Digital Exploration of Unbuilt Architecture: A Non-Photorealistic Approach

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Abstract

This paper presents a new approach to the digital investigation of unbuilt architecture. A navigable world, emulating the architect's graphic style, is built as a 3D non-photorealistic reconstruction of the unbuilt project. A cinematic journey through this world intermediates the exploration of the architect’s possible mental visualizations during the creative stages. The goals of the proposed approach are: to open new avenues for investigating the conception of architecture, to help architectural students visualize and experience important unbuilt projects that have shaped the practice of architecture, and to popularize lesser-known architects to the general public. The approach stems from the idea that architectural drawings are the artifacts reflecting most accurately the architect’s creative and thinking processes. Anchored in the concept of multi-dimensional space developed by the author, the proposed method uses the original drawing of the artist as the main artifact on which the reconstruction process is based. The present paper concentrates on those aspects related to extracting information from the architect’s drawing and embedding historic knowledge in the 3D reconstruction of the unbuilt project. It calls to attention the idea that technological progress creates tools that the Architect uses to operate with the fundamental concepts of place, space, and time.
1 Introduction

3D reconstructions of unbuilt architectural projects have been tried before. An impressive collection of 3D reconstructions including many unbuilt projects by Frank Lloyd Wright, Antonio Sant’Elia, and others, was put together by B.J. Novitski (Novitski 1998). Probably the most successful 3D reconstructions of unbuilt architectural projects to date were proposed by Kent Larson (Scully 1993) for some of the most influential projects of Louis Kahn.

The approach taken in this paper diverges from the current trend in the area of computer reconstruction of unbuilt architecture. It does not try to provide realistic or “hyper-realistic” (Ojeda and Guerra 1996) reconstructions based on the utilization of natural textures. Kent Larson’s reconstructions were aimed to offer highly realistic visualizations of Kahn’s unbuilt projects. His approach attempts to facilitate the investigation of the unbuilt by taking, in the virtual world, the next logical steps in the life of the architectural project and to represent the building as it may have appeared if constructed in the real world (Larson 2000).

This paper advocates a completely different approach. While the architect’s drawings continue to represent the starting point for the research, the main objective of the reconstruction is not to complete the unfinished project. Instead, the computer reconstruction goes in the opposite direction. It tries to recreate the steps taken by the architect during the conceptual phases, to investigate the creative process itself, and to explore the possible sources of inspiration. The architect’s 2D renderings and conceptual sketches are translated into digital 3D spaces. These are meant to assist the investigation of the project conception in various design stages. The proposed approach differs from the current trends in terms of the main objectives of the research, the research methodology, and the employed digital reconstruction techniques.

The central characteristic of the proposed approach is the translation of the architect’s drawing into a 3D navigable medium while concomitantly aiming to preserve the architect’s graphic style. The available 3D software packages are generally optimized to create realistic representations. Although results have been obtained in the area of digital non-photorealistic representation (Gooch and Gooch 1998; Strothotte and Schlechtweg 2002), these are not flexible enough to recreate a specific graphic style of an artist, but rather focus on emulating traditional media in general. As a result, non-standard techniques were devised to achieve the goal of recreating the graphic style of the architect in the 3D environment. Custom collections of textures were extracted from the architect’s drawings and were processed to allow the creation of complex materials required to build the 3D environment. As in art restoration, the process aims to digitally emulate the architect’s specific graphic treatment, including the representation of depth and lighting in interaction with the architectural volumes.

A cinematic exploration of the virtual architecture facilitates experiencing the architect’s concept of dynamic space as it can be understood from his drawing. Unlike Cameron McNall who uses Canalleto’s drawing only in the opening sequence to create atmosphere (McNall 2000a), the proposed approach maintains a consistent look and feel suggested by the architect’s drawing during the whole movie. Another difference in approach is that unlike McNall who uses the Microscribe digitizer (McNall 2000b), the elements used in the present project were modeled directly using 3D Studio Max.

