

REPRESENTATION OF ARCHITECTURAL ARTIFACTS: DEFINITION OF AN APPROACH COMBINING THE COMPLEXITY OF THE 3D DIGITAL INSTANCE WITH THE INTELLIGIBILITY OF THE THEORETICAL MODEL.

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Abstract

With the arrival of digital technologies in the field of architectural documentation, many tools and methods for data acquisition have been considerably developed. However, these developments are primarily used for recording colorimetric and dimensional properties of the objects processed. The actors, of the disciplines concerned by 3D digitization of architectural heritage, are facing with a large number of data, leaving the survey far from its cognitive dimension. In this context, it seems necessary to provide innovative solutions in order to increase the informational value of the representations produced by strengthen relations between "multiplicity" of data and "intelligibility" of the theoretical model. With the purpose of answering to the lack of methodology we perceived, this article therefore offers an approach to the creation of representation systems that articulate the digital instance with the geometric/semantic model.

Keywords

Architecture, heritage, representation, 3D digitization, measurement, digital tools, technologies, techniques, epistemology, knowledge, information, computer.

1. Introduction

During the past three decades, the fields around heritage documentation took advantage of digital and survey techniques development. One can consider that this development has been done in favor of acquisition and processing work (in order to reconstruct and document complex architectural objects).

If the (constantly growing) mass of datas has effectively enabled to approach the reconstruction of complex geometries, this overgrowth (of data) doesn't seem to increase the level of intelligibility of the representations produced.

In order to anticipate a foreseen methodological deficit, this article attempts to provide some reflections for the creation of representation systems that are able to enrich the informational value of the documents produced. The study presented here is a revised English version, augmented by figures (1 to 4) of an article presented at SCAN12 and published in "*Complexité(s) Des Modèles De L'architecture Numérique*" (Lo Buglio & De Luca, 2012).

If we can not speak of a science of representation, we can nevertheless consider that tools and

methods of that field have benefited from the interactions between many scientific disciplines. In this context, it is not surprising that the study of architectural representation systems provides a favored of experimentation for design, survey, geometrical analysis and documentation of the state of conservation of buildings.

Behind the technical advances of these fields, many difficulties are arising with the creation, the sharing and the dissemination of digital models (models whose data continues to grow). This leaves open a field of epistemological questions on the practices of the architectural representation.

But more specifically, these questions must help to position the research beyond the simple purpose of development of tools and techniques, so it provides to the field of heritage documentation methodological reflections on the scientific issues surrounding the representation of artifacts.

The study of means must also pay attention to the specific cognitive issues belonging to the architectural representation in order to take into account the link between perception and the semiotic foundations of communication. This concern assumes that the representation of an architectural object can't escape from our vision and for the knowledges we mobilize for its understanding.

This paper attempts to provide reflection avenues for innovative development of representation systems (and information technologies) that can constitute new tools for investigation and scientific visualization, assuming the dimensions of "complexity" and "intelligibility" within the same graphical space.

1.1 Toward an information system between specific knowledge and generic knowledge

Three-dimensional representation of the built environment is becoming an effective support for documenting architectural artifacts, study of built deteriorations, cultural diffusion and promotion of heritage. In this context, new technologies involved in 3D digitization give new means for observing built environment with more accuracy, more completeness and less time. However, the application of these new technologies produces a problem of "data" overload. The growing mass of points clouds, 3D models, un-interpreted data, requires innovative methodologies for knowledge processing, sorting and finally analysis.

After a brief assessment of the results obtained within the context of a critical study of the relationship between the 3D digitization of the built heritage and the informational contribution of digital models, we presented in a paper, some avenues of research in the fields

of heritage representation (Lo Buglio & De Luca, 2011). More generally, these tracks questioned the ability of representations to be transformed into tools of analysis, scientific evaluation and transmission of knowledge (Palladio, 1965). This transmission through the figure must be able to associate, the specific knowledge available on the artifact with generic knowledge drawn from the theory of architecture (Blaise & Dudek, 2006a).

2. Analysis of the informational value of architectural representations

In order to meet the supposed lack of intelligibility deficit, we suggested in the study published in the symposium VAST2011 a first approach to objectify the informational content of 3D digitization of architectural artifacts (Lo Buglio & De Luca, 2011). The first results of this critical analysis have enabled a better understanding of how certain modeling methods or digitization techniques contribute to improve the level of architectural knowledge transmitted by the representations produced. Because it's difficult to imagine that the single use of technology can replace the cognitive contribution of a human operator, the study also suggested to evaluate the contribution of the operator in the semantic enrichment of the digital model. Before discussing the findings of this study and list the new lines of research proposed, it's necessary to clarify some key aspects.

