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► To cite this version:

Emmanuel Alby, Pierre Grussenmeyer, Jean-Pierre Perrin. Visualization of architectural works by photogrammetry: a compromise between measurement and representation. Workshop on Vision Techniques Applied to the Rehabilitation of City Centres, 2004, Lisbonne, Portugal. pp.1-11. halshs-00264437

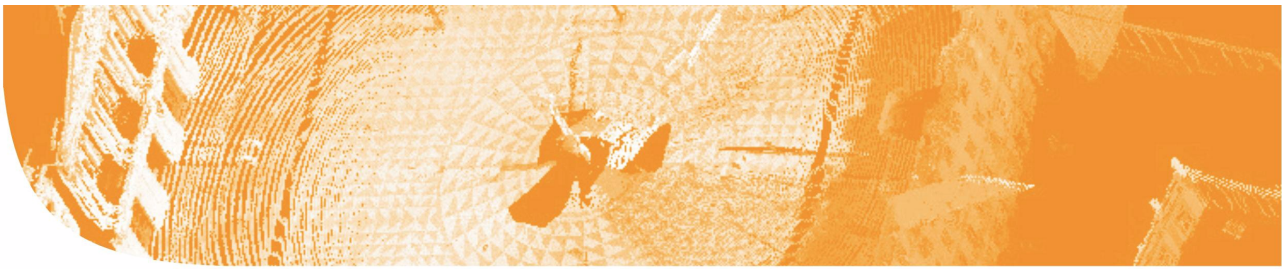
HAL Id: halshs-00264437

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Submitted on 21 May 2008

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International Workshop on **Vision Techniques** applied to the **Rehabilitation of City Centres**
25 - 27 October 2004 | Lisbon | Portugal

VISUALIZATION OF ARCHITECTURAL WORKS BY PHOTOGRAMMETRY: A COMPROMISE BETWEEN MEASUREMENT AND REPRESENTATION

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KEY WORDS: Architecture, Close-Range Photogrammetry, Conservation Project Management, Photographic Recording and Documentation

ABSTRACT:

Architectural works are carefully planned before they are erected. They are the result of an elaborated and logical process. The survey of a building is thus a singular problem compared to the contingent constitution of the rural survey. Architectural modeling can therefore be enriched beyond its dimensional knowledge by adding to it the architectural knowledge that permitted its construction. The virtual model of an element of architecture is significant when it becomes displayable. 3D visualization is however a translation of information provided by a model. The result obtained is a communication tool, not a vehicle for knowledge. The data used for its construction is transformed in order to satisfy the illusion. The geometry and textures are adjusted together. The visualization mission of the *Promenade du Peyrou* is an occasion for us to apply our principles of analysis to the remote acquisition survey.

RESUME :

Les ouvrages architecturaux sont des objets qui ont été pensés avant leur construction. Ils sont le résultat d'un processus logique élaboré. Le relevé d'un bâtiment est donc une problématique singulière comparée à la constitution plus contingente des étendues rurales. La modélisation d'un bâtiment peut ainsi être enrichie au-delà de la connaissance dimensionnelle par les connaissances architecturales qui ont permis de le faire sortir de terre. Le modèle virtuel d'un élément d'architecture prend de l'intérêt lorsqu'il devient visualisable. Or la visualisation 3D est une traduction des informations fournies par le modèle. Le résultat est obtenu dans un but de communication et non comme vecteur de connaissances. Les données qui ont servies à sa fabrication ont été transformées pour satisfaire l'illusion. La géométrie et les textures sont ajustées entre elles. La mission de visualisation de la Promenade du Peyrou est une occasion pour nous d'appliquer nos principes d'analyse au relevé par acquisition à distance.

1. INTRODUCTION

The emergence of computerized data processing enables the implementation of increasingly powerful processes of documentation. Cultural heritage organizations have increasing expectations towards this technology. Initially limited to projections, such as plans, sections and elevations, the representation of the architectural survey can henceforth be made in three dimensions and can also be textured. These new ways of representing are related to data structuring offered by the modeling techniques. All these stages of information abstraction have to be inserted between data acquisition and the final building representation. The architectural modeling process becomes more and more complex and is not only being limited to data acquisition. Based on a visualization task of an urban environment, this paper tries to analyze the means involved in such an endeavor and to synthesize them with the

aim of highlighting the importance of these intermediate stages comprised between field acquisition and final visualization.

2. ARCHITECTURAL WORK MODELING

2.1 Building Survey

The purpose of this article is to present an architect's perspective on the recent technologies that he has at disposal to carry out the survey of architectural constructions. What could be innovative in this subject? Jean-Paul Saint-Aubin has already brought the potentialities of photogrammetry to light, for example in using the stereorestitution to make architectural surveys. The problematic of our research precedes the direct application of such techniques. We consider 3D acquisition as a data source to be integrated in a global architectural survey process. Data coming from recent techniques of acquisition are parts of a scope in which the information related to a building is

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not only dimensional. The history of art, for example constructive theory, also contributes to the understanding of an architectural work. The knowledge based model arising from these data is more complex to carry out than a simple data gathering. I will thus focus on the remote sensing techniques (photogrammetry, lasergrammetry and structured light), which we consider here like information sources rather than the centre of the survey process. Starting from an external point of view to the acquisition scope, we intend to draw a link between data providers and users.