2 Related Works and Methodology

Two categories of problems are raised by the present paper. One refers to the approach proposed for the investigation of conception rather than perception of architecture through the reconstruction of unbuilt. The second refers to reconstruction techniques that allow the transposition of the graphic style of the drawing into the 3D navigable space. Numerous works have approached both problems before.

2.1 Artistic Restoration or Automated Reconstruction?

The latest trends in the domain of non-photorealistic rendering show the emergence of a large spectrum of algorithms aiming to digitally simulate traditional media. Two main sets of techniques were used in reconstructing artistic textures. In the first set, the simulation results mainly from mechanically applying sets of procedures to the final image (pixel algorithms). In the second set, procedural algorithms are applied to the three-dimensional geometry with visible results at render time.

Recently, due to the general interest in the domain of knowledge management, some interesting projects have tried to apply the progress in this domain to knowledge-based architectural CAD. Prototype knowledge based architectural modelers were developed and applied by Chassagnou and his team for reconstructing Gothic vaults (Chassagnou et al. 1998), or Boucard and his team for columns (Boucard et al. 2002). Another promising direction is represented by the development of a system for sketching in 3D. This attempts to preserve...
the “degree of expression, imagination, and simplicity of use achieved by 2D drawings” (Bourguignon et al. 2001).

All these methods allow working with simple architectural elements. While their evolution could provide in time an aid for those involved in the artistic 3D reconstruction (restoration) of the unbuilt projects, no techniques could replace the creativity and the insights of an artist or architect.

The proposed approach stems from the idea that remediating (Bolton and Grusin 1999) the architectural drawing from one medium to another is a process demanding artistic abilities similar to those required for restoring original artworks. The human intervention could not be replaced in this process. Apart from preserving the artist’s graphic style, it also helps to maintain the integrity of the architect’s concept on the project and explore the emotional, metaphoric, and symbolic content of the work. A multi-dimensional virtual reconstruction aims to create a digital solution space allowing the exploration of the architect’s possible visualizations during the conception stages. Translating the architect’s graphic style in the 3D space is not a purpose in itself. It represents the means to expand the drawing into a navigable virtual space that is as close as possible to the original artifact (the drawing), the direct result of the creative process. While transposing the architect’s graphic style from a 2D drawing to a 3D space is challenging from a computational point of view, it is even more difficult to expand the experience of navigating the virtual environment into a journey in the architect’s conceptual space. That goes beyond the mechanical reproduction of style and the automated navigation of an artificial environment. It is here that human intervention and specialized art skills are necessary to make the sensible connection between style and content throughout navigation in the virtual space.

2.2 Methodology

The proposed non-photorealistic approach to the digital reconstruction of unbuilt is centered on using human artistic abilities and expertise with new media technology to translate a 2D architectural drawing into a 3D anthropomorphic space. This approach aims to facilitate access to abstract concepts drawing on human experience gained through interaction with the natural environment (Anders 1999). In terms of preserving the graphic style and content integrity, the process is similar to the restoration of original artwork. Simultaneously, the method facilitates the exploration of hypothetic creative spaces anchored in historic research. The proposed solution is divergent from the mathematical/algorithmic non-photorealistic approach to the digital simulation of traditional media.

The overall process incorporates two major phases. The first phase investigates the direct and contextual information regarding the project. The second phase represents the digital reconstruction process.

The purpose of the first phase is to provide the necessary data for the transposition of the unbuilt architecture into an expanded 3D representation. Knowledge management packages could facilitate this phase. These can assist the artist/architect in selecting the significant dimensions from multiple available solutions for a specific instantiation.

The second phase uses the information generated in the first phase as foundation data for the digital reconstruction. Any such reconstruction is the result of a bounded creative process. The artist/architect needs and handles all the available knowledge. Different artists/architects could interpret differently the body of knowledge accumulated by historians. Because new data may become available later due to the research process, the final result is only a materialized instance of the multi-dimensional space defining the solution. Unlike in the restoration process, the virtual reconstruction does not interfere with the preserved artifact and the solution could reflect different schools of thought, different inferences, and different positions. It produces an artistic interpretation of the unbuilt project which can be used as a milestone reflecting the current accumulated knowledge.

