VIRTUAL DESIGN FOR INNOVATIVE TIMBER STRUCTURES

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ABSTRACT

The major timber structures have great efficiency and beauty, but not many use in buildings due difficulties to represent and resolve theirs geometrical complexity, regulated by several constructive rules. The spatial richness and attractive of these structures can be a contribution in architecture, and encourage the use of wood.

For aid the design and impels innovative solutions we are developing a computer system to program the geometrical regulations and allow a tridimensional visualization of different models with virtual-reality devices.

First we are studing the architectural morphology and design process of structures more typically used; beams, trusses, frames and arcs. Establishing theirs proportions, distribution, shapes alternatives and the computational algorithm.

In other hand we are evaluating the 3D-visualization in the innovation of designs. Some students of architecture developed in a virtual-system small projects based on other projects designed with traditional media. The models were compare by a panel of professors, considering overall quality and creativity.

The results of that experience shows advantages in geometrical innovation, specially in organic shapes user-centered instead of orthogonal compositions. But also some constructive fails, which is necessary to support with related procedures.

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1. Introduction

Wood has a long tradition in construction, but few use in major structures due to constrains for big pieces. However, new products such as glue-lam wood or compose boards, allow better structural behavior with minor sections, opening new possibilities of design, as demonstrated on recent architectural works based on strong personal talents [Hubner;1993, Makovecz;1992] which use, like other linear structures, a big amount of elements in different directions.
Besides, the architectural potential of wood is related to their natural characteristics; organic texture, warm colours, stable temperature, low sounds, etc., closer to human sensitivity, establishing a semantic base for organic shapes and spatial richness [Harris,1998].
These two properties encourage the architectural use of complex geometries to take advantage of efficiency and natural appearence of timber structures. But designing with orthogonal drawings difficults the visualization and organization of intricate shapes [Zevi, 1951].
Then, we proposed a computer system to program the geometrical regulations of timber structures and to get a three-dimensional visualization using virtual-reality devices, looking for implementing a design tool to generate proper and innovative architectural models, that impel the use of wood in major constructions.

2. Morphology of Timber Structures

The first stage was to study the architectural morphology of timber structures to define the regulations and possibilities of innovation. The morphology depends basically on the general volume of building. The most common are longitudinal volumes constituted by planar systems in repetitive sections [Natterer et al, 1991]. Horizontal or vertical volumes can be made with laminar, spatial or frame systems, but they are few and specific. The planar systems and the amount of elements are arranged with proportional relationships between width, height and length of volume, based on functional requirements and constructive efectivity.
The planar systems are usually composed by four types of elements; beams, trusses, frames or arcs. Each one increased in complexity of production and growth in structural capacity. So each type is related with increasing the dimension of volume, with a stable amount of elements. Because the function of buildings requires some width or height, this requirement can establish the type of elements to be used and all the general dimensions.
The size of the pieces are proportionally regulated from the main dimensions by constructive and structural efficiency (including also some constraints for transportation). The major variations are found in the shape of pieces, but frequently between range of angles or proportions defined by functional issues such as useful spaces, rain water run-off or constructive solutions for joints and cladding. Establishing several formal alternatives with progressive sizes. Also there are important variations in the distribution of pieces, based in linear

or radial organizations, although proportionally regulated by constructive performance and functionality.
Some of these variations in types, shapes and distribution involve strong differences in the architectural volume, defining spatial qualities, that must be related to the character of the activity. Then, based on the function and size of the building, an algorithm of alternative shapes and formal proportions of timber structures can be defined, to establish several models including unusual possibilities.

3. Implementation of Virtual System
The design system was mounted in software VRT-5 (Virtual Reality Toolkit 5.0 of Superscape Co.) because it offers a language programming called SCL (Superscape Control Language, similar to “C”) and an interactive 3D-visualization engine that control several virtual devices. That platform also allows to use a free browser (Visualizer-Viscape) and a trial-version of the modeling toolkit (3D-WebMaster). Up to the date, a functional prototype of the inmersive design system has been developed [García et al, 1998], that introduce the user into an open landscape with a handy control to define dimensions and to choose formal alternatives. Then, based in a library of shapes and the geometrical relations programmed, the system generates three-dimensional models of the structures where the user can walking-in, evaluating the spatial result and creating other solutions in an interactive design environment. It also includes a human body to scale the models.