2.2 The Architectural Work as a Result of a Cognitive Process



Figure 1. From existing to virtual building

The architectural survey is part of a problematic concerning the acquisition of objects upon which human has acted. A logical reasoning has already been used to obtain the object. A façade must be considered differently from a meadow or a field, because its topography is not systematically contingent (contrary to the other). The completed construction is the result of numerous steps, which requires certain logic. For instance, the architect may have applied rules of contents proportion, rules for the layout of characteristics elements, principles of initial constraints resolution or he can have used some construction systems. As a matter of fact, the description of an architectural work differs from one observer to another, depending on personal cultural background and drawing techniques, an observer will not describe an architectural work the same way as an other would. What arouses our interest here is the use of architectural knowledge to break down a building or, in other words, using a kind of reverse design process. This architectural knowledge can be tackled many ways: with architectural constructions associated with the building style (Pérouse de Monclot, 1993; Palladio, 1980; Vitruvius, 1979) or by acquired knowledge or the architect’s own experience. We will thus begin with an existing building and try to break it down according to constructive principles or in sub-elements logically divided.

2.3 Architectural Knowledge as Contribution to Modeling

The modeling of existing buildings is justified by their abstraction need with regard to the reality. Such models are also of interest for documenting the cultural heritage. Formerly building surveys were entirely carried out with tools that needed a direct contact with the building such as a tape, a compass or a protractor. Meydenbauer has worked in such a manner before he initiated the use of photography to measure out buildings. His constant attempt to make this field progress shows us how difficult the use of these tools was (Albertz, 2001). Later, photogrammetry enabled measurements without a direct contact with the building as well as laser scanning would do and soon to come the projection of structured light. These three techniques permit an entire and rapid acquisition of measurements of a given building. To build a model of a building, the dimensional aspect is essential. But one should note that the prevalence of measurement on modeling inflicts a heavy postprocessing. We would like to reduce the heaviness of this process by bringing the use of architectural knowledge, sooner in the process that is the measurement period. A given point is not only a 3D point (X, Y and Z), but also and utmost a corner of a window, the edge of a pilaster, etc. Such a point is thus easy to define in relation to others. For example it is a group of connected points that will define a constitutive object of a façade. The measured point is not a logical unit of architectural analysis; it is the relation between the model and the dimensional reality of the object. Three various elements can be distinguished: the existing object to be measured, the measured point and the delimiting point of the corresponding geometric model. These three elements are different, but they are bound together by the element they are representing. It is necessary to establish a logical relation among them. In the beginning of the modeling the representation scale would

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normally be defined. The points that make the geometrical model result from this scale definition. These points are definition points of the geometrical model; they make its qualification possible. The points measured on the existing building are positioning points. It is necessary that they correspond to the points that belong to the representation. The survey generally takes place before modeling. Measured points thus precede the model's points. If the building's breakdown were made before measurement, it would be then possible to bind these points in a logical way. The qualification of the model should be made independently of the measurements. Therefore, the geometrical model must be built before the processing of dimensional data. The dimensional relation can thus be made between the existing building and the model which represents it.

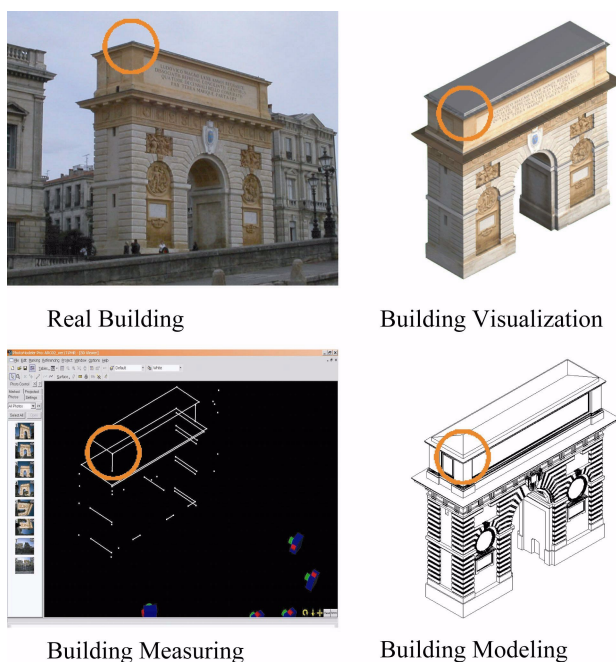


Figure 2. Various Point Definition

2.4 Model as a Synthesis of Measurements and Constructive Knowledge

The 3D model of a building is built according to the dimensions of the original. It enables, like the cardboard model would, the representation of a built work in an accurate and realistic way. The production of such models is based on measures which are taken on the original, in a traditional way or without direct contact using the henceforth current techniques. Even if the number of points measured on an object can be as high as several thousands points per second (laser scanning), they must all be screened and sorted out before we can obtain a three-dimensional model. Even if the dimensional data are numerous and very precise, we always miss a part of this, primarily due to the mask phenomena. These masks are hiding part of the object to be surveyed and create a "hole" in the collected data set. The data or information missing can always be recovered by other means. The architectural analysis of a façade enables its

reformulation according to the logic which was used to design it. It is necessary to bring up to date the logical reasoning that was used to generate the construction and re-use it for modeling. It is instrumental to find, or at least try, the know-how which the building conceals. This search for constructive logic can lie in the breakdown of the object in symmetries, repetitions, and homotheties for example. There would thus be the initial model object and the instance objects all of which are copies, modified or not, of the original object. Masked information can then be recovered by analogy.

