f2f
file to factory
continuum

The Design and Fabrication of innovative forms in a continuum

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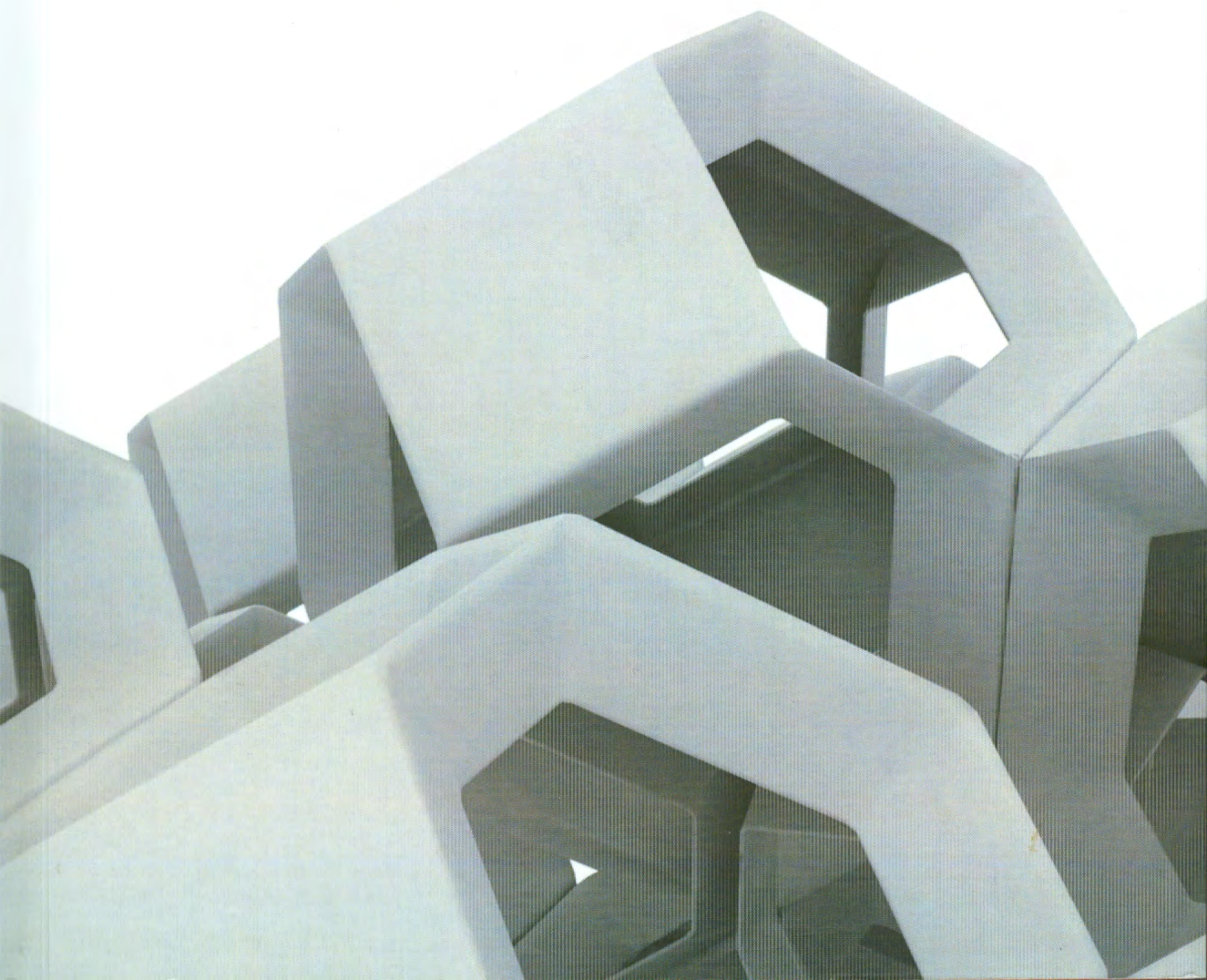

