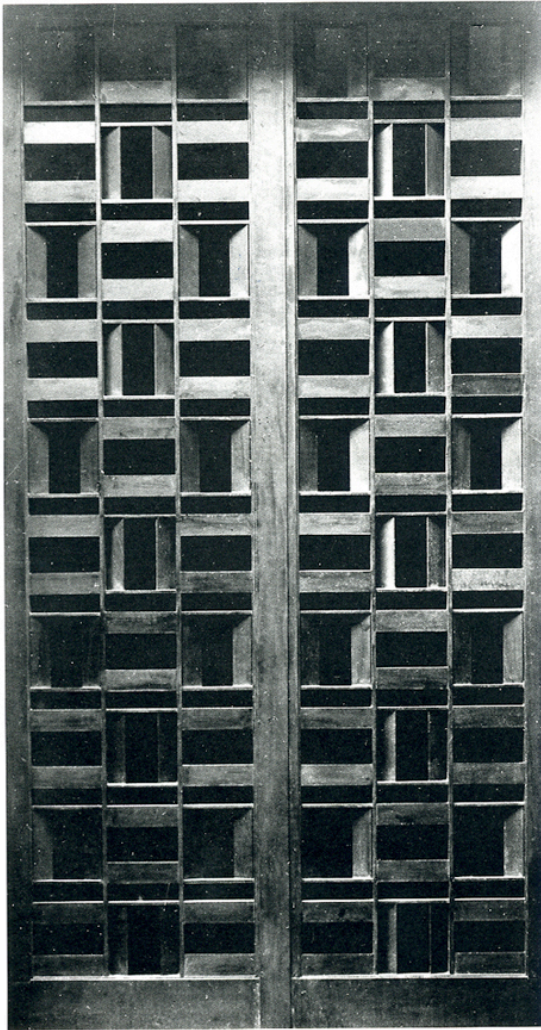
The development of architectural vocabulary is largely related to recent advances in the world of digital design. Advanced CAD tools and geometric modellers allow the creation of forms that overtake Euclidian models. But digital also affects the universe of manufacturing; CNC technologies provide the possibility of creating physical version of design alternatives.

CFD workshop - conception, fabrication, digital - is an opportunity to challenge the process of design to making. From the imaginary form to the physical one, the aim is to handle with the form in terms of its concept, construction and assembly characteristics as well as CNC facilities.

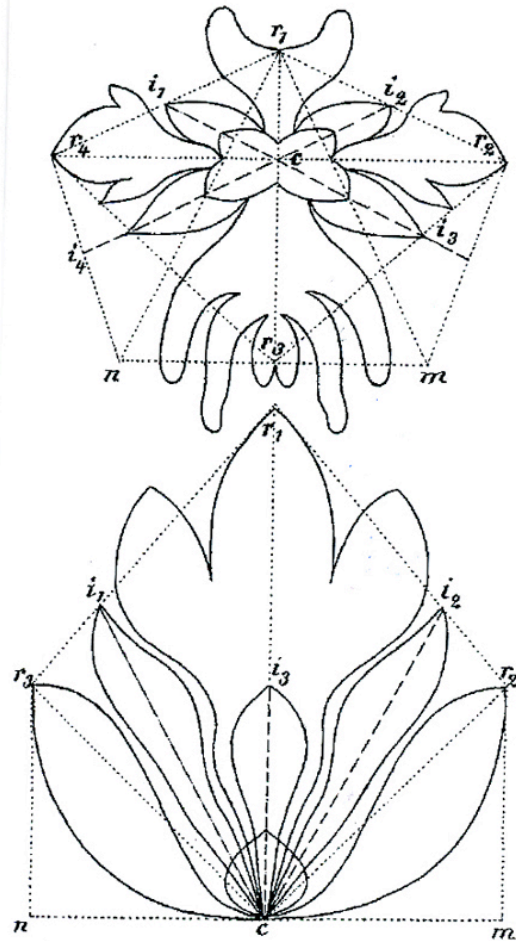
## **2 Nancy's Context:**

The City of Nancy played a prominent part in the Art History, especially during the Modern Style period, called Art Nouveau in France. The “Ecole de Nancy” movement, “School of Nancy” movement, is one of the two French modern style trends. Between the end of the XIX century and the beginning of the XX century, artists and architects derived their idea from the natural and organic forms, linking this design process with the new production methods and the material features. Ornament was no longer incidental decoration but a part of the building itself. The scientific paradigm of this period and the way the nature was analysed, showed and documented, largely participated to the emergence of the Modern Style. The decorative element was no longer defined by its nature itself but in accordance with the image of this nature as promulgated by the culture of science. The understanding of this tamed nature went through the identification and representation of the symmetrical relationships between elements (Haeckel, 2007). Moreover, the shape characteristics were subject to the production methods and materials behaviour. Basic patterns were derived depending on the different types of application and production techniques (Olaf Breidbach, 2007). Nowadays, the ornament question is reviving in contemporary architecture through the use of digital technologies. Kai Strehlke (Strehlke and Loveridge, 2005) presents a work made with students in the exploration of ornament redefinition. He lists three main generative methods, nurbs sculpting surface, programmed surface and images derived surface, and exemplifies the possibilities.