3. VISUALIZATION OF 3D MODELS

3.1 Difference Between a Model and a 3D Representation of Architectural Work

We emphasize on the difference between a model and its representation. A model can enable figuration and the combination of complex phenomena. The representation of a model is a means to show it. Representation is the result of a determined act based on beforehand structured information (in this case, a model). 3D visualization is based on the virtual model of a building and represents it in a realistic way. A model is a way to abstract the object from reality and allows the handling of the characteristics that interest us. This is a theoretical construction. In architecture, the 3D model is used very often (virtual building); it takes over the scale model (cardboard). The 3D model enables the handling of the virtual building (modifications, tests, simulations). It is difficult to differentiate a 3D model from its representation, because they are both generally displayable. The 3D model is a work tool that formalizes known existing knowledge concerning a given building. The concept of a model is closely related to the concept of complexity. In a model, different concepts can cohabit in a coherent unit: the historical evolution of a building (functional modeling), its geometrical definition, and its structure for example. Visualization is a process of representation of the building model. The process of visualization uses some attributes proper to the model in order to be seen by a spectator. The representation is an initial selection of information considered as very typical to the phenomenon. It is necessary to illustrate this selection by a projection (plane or perspective) or by 3D visualization. The 3D visualization of the outside of a building is the realistic presentation to a spectator of the external aspect of the building.

3.2 Various Sources of Models Involved in 3D Visualization

3D visualization is built from several types of sources. On the one hand there is the building shape which is necessary to restore either with a geometrical 3D model or with principles of building breakdown. On the other hand there are the details (materials, ornaments) which are necessary to be shown with textures extracted from photographs of the object (either photo coordinates delimiting texture or an ortho photograph). The proportion of use between textures and geometrical constructs varies according to the object which will be represented. It would be difficult to represent an object which presents numerous details with simple volumetry. Texture would not counteract the loopholes of geometry. Nevertheless simple geometry can be easily enriched by a good mapping resolution.

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3D visualization is thus a compromise between the complexity of the geometry and the texture resolutions. We will go into further details during the analysis of our example.

3.3 Visualization as Data Translation

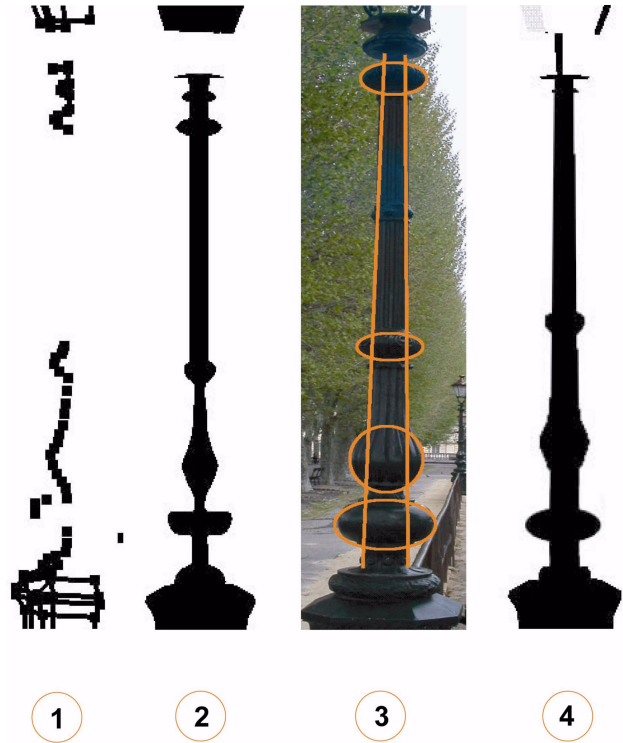
Visualization is an interpretation of a model. Restricted and selected information is thus shown to the spectator. A translation of the information provided by the model is then carried out. During the stage of translation, a simplification of the geometrical model occurs. This simplification is imposed by the representation's need. The importance of the "translation" for visualization is proportional to the model's complexity. The combination of these two elements is neither faithful to geometry, nor to the texture (even based on ortho photography). Relating to our job of visualization we must create the illusion of reality during the navigation. It is this illusion's constraint that leads to the distortion of the buildings information. If visualization is built from unmodified geometry and textures, the observer quickly realizes it is a digital visualization. This can be caused by highly defined limits and by shifted connections of textures for instance. In the visualization process, realism is the most important constraint. Consequently, it is necessary to adapt the representation to desired realism. It is thus essential to modify the sources to satisfy this constraint. The virtual building represented by 3D visualization corresponds to a loss of information compared to the original information. Visualization can therefore not be regarded as a source of documentation but as a means to communicate.