3 3D Reconstruction Project

To exemplify the proposed approach, a digital reconstruction has been developed around the unbuilt project “Pont destiné à réunir la France a l’Italie” (1829) of the nineteenth century French architect Henri Labrouste (Levine 1982). The reconstruction is based on Neil Levine’s photographs of the original drawings (Figure 1). A wireframe view and a full perspective view of the 3D rendering are provided in Figure 2 and Figure 3.

3.1 Digital Reconstruction Process

The purpose of the digital reconstruction is to make possible the experience of passing over the bridge following the dynamics of the original graphical composition and synthesizing the spirit of that experiment as expressed by Labrouste. The filmic mode of investigation is preferred over interactive exploration due to the coherent exposition of information.

The first step is to provide a computer version of the perspective drawing (Figure 3). Different angles of view demonstrate the consistency of graphic style between the 3D architectural representations and the original drawings (Figures 4, 5, 6, 7, 8). Ensuring the visual continuity of transitions between different viewpoints is a first step toward a natural dynamics of the virtual exploration.

The digital movement is designed to convey real movement. Where the investigation of the virtual architecture assumes impossible standpoint for the human viewer, the digital camera motion is based on established representation conventions used by the film industry. These are already natural to the viewer and allow her to concentrate on the space exploration while the computer medium becomes an invisible agent to support the experience. Preserving the integrity of the graphic style in the 3D representation makes the investigation of the virtual space a permanent visual citation of Labrouste’s drawings. Natural shifts
from views staged to remind of Labrouste’s frontal, section, and elevation drawings smoothly introduce angles of view never shown directly by the architect.

3.2 Depth
The suggestion of the third dimension by means of linear perspective is mathematically resolved through computer calculation. The accuracy of the automated process eliminates the approximations resulting from manual manipulation. The automated solution implicitly resolves some other depth cues as overlapping planes and relative size of objects. Therefore, these are also interpreted as the result of automated computing. The representation is highly objective.

Elements contributing to the suggestion of aerial perspective require more interpretation and decision-making. These assume a great number of manual parameters selections for both setting up and fine tuning the digital camera, colors and materials, various atmospheric effects, and particle systems. The results are then evaluated through qualitative changes in the rendered two-dimensional output. The process of digital reconstruction in the 3D medium emulates a combination of real life processes of building, film production, and traditional painting. The subjective character of the 3D field structuring is alleviated by the technical data provided in Labrouste’s drawings. The bridge has a well-defined 3D composition, and the digital depth is developed around the predefined spatial structure of the bridge. In the digital representation, the background closely replicates the drawings. The choices regarding the middle ground and foreground planes do not involve the restructuring of the spatial relationships between objects, as both their size and placement are predetermined. This allows for a very limited modulation of negative and positive volumes in conveying depth. A specific spatial suggestion can eventually be emphasized by an optimal selection of the key viewpoints.

3.3 Texture
Texture is an essential factor in translating the pictorial quality of the traditional rendering into the digital medium. Apart from this role, textures have been used for compositional purposes and for space articulation in ways trying to emulate Labrouste’s solutions for resolving the same problems.

The best textures for realistic architectural modeling are based on digitally adjusted photographic material taken from real buildings. The modifications applied to photographs consist in eliminating any cast shadows, important differences in the lighting of the surface, obvious accidents in the surface due to mechanical actions, and in adjusting the perspective to obtain the texture represented in full frontal view. These digitally adjusted textures are then applied to the geometric model and the stretching of the texture around geometry is ensured through various texture mapping techniques. Numerous settings allow the fine control of the way in which textures are applied onto the digital surface.

These procedures have been adapted to the special purpose of the bridge model. The basic photographic textures have been replaced with textures extracted from Labrouste’s photographed drawings. The extracted textures in raw form are represented in perspective. The most dramatic modification applied to these first forms of the textures consists in digitally repainting them in order to recreate them in full frontal view. Each painted stroke has been created by cloning portions from some other parts of Labrouste’s drawings and merging these gradually over a transparent grid, which helped matching the proportions of the new texture with the existing one. Modifications at pixel level followed most of these changes, and they derived from the need to preserve Labrouste’s line continuity and style, which suffered deformations...
Figure 3. Reconstruction of final drawing: View 1.