Jean Prouvé, native from Nancy, is another major actor of the Architectural History. During the middle of the XX century, he largely contributed to the renewal of the architectural language through the integration of industrial procedures and techniques. Familiar with the metal, he explored both furniture and building, through the production of structural systems or envelope components. He was very attached to the experimentation and he considered the material feature knowledge as one of the main design principles. This material knowledge was acquired through its manipulation. Especially, he considered the use of physical prototypes as a design method. Jean Prouvé was very implied in the fabrication processes and he involved industrial techniques into the field of architecture. He especially worked on the home standardisation and home industrialisation production in the context of the after Second War reconstruction. Nowadays, Prouvé's way of working is updated by digital fabrication technologies and mass customisation production. Here the object takes place in a continuous formal variation, the designer is working on an aspiring shape variation and the final object symbolizes a significant instant of the process (Kolarevic, 2005).



**Door, Prouvé's project. Light effects and variation**



**Geometric and symmetric interpretation of natural form.**

### **3 Educational approach:**

CFD is a one-week workshop with graduate students from the Architecture School of Nancy in France that took place in February 2009. Twelve students, divided in 4 groups, were asked to lead a project from the conceptual idea to a small performance model. The starting point of the design process was a picture of a natural phenomenon, organic or inorganic construction. This picture was supposed to stimulate the imagination and the creativity of the students. This approach was established on the analogical thinking, the visual culture and the visual ability of a plastic interpretation based on a picture inspiration. The analytical question was then tackled through the explicit formulation of

the morphogenetic and constructive characteristics. The image should be interpreted until a physical reality. The generative components of the shape should be identified and understood in order to digitally model them. The form composed by the adjustments of unitary forms, the growth of the form, the form in motion, the continuous deformation and isomorphic transformation are some examples of a morphologic look. Based on this exciting image selection, students were free to define a program, formulate a purpose and choose a site for the project. The second stage of the exercise aimed at a constructive interpretation. Students were helped by the formal taxonomy supplied. Finally it was asked to include the whole thickness of the architectural question. Physical qualities, sensitive affects, social effects and usage features should be argued.

### 3.1 Lectures

Students had no specific knowledge in digital fabrication and we started the week by four lectures. The first one was an introduction to the digital fabrication approach, methods, machines and processes. We presented the different digital fabrication techniques, the additive and subtractive methods and we respectively illustrated the different kind of existing machines: 3D rapid prototyping, lasers cutter, water cutter, 3D milling, cutters and engravers. We gave some examples of the continuum process associated to a file to factory approach. These examples were extract from previous experiences led in the architecture school of Lyon and Grenoble, especially with the European Learning Project Continuum F2F. We epitomized the digital process, from the digital model of the object under conception, to the constructive interpretation of the shape, and finally to the set up of fabrication files including the tool paths definition and the nomenclature of components. We exemplified the importance of convoking at the early begin of the design process the material behaviour and fabrication constraints.

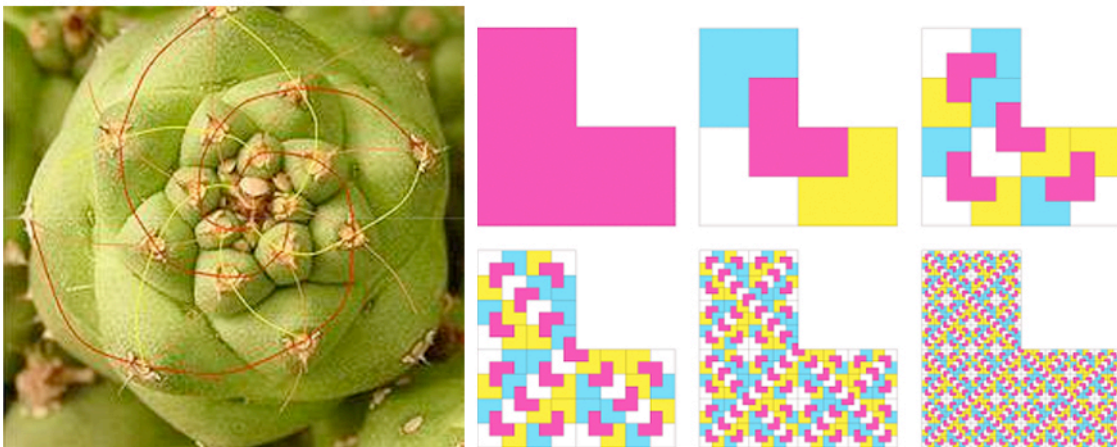
The second lecture presented a categorization of the architectural formal vocabulary in which each shape family was associated with its constructive characteristics and constraints. We identified five “Morpho-types” in function of the scale and the geometry of the shape’s components, of the material and products used, of the structural system behaviour and of the assembling and fabrication methods. These families are stacking, tilling, mesh, braces and membranes; moreover they were divided in subgroups.