Figure 1 : Design Enviroment (in Superscape VRT 5.0) and Inmersive Device (Forte VFX-1).

According to our experience the models must have less than 2.000 facets to allow a fluid navigation (this means a visualization closer to 15 frames per second) in an standard PC-Pentium. This situation restricts details like joints, minor pieces, divisions and furnishings (although aid to a quick creation of models). Besides, it simplifies the appearance, using one light source and flat colours (not real textures), and controls the complexity of programming and the amount of simultaneous models. Usually the 3D-software optimize the visualization by sorting the geometry, but in this case the models are created in the moment by the user and is not possible to predict the geometries. Then, there are rendering problems in radial structures and non-orthogonal distributions.
For inmersive visualization we used a low-cost helmet and 3D-pointer (VFX-1 and Cyberpuck from Forte), which includes two little LCD-screens, rotation tracker and headphones. The navigation was difficult by the handy control of

three-dimensional movements, lower visual quality and the occlusion of the helmet which produces sickness and tireness.

4. Evaluation of Virtual Designs

To evaluate the contribution of interactive 3D-visualization to the architectural creation of major timber structures we made three designs with fourth-year students of architecture. Each project was based in a real building designed with coventional media in timber structure, with a main space of around 200 square metres, devoted to different uses; a High-school Gymnasium; a social room for religious activities and an Industrial Pavillion for wood production. The students were encouraged to visit the buildings, to know the activities and to study the morphology of timber structures prepared to the system.
They re-designed the projects almost exclusively with the 3D software, modelling several alternatives and checking them with the immersive helmet. Although at the beginning they made some sketches by hand, during the work they take major decisions and made changes directly in the computers. By the geometrical constraints they were impelled to define a rough design without constructive details, choosing in the end one alternative for the three projects, as an “experimental group” for the evaluation. Also, they modeled in the software the original projects with a similar level of detail, as the “control group”.

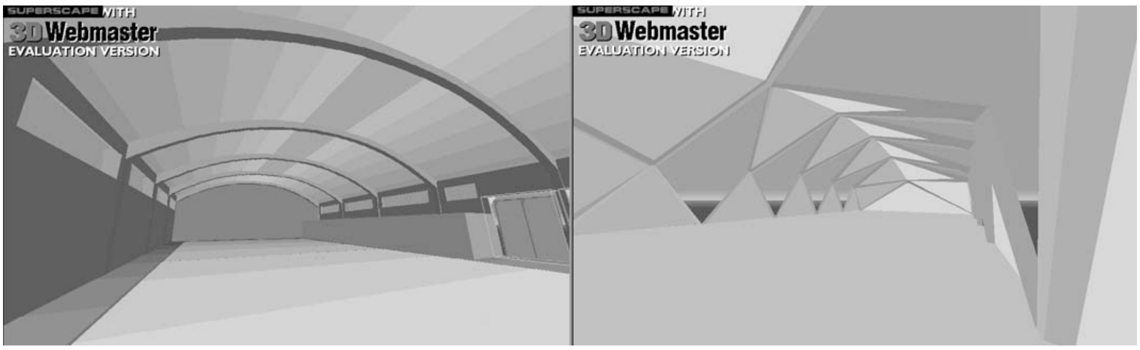

Figure 2: Gymnasium; original project (left) and virtual design (right).