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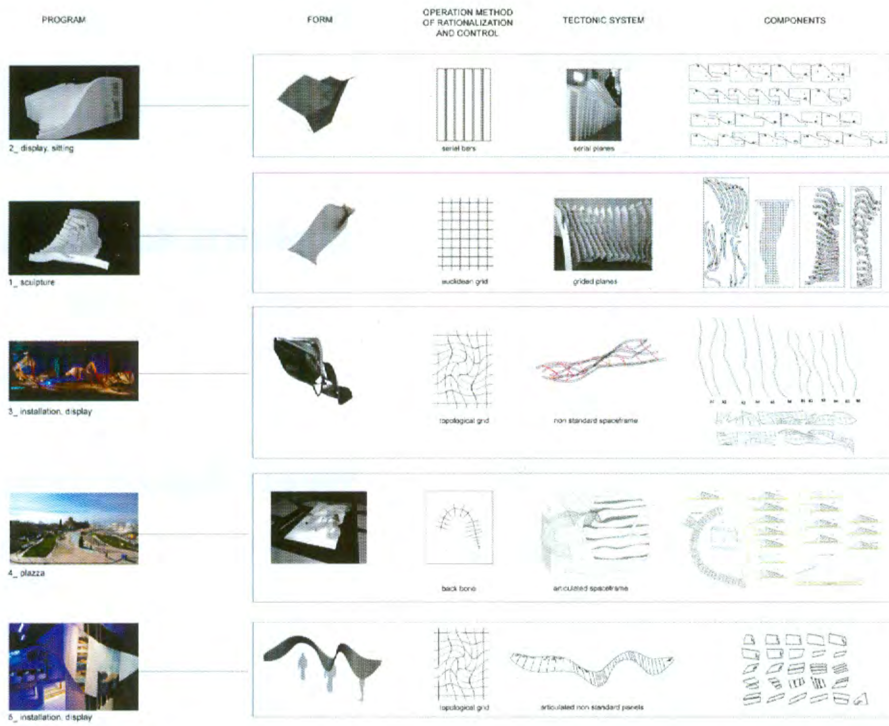
'Deep' Surface Anatomy! Five Case Studies from Design to Fabrication

Introduction

Computing design provides new possibilities for the genesis of free forms but these new shapes are just a facet if their formation and rationale is based only on the typical structural organizations. An internal logic and method is important. Cecil Balmond, an innovative engineer, writes in his book under the title 'informal': "the ingredients are all there to evolve form in fascinating ways...the challenge is to make structure the new discipline in a re-examination of space' [1].

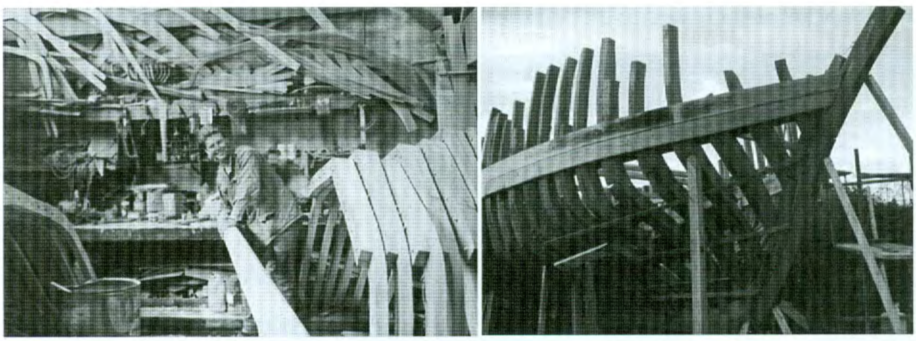
As the technical development of CAD techniques proposes new ways of thinking, representation, and simulation so respectively, the evolution of CAM techniques facilitates the production of non-standard forms and further encourages the systematic exploration of novel approaches to rationalization methods required for their manufacture. By presenting experimental and realized projects we bring to the fore the necessity of rethinking the concepts of design and construction evolution and their interconnection. There is a strong relation between techniques and the generation, control and construction of complex forms.