4. PHOTOGRAMMETRY AND ARCHITECTURAL KNOWLEDGE

4.1 Photo-interpretation as Support to Analysis

During a traditional survey, the measured sketches are made while the surveying, i.e. an understanding of the architecture takes place on site. The schematization of the work here corresponds to the phase of analysis; the building provides the answers the designer is asking himself while he draws. The quality of the building interpretation is easily comparable to the slowness of acquisition. Remote sensing survey is more efficient considering the speed of acquisition and the mobility of material; but measurement prevails over the analysis because the complexity of acquisition still concerns specialists. The photo interpretation carried out from stereo pairs taken during the photogrammetric survey is a means to introduce the architectural analysis into the process rationalized by the 3x3 rules (Waldhaeusl, Ogleby, 1994). The architectural analysis of a building is time-consuming and cannot be carried out on the field (depending evidently on the object to survey). If the photogrammetric survey is already done, the building can be broke down with the images, before they are used as dimensional sources. The stage of analysis is hence established before the stage of photogrammetric survey. The object to be analyzed should be known: a visit on the field is therefore essential. Since the distance between the laboratory (Strasbourg) and the Promenade (Montpellier) is substantial, we had to carry out the acquisition of photogrammetric data at the same time as the field exploration. For this simple reason, the analysis took place after the survey. The pictures were then used

twice, firstly as sources of architectural information and secondly as dimensional data sources.



1: Survey from PhotoModeler, 2: Profile directly deduced from measures, 3: Formal analysis, 4: Combination of analysis and measures

Figure 3. Likelihood increased by combining analysis and measure (example: a candelabrum)

4.2 Geometry or Texture?

The photogrammetric theory offers the possibility to switch reciprocally from multiple two-dimensional data to three-dimensional data (Grussenmeyer, Hanke, Streilein, 2002). It is possible to obtain the 3D coordinates of a given point located on several images as well as to know the image coordinates of a zone delimited by several 3D points. Softwares have been developed to use these mathematical tools. They give the illusion that it is possible to visualize any objects in a realistic fashion. It is true that these tools are robust and effective (PhotoModeler) for image-based measurements, but visualization cannot only be an association of textures and measured 3D points. There is an interpretative stage when managing geometry and textures that requires a modification of the 3D points provided by the photogrammetric process. The points that have been used to define an object in a realistic way are not the same points taking parts in its dimensional definition. They have been interpreted to produce the illusion of reality. Breaking down an architectural work in several distinct elements reduces considerably the number of points to be

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measured by means of photogrammetry. This is the reason why it should be implemented before any measurements are taken.

5. PROMENADE DU PEYROU : A PHOTOGRAMMETRIC SURVEY

The *Promenade du Peyrou* was built in Montpellier (France) at the end of the XVII^e Century in honor of King Louis XIV. The entire place was created to accommodate a monumental statue of the king. Classical architecture lends well itself to the affirmation of authority. Three principal elements are in the same axiality: the Triumphal Arch, in direct relation with the city, the Statue and the Water Tower. The Promenade is emblematic of the city and this is the reason why it was decided to carry out its 3D visualization and make it accessible to the public.

5.1 The Promenade du Peyrou



1: Triumphal arch, 2 King Louis XIV Statue, 3: Water Tower, 4: Aqueduct, 5: Monumental Staircases, 6: High Terrace, 7: Lower Terrace

Figure 4. The *Promenade du Peyrou* (in the town of Montpellier)

5.1.1 The Walkway in the City: The *Promenade du Peyrou* sits in the heights of the town of Montpellier. This urban composition is located in direct prolongation of a major road of the old city centre. It overhangs over the low suburbs to show the Water Tower and the Aqueduct.

5.1.2 Three building trades participated in the development and construction of the famous Promenade: civil construction (Aqueduct and Buttresses), landscape architecture (lay out of the walkway) and architecture (built elements such as the Triumphal Arch and the Water Tower). The multi-leveled walkway is formed by two terraces, a Low Terrace, in overhang of the street which surrounds it, and a High Terrace located on the level of the old city centre. These three different levels (high and low terraces and the street below) are connected by monumental staircases. The three principal elements of this composition are built along a longitudinal axis running across the High Terrace. The Triumphal Arch, veritable entry gate to the site, opens on the walkway and leads to the monumental Statue of King Louis XIV located in its dead-centre. Absolute focal point of the ensemble, the entire Promenade was built around it. Sitting on the High Terrace, the Water Tower adds a finishing touch to the composition and establishes a direct link with the lower areas. The whole composition is highly homogeneous in design, in style (classical) or in materials. The visualization of the Promenade must therefore render all these elements in a convincing and plausible manner.

5.2 P.A.G.E. and C.R.A.I. Laboratories

Two laboratories participated in this survey task, the PAGE (Photogrammétrie architecturale et GEomatique) and the CRAI (Centre de Recherche en Architecture et Ingénierie) respectively located in Strasbourg and in Nancy. Thanks to this association, laser scanning and photogrammetry could be combined in a single mission. The PAGE is specialized in photogrammetry (stereo and multi-image) while the CRAI is specialized in laser scanning (MENSIS: SOISIC).

6. TECHNIQUES AND METHODS

6.1 3D Acquisition

Topographical Geo-referencing: The *Promenade du Peyrou* is a landscaped whole of substantial size (300 x 150 meters). To control relative positioning between the various objects, it appeared essential to us that the setting were in accordance to the terrestrial references. The creation of a particular reference system is not pertinent whereas the use of geo-referencing is easier. Each significant object was thus located in space using a sufficient number of points (proportional to the dimensions of every object).