The lasergrammetry (3-D imaging based on laser scanning) and photogrammetry, as techniques for recording the dimensional and colorimetric aspects of a building are now used to reconstruct the visual appearance of complex architectural morphologies. With these advances, we might think that the representation of territory at a 1:1 scale suggested by Borges is not so far (Borges, 1982: p. 221) and the technologies used in the survey campaigns seems to be the primary source of the enrichment of the architectural representation. However, these tools respond first to the requirements of accuracy and completeness and are far from the cognitive issues of the architectural representation (Mediati, 2008). These issues (surrounding the architectural representation) are based on a paradigm that exists since the Italian Renaissance and that considers the representation (in a survey process) as a space which overlays, via the figure, the specific and generic knowledge about the artifact.

To conduct this review on methodological aspects, the observations focused on a series of digitization works. The objective was to evaluate the set of information that describes the architectural object in order to measure the information gain provided by the document,

regarding the employed requirements and means. The observation was conducted from automated reconstruction processes up to manual restitution works.

The mobilized criteria for the analysis were defined on the basis of an empirical observation of digitization works as well as on the concept of "informational modeling" developed by Blaise and Dudek (Blaise & Dudek, 2006b). Starting from this concept, they set forth certain methodological approaches to increase the intelligibility of the informational content of the 3D model. But beyond the facilities offered by this guide of "good practices" and by the logic of symmetry, these rules offer a legitimate theoretical basis to locate some informational properties of a representation.

Without going into detail, these observations have demonstrated a wider cognitive commitment of the operator as he approaches a manual restitution process. This relatively clear causality effect also indicates the existence of a double epistemological problem.

- 1. The distancing of the operator in an automated reconstruction process (photogrammetric or lasergrammetric reconstruction by polygonal meshing) leads to a gain of objectivity of representation produced. In contrast, the use of technologies enabling high levels of precision, does not seem to be a pledge of a substantial cognitive contribution (Lo Buglio & De Luca, 2011).*
- 2. In parallel, the analytical mechanisms of reading and interpreting present in a "manual" restitution process induce a form of subjectivity. It presents also a great interest to the cognitive enrichment of the model. However, the digitization observed showed us that a representation that doesn't express the relative level of knowledge may hardly be used as a tool for scientific evaluation (Lo Buglio & De Luca, 2011).*