'Deep' Surface

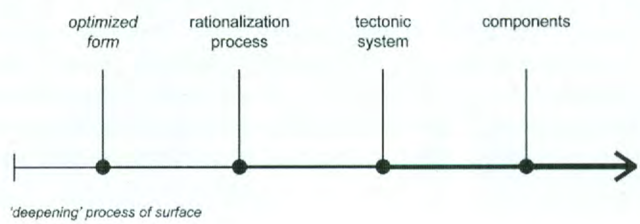
The technologies of our time offer new design techniques and processes. From the initial stages the design examples unfold in a digital 3D environment through the application of animation techniques and software that utilize time and changeability as vital ingredients of design[2]. The emergence of complex and curved shapes can be seen far back in the past. We could argue that in different periods of history there has been a strong legitimization between the developments of technology for the representation of design information and the types of architectural drawings and the invention of complex components and shapes.

The Greek word for 'tradition' ('παράδοση') means and refers to something that has been delivered from the past to the present. So in analogy we could assume that design is the preservation and medium of the established (traditional) knowledge of the past. Its continuity in time embeds a result controlled and ensured by the previous experience. In this way the design process acts as a preconception: it is a kind of standardization and classification of pre-existing information, behaviour, and cultural and social practices. This knowledge is realized and presented through a specific design process and a final design result. Design procedures are carriers of pre-existing information. These procedures have been 'published' in the past; they are preserved and memorised to produce design codes, that is, how things must be done and be ordered.



Naval architect.

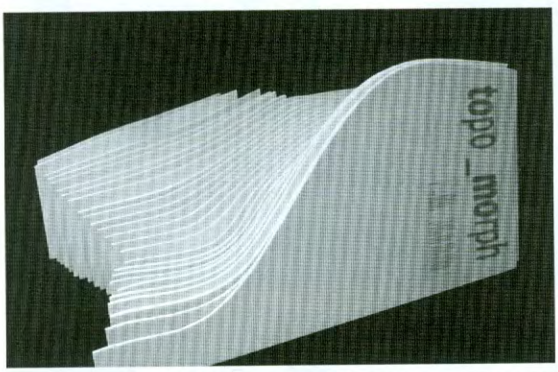
The structure of the medium of information has a strong influence on our way of life, on how we think and of course on how we design. Throughout history, man extracts gradually more and more matter from nature to imprint information on it. In this way he is transforming matter to cultural objects. Using 'traditional' techniques and procedures is a way of using specific methods for imprinting form onto the formless. In this way a designer may control and 'dominate' matter. According to Vilem Flusser, 'dominate' means to impose form, to inscript form into matter, to inform.[3] It is a commitment against the chaos of coincidence (against anarchy) and in support of the inscription of form onto matter. These procedures of matter information produce inscripted data on the sub layers of matter. Together with the embedded information, these sub layers generate surfaces which are 'deep'. A surface with more information embedded is deeper, so the more information a surface has, the deeper it becomes.



Matter is a carrier of information; it is 'intelligent' because of its embedded behavioral properties, mechanical and chemical (elasticity, flexibility, strength, hydrophilic etc). The techniques and the processes of production add new 'layers' of information to matter and produce heterogeneous properties and new behaviors. The combination of the produced materials with different properties produces a new whole, a system with new behaviors and properties.

Case Study 1: "Topo_morph" [4]

«*Topo_morph*» was produced to exhibit an architectural research project by the use of an interactive presentation which was projected onto a computer screen. It is a hybrid object that was generated by the fusion of two programs: sitting and displaying. The hybrid object was designed by determining and then morphing the initial 'functional' surface. The use of animation techniques offers a continuous parametric manipulating of the surface and the ability to adapt to local micro functional needs (for example, a small 'pocket' was created to embed the computer box).