6.1.1 Photogrammetry: For this project we had at our disposal aerial stereo pairs. They were used to position objects that required less precision (vegetation, benches, street lights, etc.) in opposition to objects that were situated with control points. Close-range photogrammetry (multi-image) was used for several reasons: for its high resolution (to realize an accurate survey, proximity with the object is instrumental), for its

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measurement effectiveness (less photographs are taken to limit the files in the project). Multi-image photogrammetry permits the combination of more than two images in the same project without having to add additional control points. Surveyed architecture being not characterized by a plane, multi-image photogrammetry allows shots from varied points of view, thus revealing surfaces that might have been hidden if only a single shot had been taken. Stereoscopic restitution is a hard-acquired discipline whereas the multi-image approach requires but any formation. From both theoretical and practical points of view, making use of the multi-image technique to acquire pictures is far less constraining than with its stereoscopic counterpart. Furthermore, multi-image photogrammetry is better-suited to fieldwork. On the other hand stereo restitution is more powerful in terms of accuracy when surveying the elevation of a building (both picture planes are parallel to the acquisition plane). Yet, multi-image technology demands angles between the shots as close to right angle. We propose this 3D approach be used directly for geometrical modeling of any measured object.

6.1.2 Laser Scanner: Laser survey technology was experimented for the Water Tower, a building adorned with rich and elaborate ornamentation. The building itself suggested the use of the laser scanner in favor of photogrammetry: hexagonal in plan, only a sixth of it needed to be scanned. In addition, the complicated geometry of its ornamentation would have been quite difficult to capture with photogrammetry, whereas it was easily captured with the laser scanner. Scanning multiple points at once (a cloud to be more precise), this technology can virtually scan any shape. The openwork crowning of the Water Tower would have required a very complex photo coverage if multi-image photogrammetry had been used.

6.2 Modeling

Two software programs were at our disposal to model all three objects of the Promenade: AutoCAD and Maya, the latter allowing VRML export. Common sense would command the use of only one software program, unfortunately both had exclusive advantages. Indeed, AutoCAD, a proven and established virtual drawing table, encourages drawing, an act cherished by so many architects. Furthermore, the software handles 2D and 3D representation in the same continuation as would be architectural knowledge to drawing. On the other hand, Maya offers powerful texture management tools. A link between the two programs, via the DXF format, enables their simultaneous use.

6.3 Visualization

Visualization work is one of figuration. It distinguishes itself from representation by its need for realism. Indeed, the user has to believe what he visualizes. This quest for realism takes precedence over the fidelity of restitution. An object can be rendered in a realistic manner whereas its dimensions are not accurately represented. Without going too far, we can say that the visualization process imposes on us a compromise between the realistic aspect and fidelity in measurement.

7. ANALYSIS AND BREAK DOWN OF AN ARCHITECTURAL WORK

7.1 Architectural Works

- The Triumphal Arch
The Triumphal Arch, an ornamental work with great symbolic meaning, constitutes an important landmark of the *Promenade du Peyrou*. Celebrating King Louis XIV, it is the city gate. The monument has two axes of symmetry and is divided horizontally into three unequal parts: the basement, the principal storey and the attic. Because the building only has a little depth, its geometry reveals itself quite simple. This weak geometric definition can be compensated by a rich texture (Triumphal Arch: figure 1 and 2).
- The Water Tower

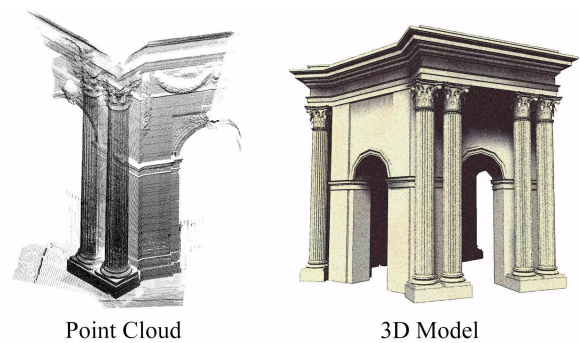


Figure 5. The Water Tower

The Water Tower is also a building made up of symmetries. Hexagonal in plan, it can be segmented into six equal parts. The breakdown of an object may permit a reduction in complication but certainly not in complexity. The module of the Water Tower (a segment of the hexagon) holds many details. Complexity must necessarily be rendered with a high definition level of geometry contrary to the texture which is, in this case, of lesser importance. The ashlar stones are in very bad condition making

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it difficult to rely exclusively on photographs to texturize them. Instead, we must rely upon procedural algorithms of stone texture to compensate this lacuna.

➤ The Aqueduct

The Aqueduct is a linear repetition system of identical elements. The geometrical definition of the arches is particularly important: their openings must reveal the surrounding environment. Both the Aqueduct and the Triumphal Arch are comparable regarding their complexity. Geometrical primitives participate into the shape definition of the Aqueduct whereas texture defines the dressed stone. It should also be noted that all textures are taken from photographs of the object. It makes it thus possible to obtain pertinent information pertaining to the stones' condition. This situation is however double-edged: while the realism might be improved by the stone patina, some ashlar stones are so damaged that their pictures can not be used.

