GEOMETRY AND ARCHITECTURE: NURBS, Design and Construction

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ABSTRACT

Geometry regarded as a tool for understanding is perhaps the part of Mathematics which is the most intuitive, concrete and linked to reality. From its roots as a tool to describe and measure shapes, geometry as 'the space science'[1], has grown towards a theory of ideas and methods by means of which it is possible to build and study idealised models, not only from the physical world but also from the real world.

In graphic architecture thought, geometry usually appears as an instrumental support for project speculation. Geometric procedures are presented as representational resources for the graphic testing of reflection and for the exposition of ideas in order to build a logical order as regards representation and formal prefiguration.

The fast rise of computing in the last decades has made it possible for architects to work massively and in a graphic and intuitive way with mathematical representations of tridimensional geometry, such as the NURBS[2]. These organic surfaces of free shapes defined by vectorial curves have allowed access to a rapid generation of complex shapes with a minumum amount of data and of specific knowledge.

The great development of modelling achieved by the digital media and the limitations in the technical and building areas and in the existence of materials which are coherent with the resultant shapes reveal a considerable distance between the systems of ideation and simulation characteristic of the computing era and the analogous systems of production inherited from the slow industrial development. This distance has been shortened by CAD/CAM systems, which are, however, not very accessible to the architectural field. If we incorporate to the development of these divergent media the limitations which are distinctive of the material resources and procedures of the existent local technology, the aforementioned distance seems even greater.

Assuming the metaphor of living at the threshold of two ages (industrial-computing, analogical-digital, material-virtual) and the challenge of the new conceptual and operational tools in our field, we work in the mixture, with no exclusions or substitutions, proposing (by means of the development of informational complements) some alternatives of work to approach the issue under discussion from the Architecture Workshop.

GEOMETRY AND ARCHITECTURE

Some departure hypotheses are enunciated that try to describe the situation state regarding which the new relationships are generated between geometry and architecture starting from a historical coexistence of means that crosses the moments of creation, development and production of the discipline:

The post-mechanical thing cohabits with the pre-industrial thing.

The systems of digital creation challenge to the similar production systems in being able to sum up and to materialize many of the ideas that are manifested virtually.

New relationships on the architectural thing and their representation. The creation of a symbolic and dynamic space of information where the representation usurps the identity of that represented.

Re-definition of concepts like reality, perception and memory. Eclipsed by concepts like cyberspace, cyberception and the synthetic image.

The emergency of the virtual thing provides new creation tools and development in the conceptual and poetic field of the architecture.
The systems CAD-CAM-CAE redefine the pre-figuration instances and representation of the disciplines linked to the design. They condition and they transform processes of production and construction, they modify their operational methodology forcing to leave the strictly graphic thing, enlarging horizons.

PROBLEMATIC

The fast rise of computing in the last decades has made it possible for architects to work massively and in a graphic and intuitive way with mathematical representations of tridimensional geometry, such as the NURBS. These organic surfaces of free shapes defined by vectorial curves have allowed access to a rapid generation of complex shapes with a minumum amount of data and of specific knowledge.

The ancestral inertia of the architectural matter and the inability of the materials traditionally employed in construction to assume and to manifest the demands that outline the space and conceptual searches of the present appear like one of the challenges of the coexistence of the post-mechanical technologies with the pre-industrial ones. The systems of digital creation challenge to the similar production systems in being able to sum up and to materialize many of the ideas generated virtually.

The great development of modelling achieved by the digital media and the limitations in the technical and building areas and in the existence of materials which are coherent with the resultant shapes reveal a considerable distance between the systems of ideation and simulation characteristic of the computing era and the analogous systems of production inherited from the slow industrial development. This distance has been shortened by CAD/CAM systems, which are, however, not very accessible to the architectural field.[3]
If we incorporate to these developments of means dissimilar the limitations characteristic of the resources of materiality and constructive procedures of the existent local technologies and we approach the challenge of a pedagogy of the design of an ordinary Shop of Architecture in the context of a public university we will be forced to put into practice some strategies of contingencies for the boarding of the mentioned problem.