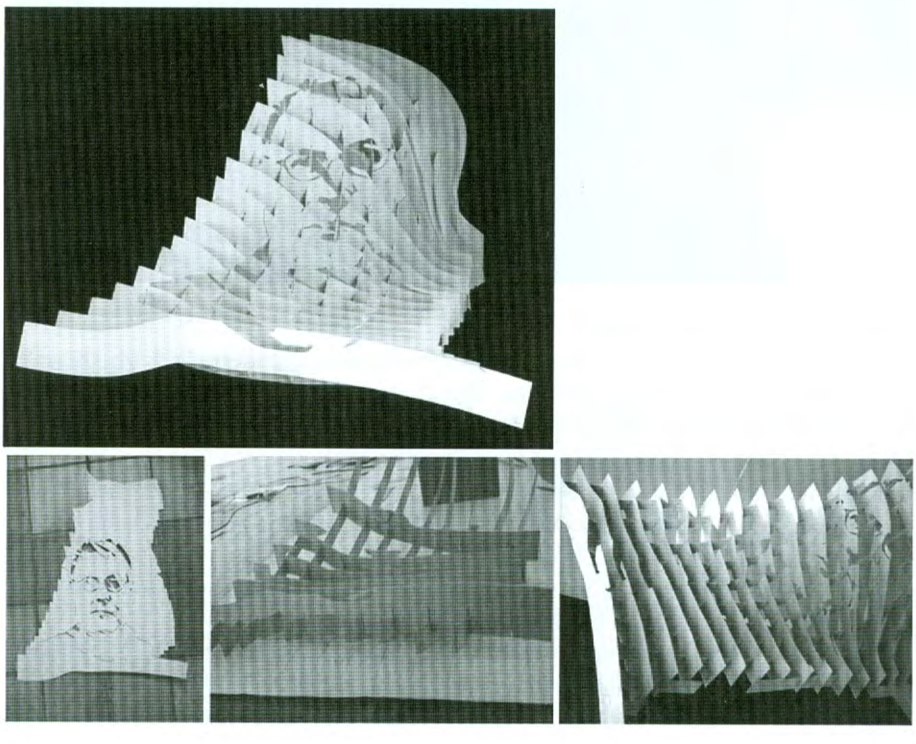
For the geometrical definition of the surface, the method of the serial cross sections, which produced 33 sectional profiles in total, was used through the whole object. This specific operational method of the geometrical definition of the 'topo_morph' determined in a way the preferred tectonic system. All the previous sectional profiles were 'interpreted' to 33 styrofoam panels of 3 cm in width. These panels were numbered and cut according to the sections and then placed in the predetermined sequence to produce the final form of the object. The panels were connected and fixed with a small gap between them for minimizing the used material. The assembly was easily completed by the use of four pvc tubes that penetrate all the panels at predetermined holes. So the pre-cut holes and the pvc tubes operate as a coordinator system for controlling the assembly.

Case Study 2: "Od." [5]

The sculpture was created for an exhibition which was organized in memory of the educator Odyssea Margari. *«Od.»* It is a free-standing hanging sculpture that displays Odysseas' face in an abstract way. From a specific viewpoint his image emerges gradually from the gridded structure.

The design of the sculpture began by the deformation of a horizontal two-dimensional rectangular-shaped surface into a three-dimensional free form. By the application of simple deformations with the use of animation techniques, the surface was deformed to reach the necessary height needed for the orthogonal projection of the facial photograph of Odyssea.

To describe the final free form, an orthogonal grid was projected onto the sculpture resulting in the generation of parallel and serial longitudinal sectional curves in both axes (33 sections in length and 12 in width). By this method the basic tectonic system was produced. The sectional curvy profiles directed the cuts of the outlines to produce the cardboard bands. The stripes were connected and fixed together at the correct distance with the help of the predetermined cuts. These cuts nested the stripes together to made the structure durable. At the first fifteen cross sections of the tectonic system, the outlines of the facial photograph were projected onto the cardboard bands. The outlined shapes were cut and subtracted in order for the face was finally "described" by the cardboard voids.



Case Study 3: anima_ta [6]

'anima_ta' is an experimental installation generated by the use of digital techniques and processes proposing a different way of display. It was designed for the exhibition 'digital topo_graphies'[7] to host computer mediated design research projects.