- The stacking refers to the superposition of horizontal evenly or not plans. Corbelling generates the form in elevation. The friction between the elements cancels the horizontal forces. A distinction could be made between modulate stacking and layering.
- The tessellation refers to the splitting up of a structural surface with similar elements, which fit together avoiding an empty space between them. A distinction could be made between facets, waffles and folds tessellation.
- The mesh is a grid of a bars network. Bars are fixed together by knots and are especially subject to traction and compression. The mesh is located in the plan of the surface or parallel with it. Edges, lattices and braiding make up this category.

- The brace is a composition of various structural elements that build a three-dimensional shape. This shape could receive an envelope surface. Braces are normal to the surface. Frames, arches and grids extend the category.
- The membrane is a continuous structural surface made with linear (planks) or surface (panels) elements but assembled with no angle. Vaults or shells represent a variation of the membranes.

The third lecture offered different assembly solutions and knots sorts. These tie principles were organised in six main categories: free union, frivolous ligature, interlocking, supported union, assisted union and intimate connexion. Each of these categories was subdivided. Straddle, ligature, padlock and fasten composed the free union family; ligature and sew the frivolous ligature one. Interlocking, mortise and tenon, wedge and splint made up interlocking category. Connect and tighten made distinction inside the supported union group; link-pin, cotter, screw, clasp, bolt extended assisted union and direct stick or assisted stick represented intimate connexion.

The fourth lecture was about the geometric interpretation of natural shapes. The digital geometric concepts and the form production strategies, that is to say the adjustment, combination of unitary forms, or the continuous shape deformation through the use of morphologic operators like twist, stretch, pinch (...), were linked to natural morphogenetic processes. The necessity of a geometric interpretation of the natural shapes in the context of digital modelling was demonstrated. Symmetric arrangements, algorithmic growth and the mathematic of the natural form were illustrated. Fibonacci sequence, fractal description, recursive processes, Voronoï tessellation were some of the given examples. Cecil Balmond (Balmond, 2008) explored the potential of nature and science as an open book able to highlight geometric realities.



**Algorithmic Growth : Geometric interpretation of natural growth.**

**Recursive sequence.**

## 3.2 Resources

To lead the design, the students had directly access to different kind of resources. First, in order to stimulate their creativity they could pick an image from a library composed of two hundred pictures ordered by types: animals, trees, art, corals, shells, water, snow, natural forms, plants, rocks and crystallography.

The following software were used: Maya© and 3DStudio Max©, mel and maxscript associated to the conceptual modelling, Autocad© and Illustrator© dedicated to two dimensional drawings and adjustments, Artcam© concerning fabrication files setting, WinPC© in charge of the post processing and the machine driving.

Moreover, a library of mel and maxscript functions were available: automatic Boolean operations and transformation, random positioning, recursive tessellating, Fibonacci sequence, multiple sectioning, unfolding facets, automatic “half-wood” assembling generation.