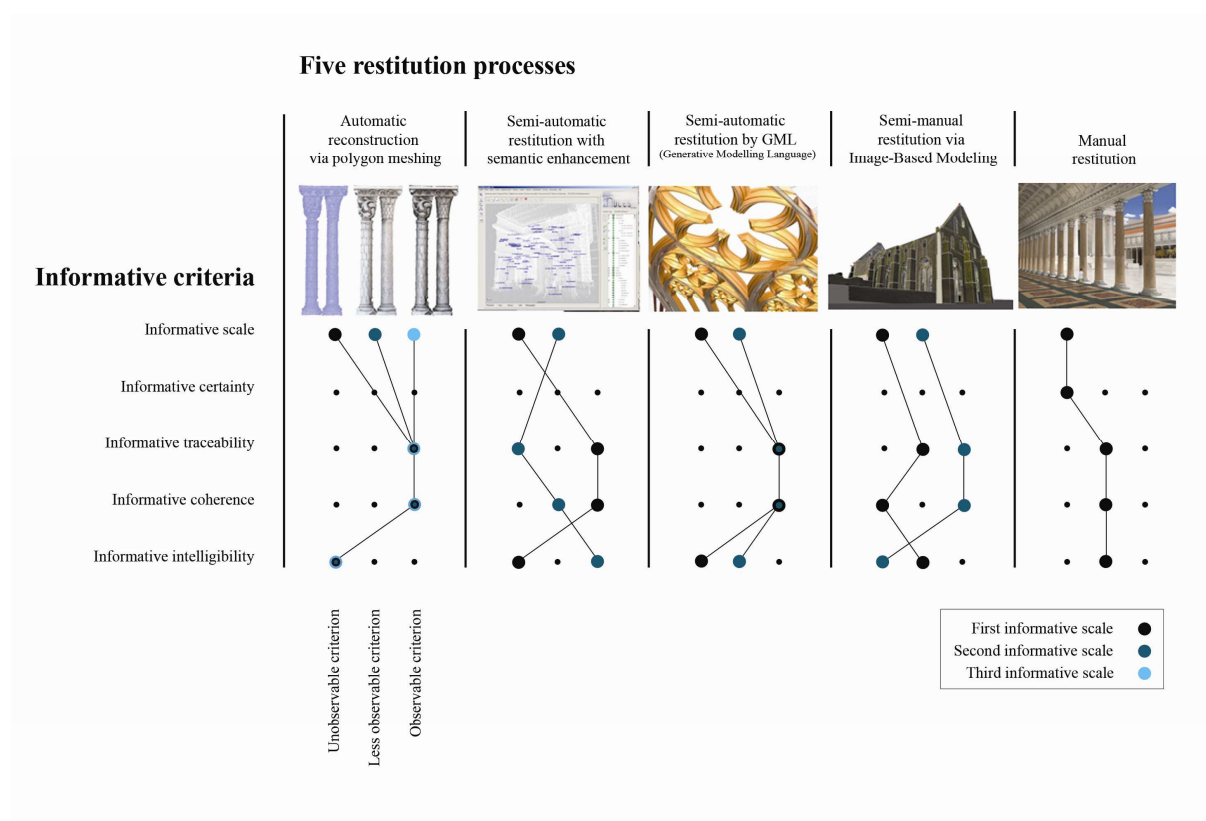


Fig. 1: Analysis of the information content of five restitution processes:

- 1 Automatic reconstruction via polygon meshing (De Luca et al., 2008).
 - Column of the Abbey of Saint-Guilhem-le-désert. Visual levels (geometry, textures, occlusion + textures).
- 2 Semi-automatic restitution with semantic enhancement (UMR 3495 CNRS/MCC MAP GMSAU, 2011).
 - Architectural semantisation of the point cloud of the Arc de Triomphe. See also Nubes project.
- 3 Semi-automatic restitution by GML (Havemann & Fellner, 2004).
 - Shape variation of a Gothic Window Tracery created in GML.
- 4 Semi-manual restitution via Image-Based Modeling.
 - Image-based modeling of the current state of the refectory of Villers-la-Ville Abbey (Belgium). Digitization done by Laboratoire AIIce, Faculté d'Architecture La Cambre Horta, Université Libre de Bruxelles (ULB).
- 5 Manual restitution (Université de Caen Basse-Normandie, 2010).
 - Digital restitution of the forum of Augustus. Restitution project: 'Le Plan de Rome'.

3. Between complexity and intelligibility of 3D digitization

3.1 Multi stereo correlation as method for the survey of architectural artifacts

The image-based modeling (survey, modeling and representation from images) reached a point where cost, accessibility, quality and diversity of results come to meet many needs and constraints identified in the architectural survey (technical and institutional). However, this technique requires a significant mastery of the matching phases, image orientations and

geometric modeling.

Recent advances in image analysis and computer vision permit now to define fully automatic treatments in particular for the extraction of corresponding points, the calibration and the image orientations as well as the generation of very dense points clouds by multi-stereo correlation (Pierrot-Deseilligny et al., 2011). These recent developments allow considering a true upheaval of the architectural survey.

Within scientific communities, the use of photography as a means of gathering information (including those of the conservation and enhancement of the heritage) opens today unprecedented opportunities. These include to be able to capitalize analysis of urban and architectural forms having the ambition to improve their understanding.

However, this work issue requires the mastery of technical aspects but also a consideration of the practices and methodologies of documentation mobilized by the heritage experts. This observation should lead us to identify "protocols", simple to implement, accessible to everyone, and able to meet the needs related to the formal description of objects under study. For automatic 3D digitization, It should be noted that open-source solutions developed within the project «TAPENADE» (Tools and Acquisition Protocols for ENhancing Artifact DocumEntation) are currently being used to generate points of clouds from multi-stereo correlation (Pierrot-Deseilligny et al., 2011).