Figure 4. Reconstruction of final drawing: View 2.

Figure 5. Reconstruction of final drawing: View 3.

Figure 6. Reconstruction of final drawing: View 4.

Figure 7. Reconstruction of final drawing: View 5.

Figure 8. Reconstruction of final drawing: View 6.
during the first raw adjustments. A library of Labrouste-textures has been created for the specific purpose of the digital reconstruction. The hand-made quality of the textures was an important factor in conveying the traditional medium in the digital surface rendering. The texture library is organized in two dedicated collections, one for the landscape part of the model and one for the bridge. This organization is due to the way in which textures have been used in the computer model and the slightly different digital adjustments applied to them. In Labrouste’s drawings, the surface definition is subordinated to the volumetric quality of the architectural forms. The direct illumination of the frontal face of the gate emphasizes the clarity of the plane surface, the roundness of the arch, and the rectangular character of the gate’s enframement. Labrouste rendered the stone block texture with elaborated accuracy to suggest the material but subordinate it to the overall geometrical character of the volume. The suggestion of a natural surface results from the manner in which the mathematical alignment of the stone blocks is combined with the illusion of slight imperfections in the surface. This is achieved through subtle modulation in the treatment of the overall surface suggesting the natural non-uniformity of materials and the uneven response to erosion. The overall feeling conveyed is that of a life-like uniformity of the surface, with subtle variation and randomness in the repeating details.

The traditional architectural rendering, even when various mechanical instruments like rulers, compasses, etc. have been used, remains very different from the rendered 3D image due to the manual quality of the contours. Various techniques offered by the digital medium for suggesting aerial perspective alleviates much of this problem especially for the representation of objects which are fading in the distance. For anything situated in the close area of view, the treatment of the contours was solved by applying more complex texturing techniques or by manipulating the geometric model based on raising the mesh resolution. In the particular case of the bridge model, this problem was addressed by using complex composite materials with multiple texture layering. These softened the artificial perfection and sharpness of the outlines. In general, the base material used is a standard material with the diffuse channel based on one of the digitally processed textures from Labrouste-textures library. The supplementary layers may add some random imperfections to the base material. This helped to exaggerate the cast shadows effect along some of the margins of the object’s surface, and was instrumental in altering the artificial sharpness of the edges. The last effect is mainly based on the use of transparency maps in the opacity channel of the base material. These maps are digitally created and are based on gradients from black or a selected grey to white. The lightest margin is placed along the contours that have to be softened by merging in a controlled degree with the other materials from the composite and with the background image. Additional slight imperfections can be added on different levels of the component materials. While the resulting contour is closely, but not entirely, matching Labrouste’s line, the overall feeling conveyed in the digital rendering is that of manual manipulation of the contours. These effects combined with the use of Labrouste-textures produce the desired effect of realistic rendering in the traditional medium.

The treatment of the landscape texture mapping is different from that applied to the bridge in a number of ways. A separate collection of Labrouste’s landscape textures was created. The need to obtain an accurate frontal view representation of the texture is not as strict as it is in the case of the architectural surfaces. Representing landscape in the 3D medium requires high-resolution meshes. The realistic representation of the landscape in Labrouste’s drawings ensures good suggestions of volume in almost all of the landscape textures. This helped to convey terrain with lower polygon geometry, based on Labrouste’s textures. For the terrain in the close area of view it was necessary to pay more attention to the contour treatment. The applied materials have been maintained as simple standard materials, and the irregularity of the terrain volumes was handled directly from the geometry of the 3D model by slightly increasing the mesh resolution. The irregularities are not shown in close detail, and a few accidents in the terrain forms ensured the necessary feeling of randomness and variation while still using low polygon geometry.