NURBS SURFACES

The NURBS are mathematical representations of geometry in 3D able to describe any form accurately, from simple lines in 2D, circles, arches, or curves until the most complex solids or organic surfaces in a free way in 3D. Thanks to their flexibility and precision, model NURBS can be used in any process, from the creation and development until the production of pieces or construction of space surfaces.

The incorporation of the *parametric surfaces* and the entities *spline* in the computer systems of modelling in ways have supposed the creation of a new graphic tool that not alone it covers the hole that has left the classic geometry, but rather it allows a quick generation in complex ways with a minimum quantity of data.

Curved Bezier, B-Spline and of Continuous Polygons, they were developed to build digital versions of the design lines used to draw the crossed sections of helmets of ships, airplane fuselages and designs of the automobile industry. The necessity to establish a rigorous geometric control of the graphic layout of curved lines with free journeys in the configuration in the way of the ships and vehicles, derived of the respective studies of aerodynamics and hydrodynamic, it justified their development and use thoroughly facilitating a later application to the field of the design in general.

The industrial design incorporates them early assisting in its designs to a control but I specify in the ergonomics in the way and later on the architectural design finds the solution to a problem of space representation that up to now had almost always been in a handmade and intuitive way.

Among the good known examples of their use in the pre-figuration stadiums and architectural space with-figuration mention to the museum Guggenheim of Bilbao of the Arq. Frank Gehry. With the help of a scanner 3D, in a well-known process as being Reviewed Engineering a program of the industry aerospace called French CATIA have been used to approach the modelling of the surfaces of double bend. The virtual reconstruction of the Sacred Family of the Arq. Antoni Gaudi (Arq. Mark Burry and other) also begun using a program of modelling of surfaces of high capacity like it is the CADDS5 incorporating then Rhinoceros and using some of the techniques of Rapid later on Prototyping (printer of solid Thermojet) for the study and validation of the pieces to build.

At the moment, most of the programs of 3D modelling have NURBS to build models of surfaces. One of the contributions but important for the design in general has been facilitating to operate, to control and to design with algorithms that overcome the complexity of the traditional Cartesian equations carrying out it alone from the graph and with an intuitive handling of the geometry. This way it has become possible for many designers and students to do without of the knowledge characteristic of the structures geometric-mathematics that sustain them. Fact that has generated among the students of architecture favourable situations in some cases and counteractive in many of them.

REVERSE ENGINEERING

It is known with this denomination to the process that, recovering the handmade tradition, it leaves of an unique model sculpted by the designer for next to be reproduced in series by technical means. These means at the moment are composed of outlying, computer, and you program CAD-CAE-CAM. A digitalizer 3D travel in an automatic way the surface of the prototype or scale model to scale, according to the programmed trajectory, it stores the coordinated x,y,z of the points of the surface. A program vectorizer transforms the cloud of points in a surface with geometry CAD. Later on the mesh of finite elements CAE is generated and after making many times the resistant calculations for MEF, they are carried out in CAD the opportune corrections that allow a correct operation. Lastly the technological requirements CAM is introduced that allow to program the machines required to manufacture the different components. It leaves of this process, very employee in the 90 for the automobile industry has been experienced in one of the architectural big works of final of the XX century: the museum Guggenheim of Bilbao (1994-1997).

