Diagrams, Modeling and Rapid Prototyping:
*Interface Between Design of Form Process and Topology*

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Abstract: This paper investigates the concept of topological processual diagrams, geometric way of surfaces construction in topology, and the paradigm of homoeomorphism shaping, procedure that keeps topological properties. It explores possibilities of using it as a process of architectural shape generation, combined to computer-aided modeling tools and rapid prototyping. It intends to go through two complementary ways of translation between object shape and topology: the making of architectonical objects in topological surfaces and, on the other way, the exploration of topological surfaces as architectonical objects.

Keywords. Diagram; topology; design process; rapid prototyping.

**Diagram and modeling process in Topology**

The crescent investigation on designing process in architecture that incorporates the processuality has appropriated itself, on practical and theoretical ways, of new possibilities of design and representation presented by object modeling and rapid prototyping computer process. Enlarging the context some researches have increased its investigations by some quotations on the field of topology, as a new espacial and formal paradigm for the architecture design. (Cache, 1995; Berkel and Bos, 1999; Lynn, 1999; Somol, 1999; Zellner, 1999). In fact, topology is the field which has the specificity of be both operational-generative – investigating operations and espacial transformations - and theoretical-conceptual, improving concepts for reflection about the space-shape binomial, distinct of those historical propositions of Euclidian Geometry.

Topology characterizes itself by the study of geometrical properties not affected by shape changes, which are: continuity, proximity, connectivity by paths between points of determined geometrical variety (Carter, 1995; Sampaio, 2000). The study of those invariability in determined surface, is processed by transformations realized and represented by so called topological processual diagrams. This diagram is not only a surface modeling tool, but also a media of representation; formed by a sequency of frames in a manner that each one of them is, potentially, any next subsequent that, with shape alteration, still satisfy topological operations of the surface modeling.

In topology, the process of modeling may be done by three basic operations, classified by keeping or changing topological properties (figure 2). The first one is called homeomorphism, process of intrinsic and continuous manipulation-

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**Figure 1. Surface H2 of David Mond, Washington Maneu. 1993.**
generation of surfaces, without addiction or substraction of material, keeping certain unchanging spatial relationships, called object topology. Second one, connected addiction, extrinsic non-continuous surfaces generation process, connecting basic surfaces, which can change the original objects topology. Third one is identification, extrinsic discontinuous operation, which does the transformation of the surface's topology, by the adding of its parts (Sampaio, 2000). Under this classification, becomes evident that the topological modeling paradigm places the shape investigation under the spatial continuities and discontinuities investigation.

Some recurrent associations to topological process diagrams, between the topologists intentions and the operation and representation of space in progress suggests the systematization of three ontological instances of this diagrams, related to three phenomenological variables. First, transdiagrams, the instance of the object presentation emergency, or even the internal diagram translating of the thoughts for the external diagrams and vice-versa, referring itself fundamentally to the thinking process. The second, intradiagram, inherent instance of the spatial elements and to the constitution of the own diagram, referred to space. The third, interdiagrams, instance of logic-sequential enchainment relationships, generating continuity paths, either of diagrams approximation, establishing relationships of similarity-contiguity, referred to processual timing.

Some topological concepts in architectural designing process

The transfer of topological modeling paradigm for the architectural designing process, not only transfers the emphasis on the static and on permanency to the processual transformation, but also changes action and focus point: replaces the use of bi-dimensional projections which shapes the object, or of models that shape it, by the use of diagrams sequences that shape one topology and makes possible the investigation on variables shapes which follow that topology.

Although, historically the material construction of the architectonical object is intimately related to a addictive constructive method, which means add material to material (distinct of the sculpture process which also admits the subtractive process), the generating of the architectonical shape, on a cognitive stage of visualization of a three-dimensional object, frequently uses two projective process, the addiction and the substraction. The generating of the architectonical shape, on contemporary times, with the aid of the modeling softwares, also have been mainly modeled mental or geometricaly by connected adding, that is solid adding or subtracting, or other geometrical entities, operations that modifies the original object's topology. And the architectonical works, resulted from the process, after they are built, are a record of that action.

The investigations of the topological modeling paradigm, in architecture, further than placing the shape explorations under the topological qualifications criteria (as it considerers modeling by
homoeomorphism operations), use not the third-dimensional generation, or of other basis, neither of a adding or substracting process, nor of a third-dimensional geometric raw material. The architectural object becomes the result of a bi-dimensional entity manipulating, the surface. The surface is not under extrinsic operations of adding or subtracting its elements, but under intrinsic operations of folding, keeping implicit the extension or retraction of its dimensions, designated in topology by homoeomorphisms, operations which do not change topology (figure 3). The folding gives the surface the possibility of generate a third-dimensional object, which the basic characterization is the material continuity.

Among the distinct uses which architects take of the representation ways, it’s possible to detach three recurrent ways. The use of drawing and third-dimensional models combined into design, the use of drawing for design and model for representation and also only drawings, for design and representation, being common this design method by bidimensional projections of architectures generated by connected-addiction of three-dimentional geometrical entities. About the architecture generated by surface homoeomorphisms, more than an option for the utilization of design method, it brings intrinsecly the solicitation of it’s projection and representation by three-dimentional models, because, in a last though, it is the plane that, by being folded, reaches the three-dimentional space. Architectural work, in this case, can be read as the last diagram of the manipulation action of the original surface and record of its process, that is, as a diagramatic work.

The utilization of rapid prototyping process in design, by this view, shows itself as a privileged media to a reliable representation of an object topology; moreover, it allows the phisical reproduction of the process diagrams and of the final one. This addictive process of continued-generatation, as a quick conversion of an idea to a phisical object (Novak 1995,1998; Sequin, 1999; Silva, 2000) can record any moment of the homeomorphism sequency or the complete process of shape design, with few or none limitation of shape complexity.

Prototyped models with three-dimentional diagrams. Some spatial explorations.

In this context, the research develops and analyzes the processes of design and modeling that try to embody both the topological processual diagrams and the topological paradigm of modeling by homoeomorphism, combining computer-aided modeling and rapid prototyping. By this moment, from the both complementary themes of this research (the synthesis of architectural objects in topological surfaces and in reverse way, the exploration of topological surfaces as architectural objects), the second one has reached some modelings and rapid prototyping of two topological surfaces, the Möbius Strip and Trefoil Node (figure 4), as well as a conceptual architectural model from the homeomorphism of a generic plan (figure 5). It still intends to develop a topological synthesis of some selected brazilian paradigmatic architectural works (among others, the Brasilian Pavilion at Osaka, and MUBE – the Brazilian Museum of Sculpture, both from Paulo Mendes da Rocha) and the architectonic exploration of some topological surfaces (among others, the torus, the Möbius Strip an Klein Bottle).
For that task, it has been used softwares destined to diverse fields as Maple (topology), Maia (animation) and SolidWorks (mechanical engineering); for the confection of the prototypes, the process of Selective Laser Sintering (SLS).

Partial Conclusions

The exploration in progress allows some brief considerations. The investigation of the topological process diagram presents in evidence two basic components of shape designing: substance and process, which join processual thinking, time and space. The investigation of the paradigm of the architectural topological modeling suggests topological relations as elements modeled by continuity or by discontinuity of surfaces, from which an investigation of the shapes that respect the chosen topology is done. In this process, the computer aided modeling added to animations and prototyped models may be used as topological diagrams presenting the designing process and the architectonical object transformation in a continuous way, allowing the investigation of each frame of the diagram and of all the different shapes it can assume.

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References