INTERPRETATIVE MODELLING OF THE ARCHITECTURAL HERITAGE: INFORMATION AND VISUALISATION ISSUES

J.Y. BLAISE
gamsau UMR MAP CNRS 694
EAML 184, av. de Luminy 13288 Marseille Cedex 09
France

Dr. I.DUDEK
Instytut Historii Architektury i Konserwacji Zabytków
Wydzial Architektury Politechniki Krakowskiej
ul. Kanonicza 1, 31-002 Kraków, Poland

ABSTRACT

Visualisation and geometric modelling are today widely applied to the field of architecture. However, they remain often considered as means to communicate about the edifice rather than means to investigate the edifice. Our research focuses on the issues raised by the development of visualisation and modelling techniques on the Internet for documenting and representing edifices of the architectural heritage. Our position is that 3D representations can greatly favour the readability and the accessibility of data related to an edifice, on the condition that this representation shows architectural concepts before geometrical ones. Such interpretative visualisations of edifices can then be used to analyse simulations of buildings partly or totally destroyed. What is more, such visualisations can facilitate the construction of an information system about the architectural heritage, in which 3D models are used as interfaces to a database.
The global disposal we propose to discuss includes:

- An object Oriented model of architectural concepts.
- A VRML (Virtual Reality Modelling Language) architectural Modeller.
- A resource database containing data on the edifices represented.
- Interfaces to the database on Internet, among which VRML models.

Our contribution details those various aspects and the experiments we have carried out on chosen buildings of the city of Cracow.

KEY WORDS: Visual information systems, Virtual Reality, Architectural modelling, Web development.

1. INTRODUCTION

The MAP research unit (specialised in the use of computer techniques), and the HAiKZ institute of Krakow's Faculty of Architecture (specialised in conservation), have initiated a joint research programme focusing on what computer methods can bring to the investigation of patrimonial edifices. In this paper we will discuss of recent works we have carried out on the use of 3D visualisations in an information system on Internet, and of the methodology we use to build up these visualisations.
Three statements will help explaining from where we start:

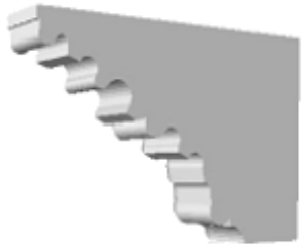
- The availability and analysis of documentation on edifices plays an essential role in the understanding of its historical evolution.
- Buildings are signed by a location in the space of the city and a position on a scale of time.

Architecture deals with forms and shapes that are better read in 3D, and documented independently from the building as a whole.
Briefly speaking, we are trying to find out under which conditions (modelling mechanism) visualisations of historic edifices could go beyond a seducing but somehow anecdotal work. Consequently, we are trying to find out how and with what means (methodology and tools) the integration of such 3D scenes as an interactive access mode to data on edifices could be achieved.
Most often, historic buildings that we study have been widely transformed throughout the centuries when they have not been totally or partly destroyed. Investigating their evolutions therefore requires, by necessity, two complementary approaches

- A theoretical analysis of the architectural form in order to propose morphological simulations.
- A thorough documentation of each building in order to validate simulations when possible and in all cases distinguish the likely from the hypothetical.

As a consequence, we believe 3D visualisations of these simulations should be considered not as representing the edifice but as representing our interpretation of what it can have been like at each phase investigated. In other words, visualisations should show what we know of the edifice more than the edifice. But achieving this goal requires that concepts and know-how from which architects have worked out built solutions should be accessible. Like one needs to know vocabulary and grammar when trying to fill in the missing words in an uncompleted phrase, such an approach requires that one builds a visualisation basing on a predefined set architectural concepts. Basing on this, we experiment an architectural modeller in which geometry is the underlying mean to visualise objects that are shown to the user as "architectural primitives" (arches, pillars, etc…).

Another key point in our proposition is the necessity to document simulations and among them virtual reconstruction. Here again, in a dictionary for instance, one does not look for information on a phrase but on each word it contains. It is therefore important to formalise an architectural model in which each meaningful individual concept can be documented independently from the others. Visualisations of such concepts can then be provided with independent query mechanisms. Scenes showing an edifice are built by instantiation of the architectural model, each concept is documented theoretically (ex: what we know of THE arch) and locally (ex: what we know of THIS arch). Such scenes can then be used as interfaces in an information system on edifices since documents we want to give access to are basically about buildings and their evolutions. In this paper, We will introduce the objectives, methods and technological choices of the research, and we will discuss three of its most representative aspects:



ill. 1 : VRML visualisation of an architectural concept

- How we identify and organise architectural concepts
- How we instance them and visualise them in a VR scene
- How we consider this VR scene as an interface in an info system

2. OBJECTIVES

Our first objective is to produce scenes in which architectural concepts are represented. The user should be asked questions about the architectural properties of such concepts (ex: the intrados and extrados of arches), properties that are then given a geometrical equivalence in order to visualise the concept. Giving a geometrical shape to the concept is therefore left for the system to handle. What is more, mechanisms of alternative graphical representation of those concepts should be provided in order to take into consideration problems such as or partial definition. It is then clear that the modelling of scenes can greatly benefit from a generic description of architectural concepts that would include properties (dimensions and others) and methods (geometrical translation and scene generation).