➤ The Water Tank

The Water Tank, on which sits the Water Tower, is one of the grandest elements of the walkway. Cylindrical in form, its wall of dressed stones is articulated with buttresses. The Water tank, along with the Tower, are the only elements of the composition to bear radial symmetry. The modeling of the Tank showed that the logical approach of breaking down an architectural work can not be applied to every object. Indeed, at the beginning, we thought to use symmetry to simplify the modeling, in particular for the monumental staircases which lead to the cylindrical promontory. Because the staircases did not unfold according to a strict and precise logic, their modeling occurred one step at the time. The only short-cut allowed in the modeling process was the mirror copy of the Tank, a consequent but conventional economy.

➤ The Buttresses

The modeling of the buttresses brings in another process. Since the buttresses have a rectilinear form, their vertical profile can be deducted from their plan by a simple extrusion. The ornaments adorning the buttresses will be locally added by network copy. The modeling of the buttresses can be compared to the modeling of a cornice as described by: Reda Begriche (2003). Texture is in this case of great importance because it is called to break the monotony of such a repetitive ensemble.



Figure 5. Water Tower (VRML and Picture)

➤ Monumental Staircases

The monumental staircases occupy a significant place in this architectural setting. They unfold in pair perpendicular to the main longitudinal axis. The multiplication of pathways thus created between the multi-leveled terraces generates architectural elements that ought to be treated like buildings, each having its own façade. They are actually modeled after a traditional classical façade, that is, the stack up of a basement, a principal storey (usually adorned with orders) and a *couronnement*. In this particular case, only the basement was necessary.

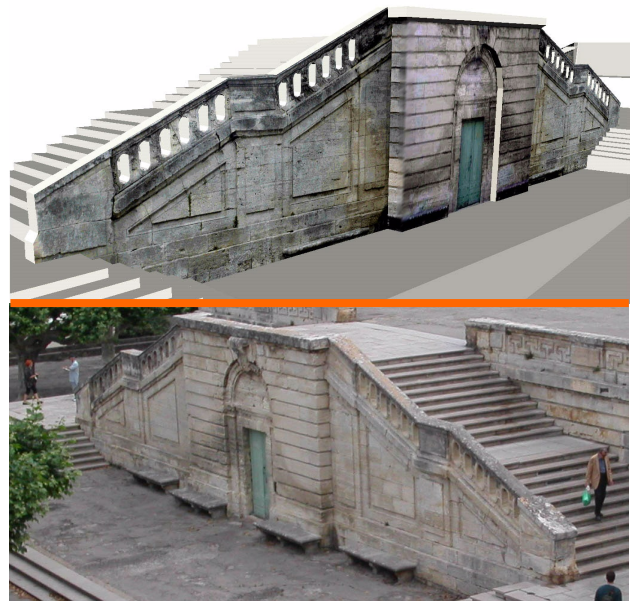


Figure 6. Visualization and picture of the Monumental Staircases

7.2 Landscaped Installations

Having treated the architectural aspects of this work, we will now focus on the landscaped environment. Landscape elements do not culturally have the same patrimonial significance buildings have. Nevertheless, in this particular instance, the surroundings of architecture are highly important. They are instrumental in contextualizing every architectural element. Evidently, the problems encountered for the modeling of landscape are quite different than those for architecture. It may be easy to break down a monument or a *Jardin à la française* by making use of symmetry and repetition, but how does one break down statuary objects or vegetation with the same principles? Furthermore, the modeling of such objects in a realistic way leads to enormous files. An orthogonal object is always easier to model than an organic one. Optimization of the modeling process is hence highly important. Even the notion of texture differs when modeling organic objects. When dealing with organic geometry, textures will be modified (i.e. in scale) to better represent the zone concerned. For example, the texture of an entire tree trunk will come from only a small area of the trunk to represent. In this visualization of the Promenade,

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ephemeral elements (in opposition to permanent buildings) are treated for sake of realism, not for restitution.

➤ Flower Beds of the High Terrace

The relief of the flower beds is quite weak compared with their dimensions. A great majority of the elements to model are thus simplified as much as possible. Mapped textures will assure they are rendered with realism. The geometry of flower clumps can evidently not be modeled considering each and every part of the plants that constitute them. The representation of the railing surrounding every bed is easily realized. The constraint of simplification applies very well to flat objects and mapping them with rectified and repeated textures brings a great deal of realism. A transparent mask in GIF picture format completes the illusion. The only problem here is the tree. Without its presence, the visualization loses its realism. If one tries to render it with great detail and realism, the great size of its file would slow the visualization to an unacceptable degree. The problems of tree modeling will be tackled later on.

➤ Flower Beds Bordering the Ponds of the Low Terrace

The flower beds of the Low Terrace differ from the preceding firstly because they have different flower species, secondly

because of their different proportions and thirdly because they adjoin a pond. Modeling the ponds can be quite challenging because they both have a fountain in them. The presence of animated objects adds complexity to the visualization. A motionless reconstitution of the fountain would clash with the realism of its surrounding environment. VRML animation, having reached its limits, produced poor results. So far, the question remains open.

➤ The Pond in Front of the Water Tower

Of a large surface, this pond takes great part in emphasizing the Water Tower. Contrary to the fountain so difficult to render, the water expanse of this pond poses no problem. It is worth noticing that the presence of water in front of the Water Tower certainly has but a symbolic meaning.