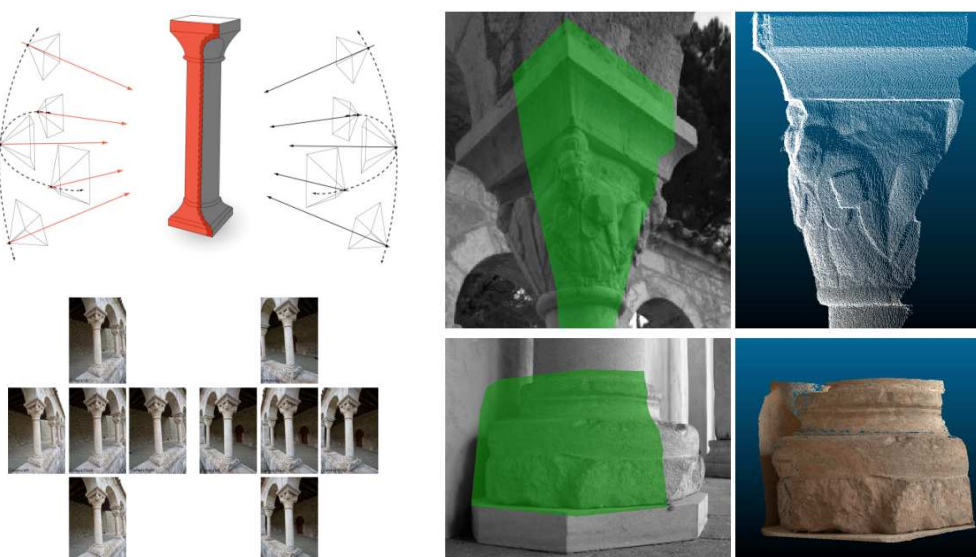


Fig. 2: Generation process of the points cloud of a column from a multi-stereo correlation.



Fig. 3: Results of the points cloud and the polygonal mesh of columns using multi-stereo correlation protocols.

3.2 Semantic processing in post and pre-survey

The introduction of new protocols for acquisition and processing of spatial data has given rise to new research perspectives. The opportunity to consider the collection of masses of data containing records, geometric analyzes and semantic characterizations of the artifacts could also be used for some new approaches to classification and comparison.

It's therefore necessary to evaluate scenarios where semantic description is introduced into a phase of pre-treatment, anticipating the survey itself. The semantization work could also be involved in the post-treatment phase, with tools to help human analysis. They could come from automated functions of geometric analysis steps (such as propagation treatments based on the analysis of similarities).

In the first case (pre-treatment), the idea is to explore ways to insert architectural semantic elements within the survey procedures (to associate them with dimensional information). This would allow an immediate reading of dimensional parameters corresponding to architectural concepts that characterize the artifact. This kind of approach provides also great advantages in the reconstruction phase of the virtual model. A better interpretation of the data prevents the production of unrealistic architectural forms and would provide models linked to specific vocabularies and grammars. Indeed, we believe that the modeling of architectural elements must refer to the formal description of characters defined by the codes of architectural representation (in relation to historical periods and stylistic trends). In this context, significant efforts on formalizing typical architectural elements should be conducted, including the study

and re-interpretation (in the context of digital modeling) of architectural treatises (geometric analysis of typical shapes, compositional rules, constraints of positioning and orientation, the principles of the scale, etc..).

In the second case (post-treatment), it's necessary to investigate the automatic or semi-automatic 3D digitization segmentation but also the issues related to semantic annotation. The digital segmentation of architectural digitization could follow a bottom-up approach, in which the meaning of the elements comes from a "free" morphological analysis or a top-down approach, which takes advantage of pre-structured knowledge of the domain. The bottom-up approach involves estimating "free" morphological properties (such as curvature) of surfaces or volumes and the aggregation points analysis. Concerning the top-down approach, it will be necessary to study the techniques of semi-automatic segmentation in order to identify meaningful parts (a base, a shaft and a capital of a column) corresponding to well-defined concepts (in terms of architectural vocabulary). The study used for the transfer of segmentation and semantic annotation on unique items, even on the entire model, will be studied in a second time.

The study on segmentation and semantic annotation should complement an analysis of the geometric similarity used to compare elements or architectural objects between them. This would create a library of architectural forms and morphological criteria organized around pre-structured knowledge. It's therefore possible to conduct investigation on the variability of the instances in the field of architectural heritage with significant impacts on the stylistic trends analysis (eg mechanisms of self-extension that could provide effective solution for handling unclassified and un-interpretable shapes).

Our study is therefore based on a dual approach:

1. On the one hand, the study of the typical characteristics extracted from the formalization of architectural knowledge associated with an existing semantic characterization conduct "by intention" (integration of pre-defined knowledge);
2. On the other hand, the definition of an analysis strategy "by extension" (identification of a model that can integrate multiple instances) able of bringing out the common morphological characters of elements collections analyzed mainly through geometric criteria. Studies on both aspects should succeed in the identification of semantic/geometric classes.