In Labrouste’s drawings, texturing plays an important role in the graphical composition and in creating the suggestion of aerial perspective. The shadowed texture on the ground in the fore plane has an important visual weight. The texturing of the architectural forms is subordinated to their volumetric character, and emphasizes their almost purely geometric definition. The relationship between the detailed shadowed foreground textures and the faded textures in the middle and background planes has an important contribution in the articulation of space.

In the 3D medium, the compositional texture contrast between the ground in the front plane and the bridge automatically results from the application of adequate textures on the geometry and from the interaction with the digital lighting, coloring, and various other atmospheric and combustion effects. The texture mapping applied to both the landscape and bridge geometry uses the same maps numerous times in both close and far distance. These are automatically modified for representation in linear perspective. The modifications suggesting aerial perspective result from the interaction of the textured surface with light and other atmospheric effects which are set by manual manipulation of given parameters.

3.4 Light
The problem of using digital light is in many respects similar to the use of light in real life. 3D lights are manipulated by applying film and television production techniques, and the results are evaluated in the rendered output as a pictorial composition. Thus, the 3D light was applied through the metaphor of light in real settings, but was conceptualized as a brush with the capability
of changing the perception of the objects’ color, volume, and position representation in the final flat image.

The lights have been manipulated as light objects, with clearly defined positions in the 3D world, and with adjustment parameters emulating the operation of lights in the real world (light intensity, color, shadow, transparency and softness, size of the light cone and falloff area) plus other parameters which are more specific to the computer medium. However, the digital lights are in many ways different from real lights allowing, for example, the control of the cast shadows’ color and way of blending with the environment. In order to emulate the graphic reality of the drawing, the capabilities offered by the digital lights must be used as painting tools for the purpose of the final two-dimensional representation. For this reason, manual manipulation of light parameters was the preferred choice over automated lighting solutions like radiosity and raytracing. This allowed greater flexibility in the process of digital painting.

A global illumination system has been defined manually. The direct illumination is organized in the form of a ring array of omni lights of variable low intensity with a central key light, which has the highest intensity and is elevated by approximately 30 degrees from the plane defined by the ring array. The color of the key light varies from yellowish-orange to a slightly yellowish tint emulating lighting conditions at the end of the morning and before noon. The lights in the array are non shadow casting and suggest the skylight contribution. Those placed in the semicircle opposing the key light have a color tint complementary to the key light, covering a range of blues. Those placed on the semicircle behind the key light in relation to the position of the bridge, have neutral white colors, with a very slight yellowish tint. The light-bouncing phenomenon is simulated with local lights and it is more accurate in relation to the architectural forms of the bridge, and more economic and loose in relation the landscape. A great amount of fine-tuning of the local lights has been done in order to render the pictorial effects from Labrouste’s drawings. In spite of the emulation of photographic and film lighting techniques, the process can be resumed as one of digital painting with light.

### 3.5 Time

In the digital space, time and movement coexist intimately interwoven. The feeling of time in the 3D medium is related to the way in which motion is perceived. In real life, while one is static, time can be experienced in various objective and subjective ways. In the digital medium, as soon as the movement ceases, the computer representation loses dynamics and becomes a still picture. The illusion of life is lost and with it, the temporal dimension of the digital space.

The main object of the exploration, the bridge, is a still element. All the primary motion comes from the environment: water, clouds, cast shadows, mist. The movement of the water, clouds, and fog happens in objective time. The accelerated movement of the cast shadows sublimes the objective time, and leads observers to qualitatively different experiences, in a subjective time and space. The movements of the shadows create directional forces around which the bridge investigation is structured in a symbolic time.

Camera movement is instrumental for creating meaning. Often, it offers a subjective angle of view. It takes the viewer inside the digital time and space. It takes the viewer from the objective time of the physical simulation of the bridge into the subjective time of a transcending experience toward another space of existence.

### 3.6 Movement

The exploration in the multi-dimensional space is organized around the main compositional lines of force from the perspective drawing. The goal is to follow the path of movement and capture the dynamics of the architectural space as suggested in the original design.