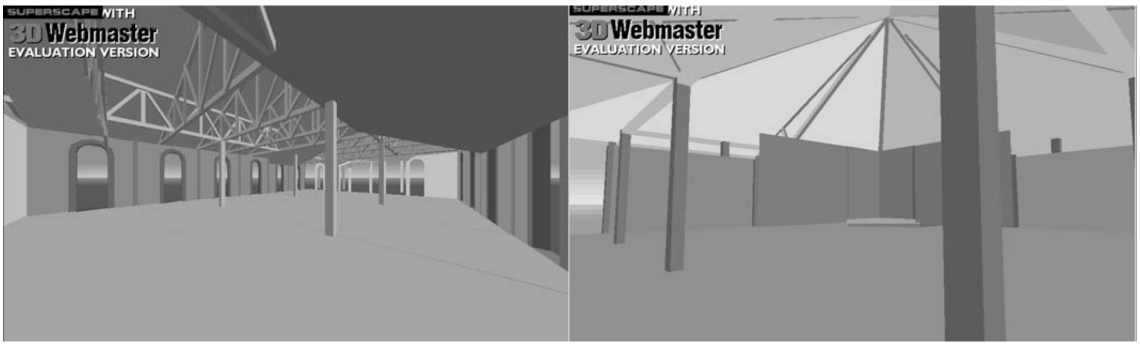

Figure 3: Social Room; original project (left) and virtual design (right).

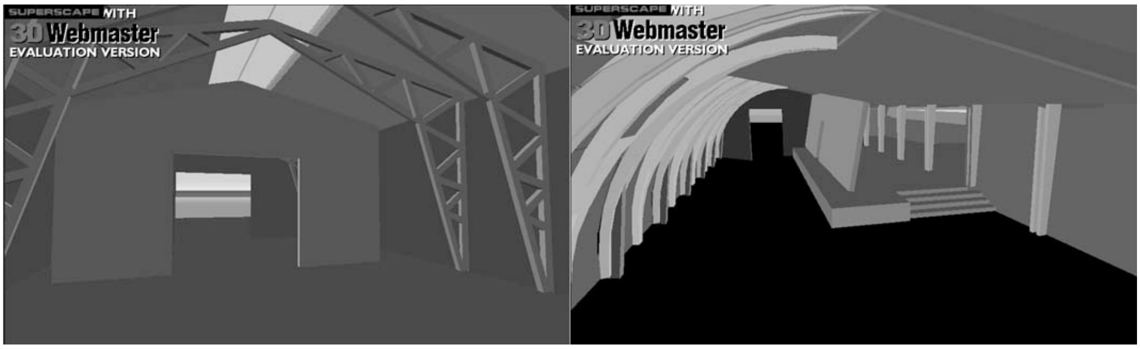

Figure 4: Industrial Pavillion; original project (left) and virtual design (right).

After that, the six models arranged in pairs according to their function, were evaluated by a panel of ten critics of architecture (professors of architectural design of different levels and institutions). Each sessions considered the presentation of printed views, guided tours of the models in the computer screen and/or visualization with the immersive helmet. Finally, they respond a similar questionnaire about the designs.

5. Results and Discussion

For evaluating architectural quality is a polemic issue, we based the questionnaire in a traditional reference, the Vitrubio's categories: utilitas, firmitas and vetustas (functionality, stability and esthetic). We consider two complementary questions about each category (ranged from 1: bad to 10: good), plus one of overall coherence and another specific one about innovation (usually a positive value in architecture, but not directly related to quality).

	GYMNASIUM		SOCIAL ROOM		INDUSTRIAL PAVILION		SUMMARY		
	Original	**Virtual**	Original	**Virtual**	Original	**Virtual**	Original	**Virtual**	Difference
GENERAL									-0,30
Overall	8,00	**4,80**	6,20	**8,60**	7,80	**7,50**	7,30	**7,00**	
FUNCTIONALITY							7,60	**7,20**	-0,40
Capacity	7,80	**4,80**	7,00	**8,60**	8,20	**7,60**	7,70	**7,00**	
Distribution	7,60	**6,30**	7,10	**8,50**	8,10	**7,30**	7,60	**7,40**	
STRUCTURE							8,50	**6,40**	-2,10
Stability	8,40	**5,60**	8,30	**8,20**	8,50	**6,80**	8,40	**6,90**	
Construction	8,80	**4,80**	8,10	**7,20**	9,20	**5,30**	8,70	**5,80**	
ESTHETIC							6,20	**7,40**	1,20
Composition	6,50	**6,10**	5,70	**7,60**	6,60	**6,60**	6,30	**6,80**	
Attractiveness	6,40	**7,90**	4,90	**7,30**	4,60	**8,40**	6,20	**7,90**	
CREATIVITY									3,10
Innovation	5,20	**8,00**	4,20	**6,60**	4,40	**8,50**	4,60	**7,70**	
AVERAGE	7,40	**6,00**	6,40	**7,80**	7,20	**7,30**	7,00	**7,00**	
Difference		**-1,40**		**1,40**		**0,10**		**0,00**	0,00