In our context and for the Architecture it is practically impossible to think of these moments to appeal to this technological process. Although it is possible to recover the concept. A suggested work alternative is to carry out the modelling one digital three-dimensional of our analogical space models by means of the conversion of images raster to vector by means of two different registrations of information: A) the first one is of scanning in 2D the physical pattern and to obtain pixels images that we will convert to entities lines using a conventional vectorizer (corel trace, etc). The resulting file will care him in the conventional programs of drawing to build the geometry 3D of the digital pattern; B) the second registration is carried out taking images with digital camera of the analogical pattern to care them then to programs of image treatment and three-dimensional reconstruction starting from the generation of points and a calculation based on the law of conical perspective. They correspond to the programs habitually used in architectural photogrammetric (for example Photomodeler).
Both alternatives are justified in situations of formal complexity of the used geometry allowing us an approach of the physical and virtual processes of creation starting from the digitalization and vectorization of points that will serve in the generation of the geometry 3D for a three-dimensional patternmaker.

RAPID PROTOTYPING

To allow to re-think changes of an early phase of the design process, articulating the resulting geometry to a materialization wanted in rapids and economic physical models is one of the contributions that base the use on the part of the architects of the tools of Rapid Prototyping used by the industrial engineers.

Among the different prototype we differentiate the constructions of pieces for successive layers (2D) and directly in the space (3D) and we classify them according to the process of solidification of the material (liquid polymers solidified by the impact of a luminous sheaf; you castrate united by photopolymerized of badges of plastic semi-polymerized ; materials in powder form; material sheets united by means of having hit; etc).

The Rapid Prototyping of built paper for successive layers, offers the possibility to make at one time relatively short and with a cost of development very low, diverse tests of geometries on the design object, confronting different space solutions and bringing near the processes of virtual initial searches of the modelling ones of the idea, to the materiality and construction in the resulting final way.[4]
The creation of the first conceptual prototypes and the possibility of the physical manifestation in the way operates in the industrial design reducing costs and time in the verification of a product avoiding that the same one arrives almost obsolete to the market, while in the architecture intends as an instrument articulator of the virtual and physical phases of the design process influencing directly in the architectural graphic thought.

UNFOLDING

An alternative of work proposal for a shop of architecture of a public university characterized by a relative popularity (150 students) and with different systematize levels it is the boarding of technical of development and unfolding of geometric figures in surfaces 2D. This quick, economic and accessible method for many students allows by means of a court plotter or impression of ink and manual cuttings, to recompose in 3D the complex morphological syntaxes (very appealed at the moment) in different work scales.

Programming routines (autolisp in autoCAD), plug-ins of programs of modelling geometric (Expander for Rhinoceros) and you program or unfolding utilities (TouchCAD; Form Z; 3D Canvas; Javaview) they allow, by means of the import of three-dimensional models, the unfolding of the faces of the polyhedrons in plane surfaces to the way of the traditional Japanese art of the Origami. Although several utilities and some not very specific programs exist in the market that attend the development of figures 3D, each one has their limits when caring files and non conventional geometries because much of them was created for complementary necessities to the industrial design. For example to allow the development of encounters between metallic pipes and industrial accessories of low formal complexity. That is to say that alone they allow the development of plane surfaces or of simple bend (conical, cylindrical and tangential).
In the case of the surfaces NURBS (surfaces of double bend, therefore conceptually non developmentables) the unfolding of the complexity in the warped ways is possible starting from the conversion to MESH. The resulting triangulation of faces when exporting models of defined surfaces for curved vectorial (NURBS) to the traditional one modelling polygonal of the programs CAD (MESH), it facilitates to approach the development of warped surfaces and of double bend impossible to project on oneself plane without deformations. This conversion is very suggestible when re-thinking the materiality of the figure. The same one broken down in plane faces or ruled surfaces allows to speculate on the construction of the entirety in the way starting from the addition of the different planar pieces that compose it. The screens of glass of the museum Guggenheim of Bilbao and the developments of three-dimensional structures of companies like Bellapart-Spain, they exemplify this concept.

THE ARCHITECTURE WORKSHOP:

In graphic architecture thought, geometry usually appears as an instrumental support for project speculation. Geometric procedures are presented as representational resources for the graphic testing of reflection and for the exposition of ideas in order to build a logical order as regards representation and formal prefiguration. Geometry traditionally appears in the initial as well as in the final stages of the generative process of design, operating as a tool for order and synthesis, reassuring the definition of technological and spatial components.