➤ Various Floor Coverings

The floor coverings are varied and badly damaged. Their rendering in the visualization does not show their actual condition. Modeling the deteriorations would introduce a lot of unnecessary work so we have opted for an idealization of the floor coverings.

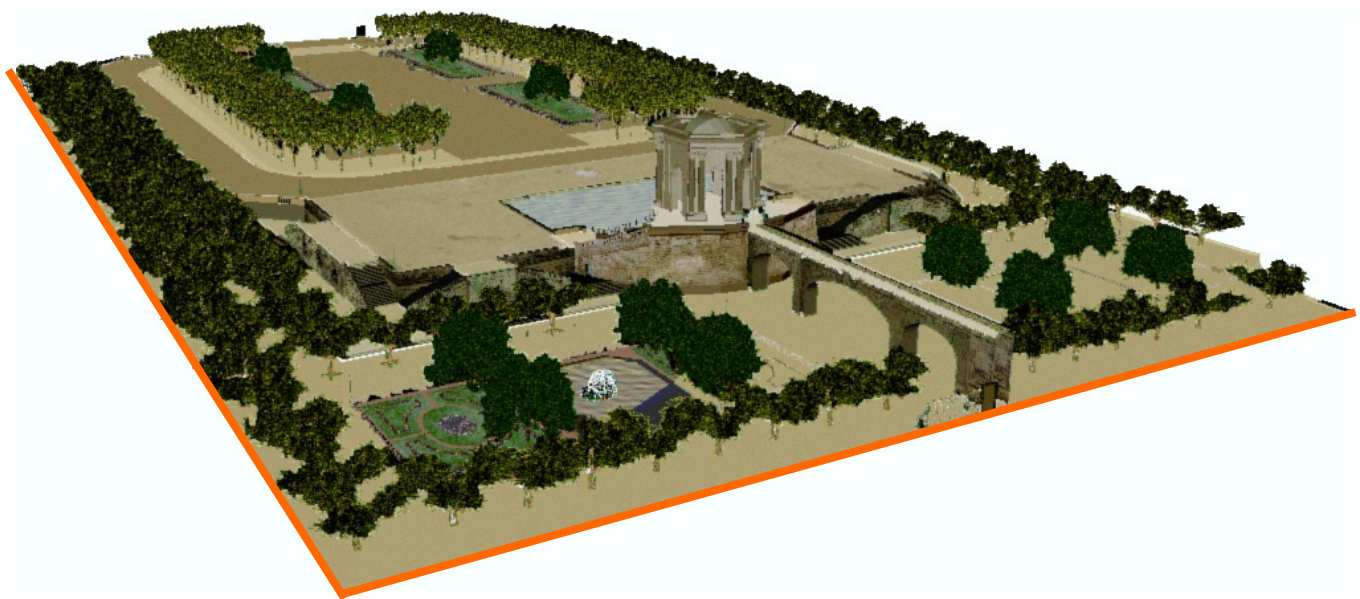


Figure 7. Whole visualization of the *Promenade du Peyrou* (VRML)

7.3 Statuary Objects

The statues and ornaments are essential elements of the walkway. Every carved element is unique and particular. Each of them brings a sense of aesthetic to the Promenade, a grand urban place.

➤ Medallions and Capitals of the Water Tower

The laser scanner is the ideal tool to survey carved elements. The Water Tower has been scanned on one sixth of its facade and its ornaments were captured at the same time. Several types of carved elements can be distinguished: capitals, masks and

many more ornaments. Like we had done for architecture, we tried to break down the capitals into intelligible elements. Capitals follow more or less theories based on the concepts of order stated since Greek Antiquity. Even though capitals are somewhat systematized, each work depends on its designer and sculptor. We had difficulty to break them down (Fuchs, 2004). Nevertheless, this theoretical approach permitted a geometrical rebuilding to the scale of our representation. Capitals sit atop columns; they have a geometrical importance that is dependent on the model's homogeneity. However, this is not the case of the medallions and other ornaments that stick out the wall

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plane. Textures are therefore more efficient than complex geometry to depict them.

➤ King Louis XIV Statue

The equestrian statue is located in the dead-centre of the High Terrace. Built on a tall ashlar pedestal, the bronze sculpture dominates majestically its surroundings. The pedestal can be compared to a simple architectural element and it can easily be modeled geometrically. On the other hand, the statue of the king is a singular element and its rendering poses great difficulties. The use of the laser scanner was impossible. Its material, bronze, revealed itself too reflective. Moreover, a complete data-capture would have required angles from raised points of view. Multiple stereo-pairs were instead carried out. We began testing the automatic generation of point clouds without concluding results for the time being. So far, we have created an object in the MAYA modeler with all the realism we could bring in. The model was then fitted with control points measured from stereoscopic pairs. It is important to note that for our visualization task, realism prevails over dimensional accuracy.

➤ Medallions of the Staircase Façades

The façades of the staircases have been almost exclusively represented by their texture, the medallions not being prone to complementary modeling. They appear as sequential texture on the geometry of the cornice.