Table 1: Results of Evaluation by Critics of Architecture.

The final average of the questionnaires shows peculiar differences within the three projects; in the social room the scheme created with virtual system qualify 20% better than the original one made with traditional media, but in the gymnasium the results are inverted and in the industrial pavilion are almost matched. This reveals the big amount of additional variables in architectural design (theme, proposal, designer's capacity, etc.), which disturbs the

reliability of results. Besides the few cases studied and lack of statistical base obbey to consider that experience only as an example.
The total summary of evaluation lead to a close matching between virtual and conventional techniques. Then, it is possible to say that to generate the design with virtual systems do not produce major differences in the overall quality. But it is also important to notice the differences by subjects, the traditional projects were better evaluated in functional and constructive issues, and the design created by virtual systems in esthetic and especially in innovation (66% better). This result support the initial hypothesis about a positive contribution of virtual design in the creativity, but also warned about pitfalls in functionality and constructive solutions with that media.
It is interesting to note similarities in morphology of designs created with virtual systems. In each case the shape of spaces were "rounded", with a central organization in the social room (although with straight pieces), with a linear increasing-decreasing organization with diagonals in the gymnasium, and with curved pieces in a complex distribution in the industrial pavillion. The three projects apply more complex geometries, with three-dimensional rotations and a perimeter in a more "constant distance to user" than orthogonal buildings. This reveals the predominance of user point-of-view to define the design, instead of 2D regularities used in the traditional media, impelling innovation with organic and centralized spaces, instead of orthogonal and aggregated organizations.

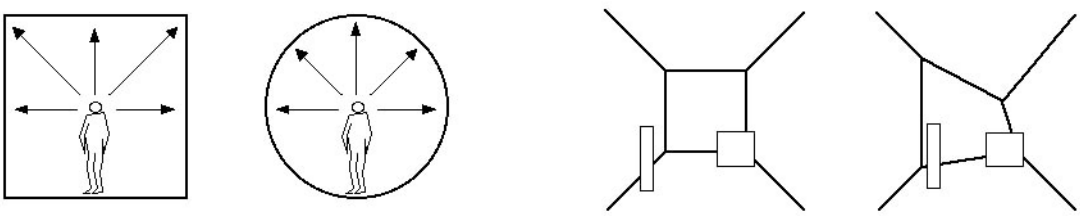

Figure 5: Sketchs of Spatial differences from conventional (left) and virtual design (right).

Besides, the shapes used in all virtual projectsdifficult the perception of distance and dimensions. However that characteristic is related to complex geometries and encouraged by simplification of appearance in the virtual media. The designers don`t take attention to use grids, regular rhythms or orthogonality to give orientation and dimensions. The projects focused in the visual impact instead of right forms.
These two characteristics of the schemes; organic centrality and visual predominance can be influenced by the ecological issues and broadcast media increasing in our culture. Two strong (and in part contradictory) trends of current society, showed in the sentence used by Peter Einsenman to describe the zeitgeist (the spirit of the time); "dissociation between body and mind-eyes" [Zaera Polo, 1997]. Although that kind of link could be casual, is important to relate the formal innovation in architecture to concepts and cultural view to focus creativity like an evolution, instead of alleatory formal play.

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