The incorporation of the parametric surfaces to the traditional geometries Euclidean's is manifested in the architecture shop like a necessity of the students to approach the manipulation of geometries in free ways in a marked intention of assuming an space thing of the present or simply for a frank seduction of the formal possibilities of the new instruments of modelling digital.

The systems of creation digital powered the capacities of the students' thought toward an address that he/she forces them to force many times the traditional constructive systems or to modify the graphic results to achieve a correct materialization of the architectural project.

In the Shop of Architecture the pedagogy should assume the traditions of the occupation and to participate of the impulses of an innovative time and loaded with challenges. In the face of the concern of a certain frank use of the digital resources it is that intends to be defined some strategies that accompany

the demands of the heuristic process and the expectations of the project avoiding that they are constituted in autonomous instruments where the representation usurps the identity of that represented.

Assuming the metaphor of living at the threshold of two ages (industrial-computing, analogical-digital, material-virtual) and the challenge of the new conceptual and operational tools in our field, we work in the mixture, with no exclusions or substitutions, proposing (by means of the development of informational complements) some alternatives of work to approach the issue under discussion from the Architecture Workshop.

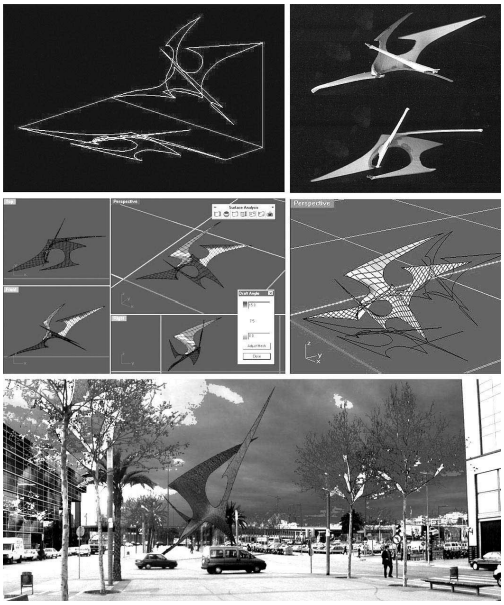

Fig.1 Reverse Engineering and photogrammetric
Urban Sculpture - Student: Paulo Chiarella

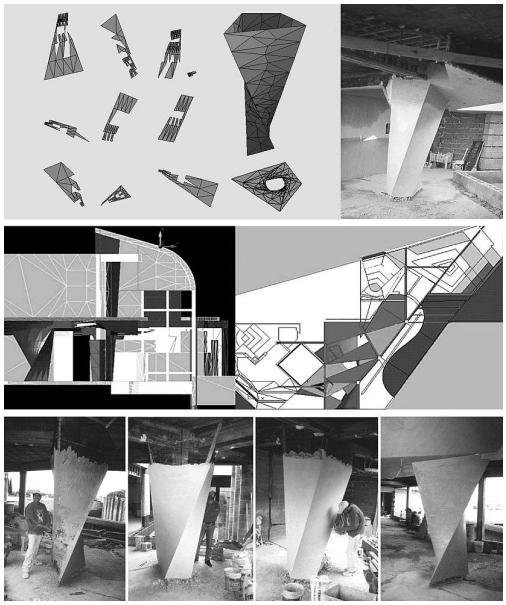

Fig.2 Unfolding NURBS surfaces and construction
CHIARELLA y ASOC - Lamperti & Cia – Paraná 2001

[1] Perspectives en l´Ensenyament de la Geometria pel segle XXI. PMME-UNISON. Febrero. 2001.
[2] NURBS: acrónimo de Non-Uniform Rational B-Splines.
[3] VII SIGRADI-Rosario 2003. Branco Kolarevich. Digital to Material.
[4] Ibid. Tom Maver: Digital Prototyping in the Architectural Design Studio.