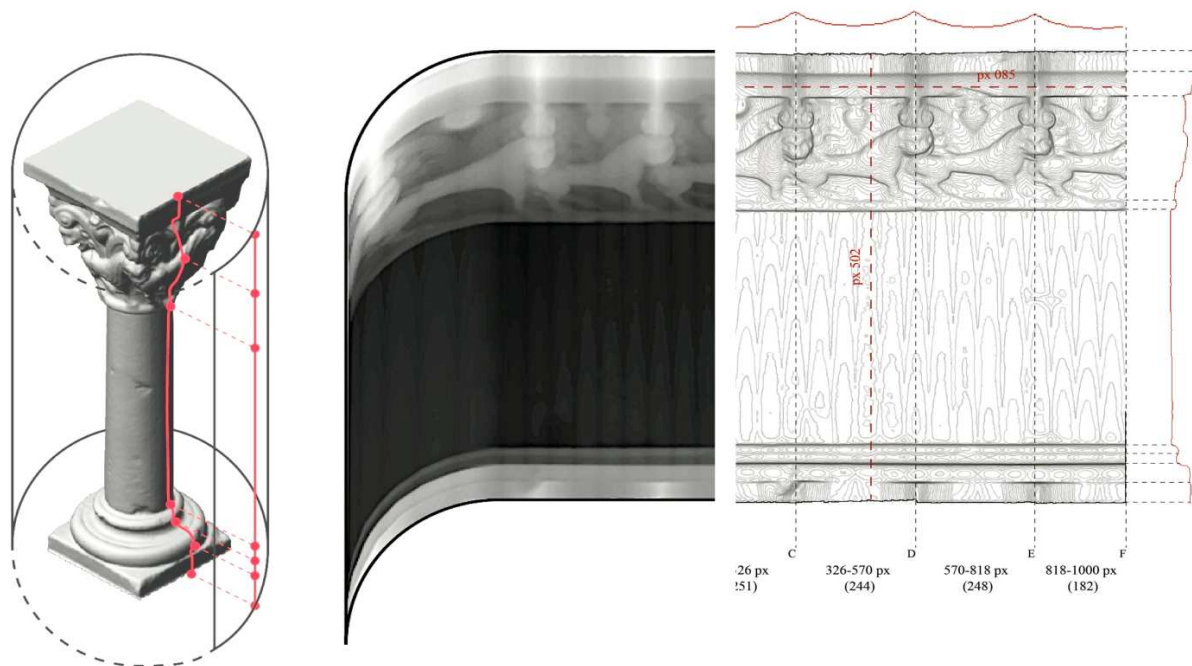


Fig. 4: Generation of a depth map from the polygonal mesh and analysis of geometric discontinuities and profiles directly on the map.

3.3 Hybridization of the digital instance with the geometrical/semantic model in a 3D representation

As we wrote in the introduction, digitization generally respond to one of these two concepts: multiplicity or intelligibility. If the multiplicity refers to un-interpreted and visible digital instance of the architectural object, the notion of intelligibility cross-reference to the theoretical model of the same object. In other words, it expresses its ability to evoke a universe of knowledge that can inform us about the semantic construction of an architectural element (Quintrand et al., 1990). The shift from multiplicity to intelligibility presupposes the presence of a human operator whose aim is to filter, reduce and interpret all data collected in order to retain only those which will replenish the theoretical model. This is essential to produce a set of relevant information in relation to the analytical objectives pursued.

But beyond the analytical issues, it's necessary to think about the distance between the instance and its theoretical model, and how these two concepts can be articulated in a unique representation system.

The comparison and the re-implementation of computer solutions developed by De Luca (De Luca et al., 2007) and Havemann (Havemann & Fellner2004), could contribute to the definition of a description system combining their two approaches. Their approaches are

based on formalizing of a geometrical semantics on one hand (Havemann) and on architectural semantics on the other hand (De Luca). We think it would be interesting to define a geometric/semantic model allowing a hybridization of the complexity (representing instances without interpretation) with semantic concepts (linked to the notion of intelligibility). The suggested procedure thus follows these steps:

1. Interactive and semi-automatic 3D reconstruction based on several methods that depend directly on the morphological complexity:

Basic adaptation of geometric primitives on an extension from the geometry (bottom) to architecture (up).

2. Computing a disparity map between the original item (dense points cloud or polygons) and the simplified elements (primitive, lightweight mesh, etc.).
3. Mapping of visual and geometric information (from the original elements) on the simplified elements by creating "enriched textures" (depending on the UV setting) composed of:
 1. A displacement map altering the surface geometry simplified to integrate and simulate surface details. This one is created (in the step of rendering) by capturing the vertical distance between two points on a surface in the disparity map computed.
 2. A normal map capturing information relating to the normal of polygons or original points clouds.
 3. A color map containing textures extracted from high definition oriented photographs.