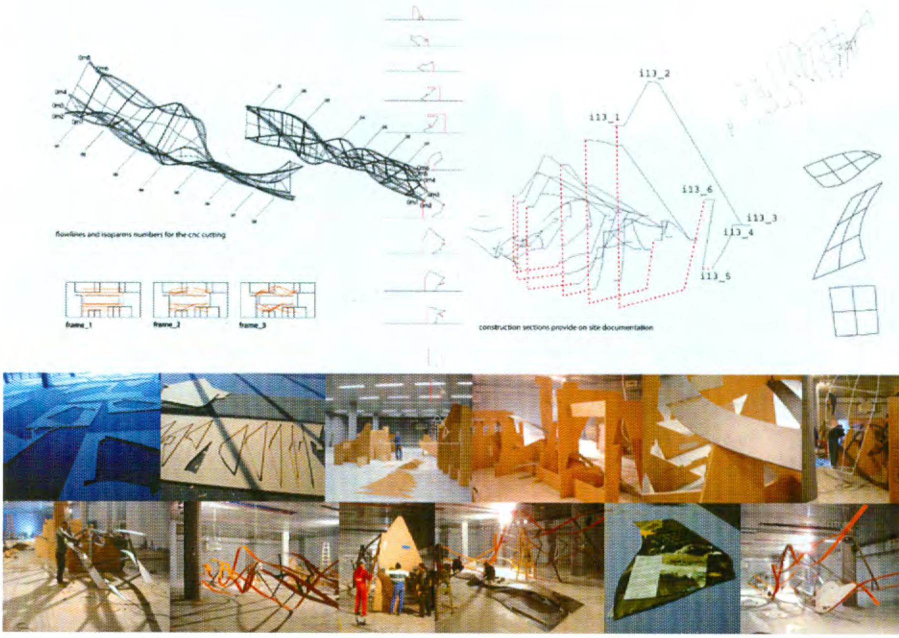
Revealing the Euclidian grid of the building was a starting point for the morph genesis of the 'anima_ta'. By connecting the existing rows of the columns of the building, six pairs of lines became visible. The design results from the influence of the force turbulence on these twelve lines which follow the direction of the columns. By transforming them to 'soft' curves, a net of related point-locators, defined exactly in space, was constructed. By introducing gravitation, the 'frozen' lines became 'elastic', supple to the forces applied. The result was differentiated by testing combinations of magnitude and attenuation values. The animation of the curves was paused in the time frame that provided the desired quantity of the force influence in order to achieve the suitable spatial relationships. These alternative forms lead to a new relation of body and display beyond the Cartesian geometry of 90 degrees. The twelve curves in space are translated into the structure and content of the exhibition. The lines (interpreted into iron sheets) form 'lofts" (translated into fabric), offering areas for printing and projection. The semi-transparent material allows light to make the installation lose its solid form and reveal its structure.

Experimental installation *anima_ta.*

The use of parametric design gives the digital information in order to direct the construction in detail. The materialized form is a result of merging new techniques of CAD, CNC milling machines with traditional handcraft experience. The final 3D model provides the data for cutting the metal stripes and the perforated fabric. The outlines of the fabrics were sent via email to participants to design the layout of their presented project by following a few pre-given simple graphic rules. Then they sent the print files back for printing and cutting. In fact, this procedure meant that the construction of the metal structure had to be very precise.

So the free form installation had to be very precisely constructed in the physical space. For this reason another technique was used. An orthogonal grid was projected onto the final 3D model to generate serial sections every one meter. These sectional profiles or outlines were used to cut mdf panels and then assembled at the exhibition space in a serial order according to the floor plan.

By this procedure we created a wooden skeleton of the form, a scaffolding for the metal structure that we had to construct. The outlines of the mdf panels defined precisely the points where the metal stripes of 20 cm in width had to be located in the 3D physical space. After the exact placement of the metal stripes onto the mdf skeleton, the in-between metal trusses of 'U' profile were installed to produce the final metallic skeleton. A final irregular metal space frame was constructed. The next step was to remove the mdf panels, to paint the resulting light metallic space frame, and install the perforated fabric printed pieces at the exact places.