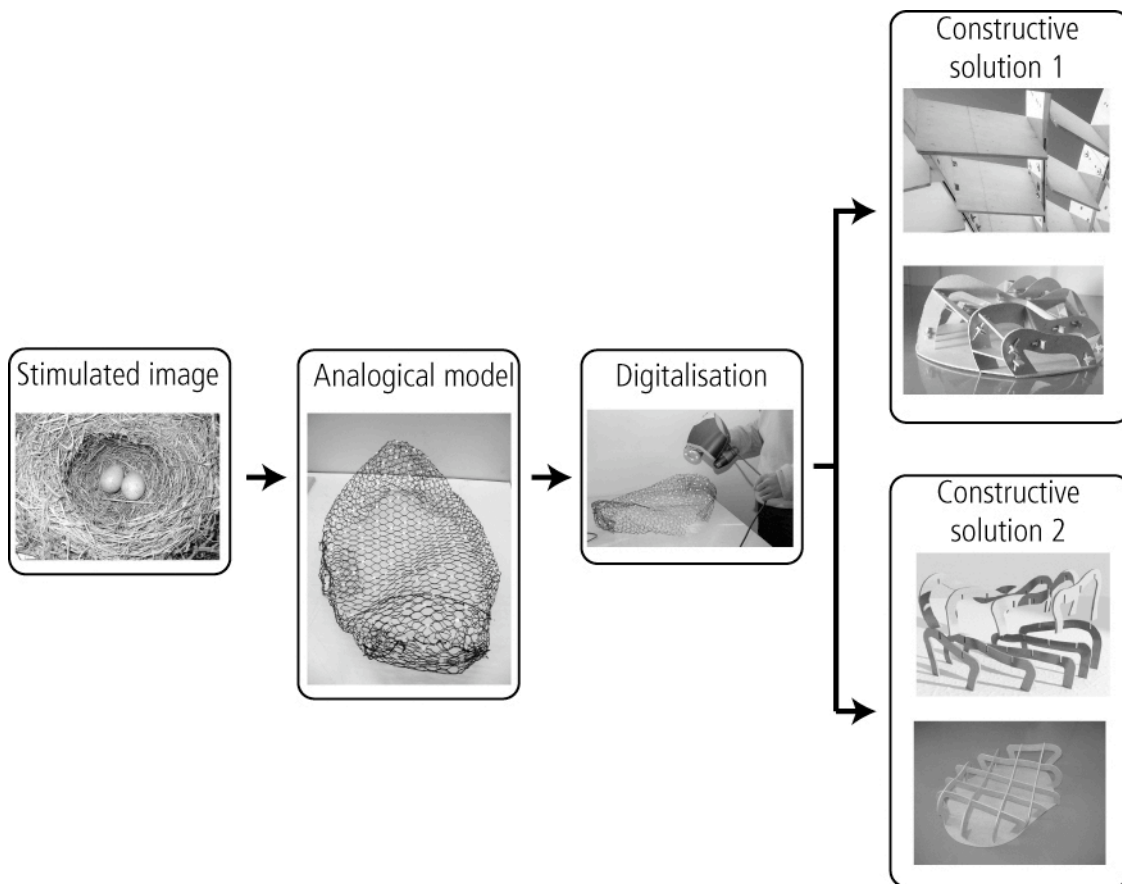
Finally, a 3D milling machine was installed. This machine has an 800 x 750 mm cutting area. From 3 to 8 mm diameter wood wicks and 3 mm thickness MDF panels were available. This CNC machine is part of the Digital Fabrication Lab of the Architecture School of Lyon.

## 3.3 Work in progress

The first half-day was dedicated to the lectures and general information. But very quickly students started to work on their own project. Between half a day and two days were conceded to conceptual design, then each group, based on temporary reviews, had to prepare its fabrication files. The last two days were devoted to the panels cutting, fabrication and assembling. The generation of Numerical Control (NC) machine code was done with traditional CAM software such as Artcam©. The files setting up were important during this phase and students had to defined cutting paths, cutting tools and specific machine parameter. Due to the lack of time, students were supported during this phase.

## 4 Case study

The following project is interesting because of its go and back between atoms and bits. The starting point of the project was a picture of a bird nest: beginning with this evocative image, the students projected a small museum evoking a natural form. They started by hand modelling a grilling in order to obtain the desired shape. Then they proceeded to the digitalization of the physical shape with the help of a portable handheld 3D laser scanner. After an optimisation phase of the point cloud data, two constructive hypotheses were explored.



The first constructive solution was based on an assembly at “half-wood” of series of arches. This arches grid was made with the use of a parametric script that allows defining distance between two beams, beams’ thickness and depth fitting. Geomagic© software and 3DStudio Max© with maxscript were used to design this structural envelop.

The second constructive solution intended to keep the notion of random in the final structure, as it is present in a natural bird nest. In order to evoke this, students evenly placed vertical plans and thus defined structural arches. Then they randomly displayed series of struts. Here, all the drawings were handmade in Autocad©, no automatic procedure was implemented.

## 5 Discussion

Our experimentation remained at the scale of model production. Nevertheless, it seems very important to explore the digital production at the one to one scale. First because materials behaviours will change, the linear transposition from model to final project is not possible, and second because the physical experimentation of the space and effects generated are really instructive. Nevertheless, such experimentations require larger machine capacities, a dedicated workshop, equipments and technician competences. Such equipments are available in architecture schools like ETH (Zurick), University of Oulu



(Finland), Harvard University (USA) or Les Grands Ateliers (France), and in the next future in Nancy with the Innocité project.

We started to build a tools box putting together scripts and functions but we have to enhance it. Supplying students with predefined scripts is fruitful and enables to increase in return the available tools. Our aim is to link together our morpho-types with their corresponding assembly solutions and thus implement scripts that allow a parametric production of respective components.

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