4. Conclusions

Trying to identify methodological deficits surrounding practices related to the digitization of architectural artifacts, this article highlights various indicators to better assess the informational value of an architectural representation. But beyond this first aspect, this work has two objectives. First, it brings out the cognitive dimension present in the digitization work and second, it attempts to establish the relationship between the concepts of multiplicity of data and the intelligibility of the theoretical model.

The study about the instances similarity or detailed digitalization from simplified geometrical/ semantic models constitute a relevant research avenue allowing to visualize the gap between a theoretical model and a digital instance. On the other hand, this approach opens up interesting prospects for rapprochement between the detailed documentation of an architectural object and its description in an analytic language (parametric). In other words, it helps to consider the description of an object in a language that separates the formal analysis from the visible form.



Fig. 5: Process of mapping visual information and geometry on geometric primitives through the creation of "enriched textures".

REFERENCES

- BLAISE, J.-Y. & DUDEK, I., (2006a). Modélisation informationnelle: concepts fondamentaux. Visualiser pour raisonner sur des connaissances architecturales. *MIA Journal*, (1), (pp. 143-154).
- BLAISE, J.-Y. & DUDEK, I., (2006b). *Modélisation Informationnelle*, Imprimerie du CNRS - Provence.
- BORGES, J.L., (1982). De la rigueur de la science. In *L'auteur et autres textes* (p. 221). Paris: Gallimard.
- DE LUCA, L., VERON, P., FLORENZANO, M. (2007). "A generic formalism for the semantic modeling and representation of architectural elements," *The Visual Computer* 23 n°3 (pp. 181-205). Springer Berlin / Heidelberg.
- DE LUCA, L., DRISCU, T., LABROSSE, D., PEYROLS, E., & BERTHELOT, M. (2008). Digital Anastylosis of the cloister of Saint-Guilhem-le-Désert. In *Research in Interactive Design. Proceedings of IDMME-Virtual Concept 2008* (Vol. 3). Beijing, China.
- DE LUCA, L., (2008). *Relevé et multi-représentations du patrimoine architectural. Définition d'une approche hybride de reconstruction 3D d'édifices*. Spécialité Conception. Aix-en-Provence: Arts et Métiers ParisTech - Centre d'Aix-en-Provence.
- HAVEMANN, S., & FELLNER, D., (2004). "Generative parametric design of Gothic window tracery," in *Shape Modeling International*, (pp. 350-353).
- LO BUGLIO, D., & DE LUCA, L., (2012). Caractérisation sémantique de numérisations 3D d'objets architecturaux: Une piste de recherche entre «complexité-complexité-intelligibilité». In *Complexité(s) des modèles de l'architecture numérique*, (pp. 129-140). Paris: PUN-Presses Universitaires de Lorraine, 2012.
- LO BUGLIO, D., & DE LUCA, L., (2011). Critical review of 3D digitization methods and techniques applied to the field of architectural heritage: methodological and cognitive issues. In *Vast 2011. The 12th International Symposium on Virtual Reality, Archaeology and Cultural Heritage* (pp. 5-12). Prato: Eurographics press.
- MEDIATI, D., (2008). *L'occhio sul mondo per una semiotica del punto di vista*, Soveria Mannelli: Rubbettino.
- UMR 3495 CNRS/MCC MAP GAMSAU, (2011). *Nubes project*. Find june 26, 2011, from <http://www.map.archi.fr/nubes/visum/captures2.htm>
- UNIVERSITE DE CAEN DE CAEN BASSE-NORMANDIE. (2010). Projet de restitution. *Le Plan de Rome. Restituer la Rome Antique*. Find june 3, 2011, from http://www.unicaen.fr/cireve/rome/pdr_restitution.php?fichier=objectifs
- PALLADIO, A., (1965). *The Four Books of Architecture*, New York: Dover Publications.

PIERROT-DESEILLIGNY, M., DE LUCA, L., REMONDINO, F., (2011). “Automated Image-Based Procedures for Accurate Artifacts 3D Modeling and Orthoimage,” in *XXIIIth International CIPA Symposium*.

QUINTRAND, P., AUTRAN, J., FLORENZANO, M., (1985) *La Conception assistée par ordinateur en architecture* Paris: Hermès.