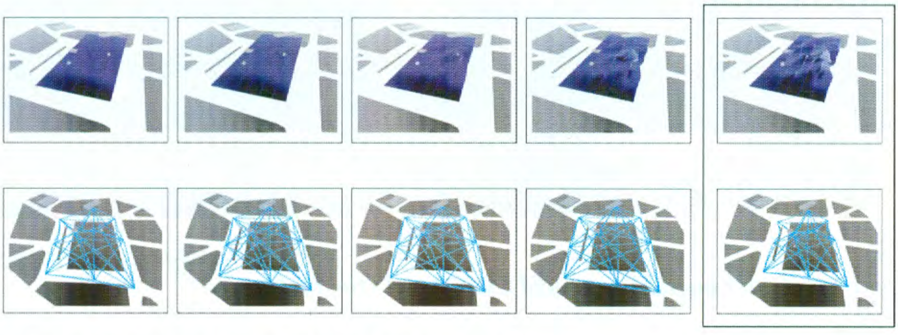


Construction and assembly of the installation *anima_ta*.

Case Study 4: Central Square of the City of Thermi [8]

The design process of the central square of the city of Thermi produces an informal architecture in contrast to preconceived and predictable results based on the implementation of conventional square typologies and standards. From the initial stages, the design of the central square «Paramana» unfolds in a digital 3D environment by the application of animation techniques and software that utilize time and changeability as vital ingredients of design. The proposal is based on the dynamic 'formation' of two overlapping and interactive network-fields: a 'path network' of all the possible pedestrian movements and a 'programmatic network' of the potential activities on the surface of the square. The square programmatic surface is transformed from a 2D surface to a 3D surface with 'depth', behaving as an intelligent interface able to host and generate the new program by proposing new activities and provoking other, unpredictable ones, as an outcome of the users' personal experience. The gradual decisions of materiality, load resistance and surface programmatic performance informed the digital model with the required data. The final form of the square is the effect of two processes of morphing and controlling. It is the amalgam of the two dynamically transformed networks and the outcome of the intensive inspection of the surface altitudes and inclinations by serial cross-sections along the whole length of the square. In this way the generative curves are reformed and improved to shape the final surfaces of the square.

'Paramana' central square of Thermi Municipality.

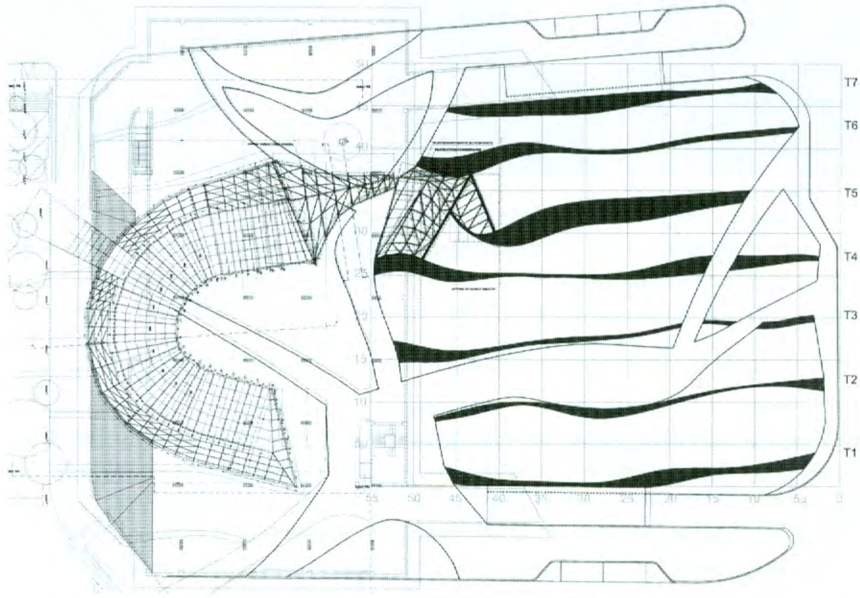


Animation techniques applied to the initial networks.

As the technical development of CAD techniques proposes new ways of thinking, representation and simulation, so, respectively, the evolution of CAM techniques facilitates the production of non-standard forms and further encourages the systematic exploration of novel approaches of rationalization, which is required for their manufacture. A systematic method is needed to describe and define geometric free form shapes, as in many examples constructed internationally. A method beyond the orthogonal projections which is more similar to axial tomography is used and involves serial transverse sections along the irregular – curved axis (backbone) of form growth.

The evolution of design as a continuum to manufacture has focused on a systematic attempt to rationalize the form through standardization as much as possible. The atypical, non-standard shapes of multiple curvatures due to different local conditions, available means and material performances, lead to the implementation of customized rationalization methods.