The graphical composition in the perspective drawing indicates a passage over the bridge from east to west with an evident discontinuity related to the cippi. The core of the symbolic meaning comes from the experience provided by this interruption in the action of passage.

Another avenue of movement is suggested in the lateral view. The symmetrical arrangement of the architectural forms defines the cippi as the central element of a symbolic motion of passage from the earth to the sky. As this motion is centered on the cippi both as a boundary stone and a symbolic container of meaning, the symbolic vertical movement becomes tied to myth motifs: beginning and end, death and rebirth, and cycle (Figures 9, 10, 11, and 12).

The dynamics of the cinematic exploration is centered on these two passages: one following the natural direction indicated by the architecture of passage, and the second following a vertical direction suggested by the symbolic components in the bridge architecture, the cippi. The two passages are discontinuous and overlap, while their dynamics help the viewer perceive the sacral connotations of the interior space of the bridge.

The exploration of the architectural forms is mediated by their interaction with the natural environment and interferes with the sacral dimension assigned to the bridge. This gives intensity and a dramatic quality to the experiment emulating the feeling raised by a possible transcendence from the human world to another incomprehensible world. Crossing the bridge becomes a “rite of passage” related to the bridge as a temple.

### 3.7 Color

The material artifact that provides the basis for the multi-dimensional space reconstruction consists in black and white photographs from original drawings. In general, Labrouste used a restricted, low-energy color scheme based on a dominant pale yellowish-ochre. Both the ornaments and the use of color are austere and subordinated to the architectural forms, leaving the major compositional role to the interplay of volumes. The lighting used by Labrouste is important in supporting this approach. The color dimension of the digital reconstruction was developed
based on Labrouste’s specific color range and lighting scheme giving the bridge an evocative character. The ineffable value of the digital exploration comes from the feeling that we enter an intangible world of the past.

3.8 Digital reconstruction of sketches
Other sets of reconstructions developed include 3D visualization of earlier stages of Labrouste’s design process and cinematic interpretations of the bridge’s symbolism. Renderings and movies were generated based on Labrouste’s sketches (Figures 13, 14, 15, and 16).

4 Conclusion
New computer tools, new approaches, and ultimately new philosophies facilitate new ways of manipulating space during the architect’s creative process. As Louis Kahn wrote “Architecture is the thoughtful making of spaces. The continual renewal of architecture comes from changing concepts of space” (Kahn 1957). While Architecture moves rapidly toward the paperless office (Norman 2001) and regardless of the techniques used it remains obvious what Fredrick Norman pointed out: “digital media is a tool for design.” Architecture has been and will be about the traditional notions of place, space, and time. The architect’s traditional forms of representation will continue to evolve. While New Media may remediate paper, clay, or wood, in the architect’s studio, line, shape, texture, transparency, volume, time, movement, and light will remain the real objects manipulated by the architect. New equipments and software solutions will be successful only if these are developed to help the architect in this process.

The present paper is an attempt to answer the question: “how artificial worlds and new technologies begin to reconstruct ideas of place?” (Tilder 1998) It proposes the use of the architect’s drawing as the basis for the digital re-creation of unbuilt architectural projects promoting the research of the architect’s vision. It introduces a new approach to the reconstruction of the unbuilt architectural projects rooted in the known truth that architecture is mainly in the realm of concepts, ideas, and propositions, and not necessarily in concretized forms of expression. Unbuilt projects allowed architects to advance impressive analytical, descriptive, and experiential scenarios. This paper looks towards this rich world and proposes the creation of parallel multi-dimensional worlds on the basis of the architect’s drawing. This could allow the “graphic reality” of the architect’s representation to be transformed into a digital navigable environment adding new opportunities for critical thinking besides the traditional architectural walk-through.

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Figure 10. Rendering of detail: cippi

Figure 11. Rendering of detail: cippi.

Figure 12. Rendering of the cippi group.

Figure 13. Labrouste: Sketch.

Figure 14. 3D reconstruction of sketch Version 1.
Figure 15. 3D reconstruction of sketch Version 2. View 1.

Figure 16. 3D reconstruction of sketch Version 2. View 2.
References