➤ The Buttress Shields

The buttresses, like the façades, are treated as flat walls on which particular elements are added, in this particular case, the shields and mouldings. It is worth noticing the flimsy difference between façade medallions and buttress shields: medallions are geometrically complex to represent because they are located on the mural part of the façade and cornice (in addition to their intrinsic complexity), while the shields are complicated elements easily rendered geometrically. The purpose of their representation in the visualization is symbolic.

7.4 Street Furniture

Although of functional purpose, street furniture participates in the aesthetic of the *Promenade du Peyrou*. Its modeling poses no problem, which is why we paid them only a little attention. By modeling them before the entire visualization was completed, we were then able to refine our principles pertaining to the analysis, to the simplification, to the break down and to the representation of any given object (figure 3). These principles have been repeated in a rather consequent fashion over the whole walkway space. Repetition must be varied according to the object to model. For instance, a candelabrum of a particular style may be represented in different versions. Variation constraints may be functional (performance of lighting) or aesthetic, repetition leading rapidly to lassitude.

➤ The Benches

Benches are essential elements that characterize a public walkway. There are two types of benches in the Promenade du Peyrou: benches under the trees have cast-iron footing and wood seating whereas those near the architectural elements are

made out of stone. Their modeling does not pose any specific problem.

➤ Candelabrams

The candelabrams are cast-iron. Their constitution is rather slender. Their main characteristic is that they are outlined against the landscape especially when the spectator is moving in the scene. Their profile must then be finely rendered to participate to the illusion. A multi-image survey of a profile was carried out (PhotoModeler) with a precision approximately three centimeters. The surveyed profile presented aberrations that could not be tolerated and needed to be corrected. We then confronted the object with constructive knowledge and aesthetic of traditional cast-iron objects. Knowledge of the material guided us towards progressive changes in its section, whereas references to flora guided us in the geometrical approximation of its pole: a cone-shaped object intersected of spheres of various sizes. From a simple profile at the beginning, we ended up with a faithful and rationalized object.

➤ Trash Cans

Cone-shaped objects with a wide opening, small sized, the trash cans are not a problem to model.



Figure 8. Street furniture (candelabrum, railings, bench, trash can)

➤ Railings Surrounding the Walkway

The wrought iron railings pose almost no problem regarding their modeling (cf. Flower Bed Railings). The extremities of the railings are elaborate and finely-worked. To model them scrupulously one must absolutely break down the geometry of this 3D lace-work tracery. From the observation that they are all

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square in section, we began the construction of their geometry. Points identical in shape are then laid over the square profile. These traceries need only be defined by their geometry, the surface of its material being uniform.

7.5 Vegetation

Modeling elements with complex and singular geometry induces difficulties in the process of visualization. Indeed, the modeling of flora is a singular problematic of 3D visualization. A great contrast emerges between the accurate representation of flora and the complexity it involves. A tree can obviously be broken down into several parts easily identifiable: roots, trunk, branches, bronchioles, leaves, etc. but the contingency of their form makes them unique.

➤ **Trees Bordering the Paths of the High and Low Terraces**
The trees bordering the High and Low Terraces are plane trees. With their multicolored bark they are easily recognizable. When modeling them, we will emphasize their tortuous and multicolored trunks with specific textures.

➤ **Ornamental Trees of Flower Beds**
The trees in the flower beds are magnolias, bunches of dense foliage. Accordingly, we will represent them as large green masses.



Figure 9. VRML View from the Aqueduct

8. CONCLUSION

In this paper we insisted on the particular nature of building surveys: the knowledge that permitted the construction of a building is readily available for its modeling. Virtual buildings can thus be built on the basis of two principal sources of information: architectural knowledge and dimensional data. The synthesis of these two sources of information enables the production of a three-dimensional model from which various representations can be extracted. Architectural knowledge and dimensional data are not to be understood as fully distinct, but rather as part of a sometimes redundant and contradictory

whole. One must therefore favor one over the other (dimensional vs architectural definition). Dimensional information is captured from an existing building and has a pragmatic aspect that gives it great credibility. Moreover, its very high degree of accuracy increases its reliability. However reliable are those techniques, one can not yet have a complete overview of the surveyed object. Furthermore, they produce an enormous quantity of data to be stored and treated with great difficulty. The construction of a model on the basis of architectural knowledge is based on assumptions of composition, juxtaposition or superposition. The synthesis of this information permits the creation of a complete and coherent model. The model is thus very realistic, but it does not refer to its actual dimensions. When modeling, dimensional data communication is not enough if deprived of realism: the former must be favored over of the latter. Nevertheless, these two modelling processes are interdependent: theory and practice are combined to provide the most coherent and realistic model but their association requires a compromise. The visualization of the *Promenade du Peyrou* clearly exemplifies this compromise.

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ACKNOWLEDGEMENTS

This article is based on the visualization work of the *Promenade du Peyrou* in Montpellier, commissioned to the PAGE by Franck Perdrizet of the Montpellier Geographical Information Service. Pierre Grussenmeyer, Jean Pierre Perrin, Samuel Guillemain, Vincent Marchal, Emmanuel Alby, Alain Fuchs and Nicolas Pointeau took part in the fieldwork. The Water Tower was laser scanned and modeled by Alain Fuchs. Some illustrations are after Pior Oberson's and Thomas Clouet's works. We would like to thank Dominic Boulerice for his great contribution to this paper.