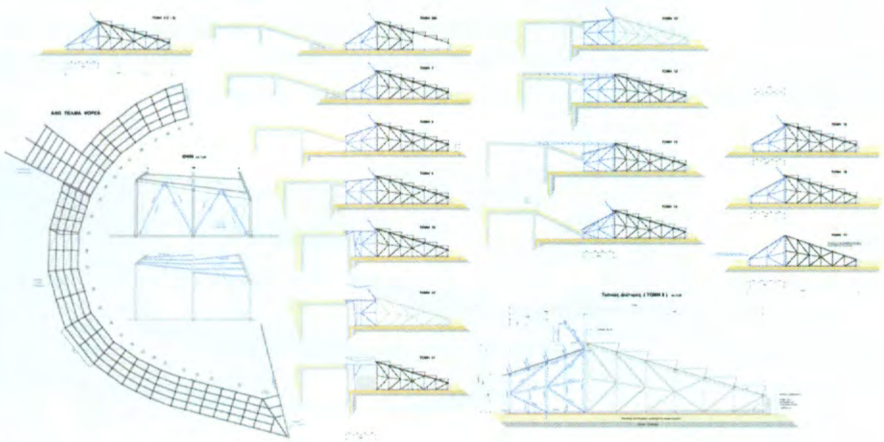
The main challenge that had to be confronted during the design process and construction was the limited load-bearing resistance of the pre-existing underground parking lot which is located under one half of the square surface. Due to this fact, a more complex but significantly lighter structure was required for the half part of the square located over the parking lot. Because of its limited load-bearing resistance, a metal structure is chosen and developed as a tectonic system above the underground parking lot, while at the remaining area of the square reinforced concrete is used to materialize the varied curvilinear surfaces: space frame as components.



Space frame as components.

Cost reduction requires maximum standardization of the metal structure. The structure consists of a metal skeleton covered by two kinds of cladding. The atypical shape gets rationalized and described by the same articulated space frame derived from cross-sections perpendicular to the curved axis of the form, which ends up being the load-bearing structure also. Standard elements are combined into repetitive triangular-shaped space frames, components (derived from sections) repeated serially by changing in-between angle and distance as they follow the curved axis of the form. However, many space frames vary gradually following the shape transformation. Despite geometric variations, they are easily produced as typical parts. They are cut, assembled and painted in an industrial plant using CAM technology. Afterwards, the components are transported to site, placed in the exact location and connected by using varied linear elements that are regulated on-site.

The rationalization of the metal structure (by space frames) embedded in the reinforced concrete stripes.



The metallic space frames as components derived from the cross-sections of the shape.

Cladding is attached to a specially designed light metal frame fixed to the bearing structure. The two materials of cladding are planks of tropical wood and perforated galvanized metal panels as prescribed by the design, one for each surface of the atypical form. For further cost reduction, incurvation of materials is avoided. Thus, out of necessity, the curved contours are translated into polylines and the topological surfaces are analyzed to polyhedrical and then triangular faces. The triangular panels of perforated metal sheet and their metal frames are welded together, transported and placed in predetermined positions on the metal structure. Some stages of the construction, such as the connection of the frames on site and the attachment of cladding, are not completely automated and are therefore driven by creative treatment and the use of available tools.

Case Study 5: "Surf" [9]

This installation was proposed as an alternative presentation and display of an architectural project. The exhibition space was used as a promotion and archive space of architectural products and materials. The design of the installation unfolds from the initial steps by the use of animation techniques. These techniques offered to the initial surface the required parametric control and adaptability to respond to altered design intentions and needs. The basic design tasks were that the installation had to be a piece of experimental research based on the project that would be displayed and

presented; and also for it to be an autonomous exhibit by itself. The exhibition space restricted dimension and its equipment determined the disposable areas and the areas where the installation could unfold. These possible areas describe a virtual path of movement and vision. That path generated the lofted surface which was deformed accordingly by responding to the positions and angles required for better visibility of the displayed information.

These deformations transformed the geometry and the width of the displayed surface without destroying its topological continuity. At the next stage the smooth **nurb** *(this is a technical word I assume?)* surface was converted to a polygonal surface and was divided into 42 connected faces. These faces were the components that would produce the installation. By this method the initial curvilinear surface was described by differentiated four-sided shapes or components. For their assembly a small extension of 3 cm length was added to each component. These extensions were designed at two of the four sides with the appropriate cuts and folds so as to be able to couple the components one with the other in the predetermined serial order. It was decided that the polygonal surfaces were to be materialized by PVC panels. Twenty five panels (100x70 cm) were used to produce the 42 components. The files that were sent to automate machines included all the required data for printing, creasing and cutting. The material properties of the pvc made the assembly of the components easier. Its flexibility allowed the final assembled surface to transform and adapt itself to the exhibition space; the folding of the components provide the final surface with the appropriate strength.

Conclusions

In the five paradigms presented, the design evolved in a computational environment by using animation software and morphing techniques. Time, from a measuring tool, becomes a vital design 'substance'. The initial rigorous rigid and standardized organizational grid is transformed into a flexible, dynamic and responsive network. These design paradigms indicate the ability of the designer to construct a variety of dynamic and digital parametric systems according to the specific occasion, and his/her objectives and desires. Also the design stages and the hierarchic relations of the system can be preserved in its memory as 'the history of the design processes'. This ability of the system to be 'open' offers the capacity to recall the necessary information and be re-informed to the new demands at every stage of the dynamic design process.

The available computational tools and techniques also provide the designer with the ability to generate customized approaches and strategies of rationalization processes. It would be better for these processes not to develop these processes in a linear way but to integrate them in the form finding process from the very beginning in order that the rationalization methods be really integrated from the initial decisions and intentions that generate and describe the evolving form geometrically. The technical development of CAD and CAM facilitates the production of non-standard forms and further encourages the systematic exploration of novel approaches of rationalization which is required for their manufacture. One possible way of a better rationalization process would be to design more intelligent and differentiated components.

A better correlation of material, structure, form and program would be achieved by exploring, describing and controlling the articulation of components and geometrical and material behaviour of components. What is obvious is the need for dynamic systematic methods that escape the common ways of describing and defining the a-typical shapes. The atypical, non standard shapes of multiple curvatures need a different method of rationalization adapted to various conditions and material performances.

References

1 Balmond, C. (ed.): 2002, Informal, Prestel, Germany, page 14.

2 The branch of mechanics that treats of motion in itself and of the motion of bodies or matter under the influence of forces in opposition to kinematics which is the branch of mechanics that deals with pure motion, considered without reference to the objects in motion, or to the forces acting on them.

3 Flusser, V. (ed): 2008, *Προς το σύμπαν των τεχνικών εικόνων*, σελ. 168
Original book title. Flusser, V. (ed): 1985, *Ins Universum der technischen Bilder*, European Photography, Göttingen.

4 *'topo_morph'*, a hybrid of display and sitting object for the exhibition 'art in action, Vagabond', Thessaloniki, May 2004, Architect: Spiros I. Papadimitriou.

5 *'οδ.'*, three dimensional surface – sculpture for the exhibition 'Odisseas Margaris, texts and works for Odissea' Amfilohia, Thessaloniki, August 2005, Architect: Spiros I. Papadimitriou.

6 Experimental installation *'anima_ta'* for the exhibition digital topographies, Thessaloniki, February 2005, Architects: Yota Adilenidou, Spiros I. Papadimitriou, Lighting design: Aris M.Klonizakis.

7 Information about the exhibition and the catalogue can be found at www.digitaltopographies.com

8 *Central Square 'Paramana' of Thermi Municipality*, Thessaloniki, December 2008, Architects: Dimitris Kontaxakis, Marilena Kosmidou, Spiros I. Papadimitriou, Associates: Aggeliki Ioakimopoulou, Meropi Hatzimichali, Lighting design: Aris M.Klonizakis.

9 Experimental *'Surf'* installation for the exhibition 'Moving Surfaces, generate public space' Archive, Thessaloniki, June 2009, Architects: Dimitris Kontaxakis, Marilena Kosmidou, Spiros I. Papadimitriou, Lighting design: Aris M.Klonizakis.