Our second objective is to use visualisations as an access mode to information related to edifices. In short, we want the system to answer not only to this question:

What did John Smith write?

but also to this question :

What did John Smith write about the gothic phase of the town hall?

and moreover to this question :

What information, what documents, can I find on the buttress of the town hall's gothic phase?

In other words, the modelling method and the resulting visualisations should allow searches not only on what the document is (a book, a research paper, a map, etc.) but on what the document is about (edifices at different periods in time). It is then clear that visualisations should let us to attach to each concept elements of information that result from a critical analysis of the sources.

3. VISUALISATION ISSUES

Representation of a patrimonial implies various problems:

- Architectural objects can be analysed by various aspects (urban relations, structural logic, functional evolution, etc.).
- Different scales (urban scale, architectural scale, scale of the architectural detail) require different levels of abstraction as well as different levels of detail of the 3D representation.
- Visual perception of the architectural object changes with the distance to the observer. Some of its architectonic elements (ex. profiles) and some of its characteristics (ex. opus) tend to vanish with a growth of the distance, some get only simplified (ex. cornice).

What is more time and human activity often results in a complex stratigraphy of the edifice. When gathering data on edifices that are transformed or partly / totally destroyed, some elements of the edifice are precisely documented, some of them have contradictory descriptions and for some of them, no single piece of documentation was found. How can we then represent in the same model parts that were documented together with totally hypothetical elements?

We believe unerring visualisations of architectural edifices require visual codification rules that would let us represent differences for instance between original parts and elements that were added later, were reconstructed or reused, that would let us show incoherence, impossibility, level of certainty, etc...Such an adaptability of the model is possible only with an interpretative model because all forms of realism imply a unique level of definition. As opposed to that, our knowledge about edifices can be neither complete nor consistent. In such a case attempts of realist representation force fiction.

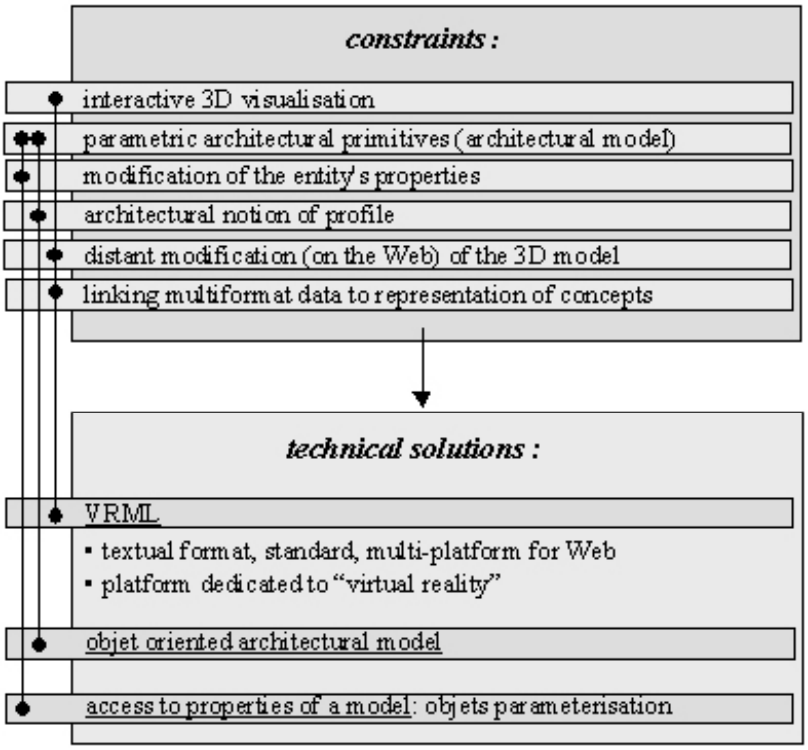
Another reason pushes us to favour interpretative modelling. What type of knowledge can we gain from purely *realistic model* (considering that there is no fiction in it)? Examining realistic models can be compared to an unguided visit in an architectural monument. We can observe and admire all the elements. We see them but we do not know their origin, history, specificity, etc. Interpretative models can favour a better understanding of the edifice by enabling the representation of different problematic and the reading of joined data as well as their interpretations by various authors. In the end, such models can be usefully discussed and the hypothesis they show agreed for or not among specialists.

4. METHOD

Our work is based on a knowledge representation formalism – Object Orientation -, on a standard Web client/Web server architecture through CGI programming and on a visualisation platform dedicated to the Internet, VRML (Virtual Reality Modelling Language).
Architectural concepts are formalised in classes of objects (in the meaning of this word valid in Object Orientation Programming). This means isolating object categories for which similarities of structure or behaviour can be observed. Objects have VRML representation methods but also non-geometrical properties (bibliographical sources, etc.) that will be conveyed inside the representation (for instance URL or queries inside the VRML scene). We have built up a web-based application called VALIDEUR dedicated to the construction of such scenes. It is a CGI application in which the user instances architectural concepts and modifies their properties online. Properties include of course dimensions and position of the object, but also appearance and queries to execute on selection of the object inside the VRML plug-in. This last point introduces the idea that scenes produced inside the tool may be used as interfaces in an information system, as will be shown in the SOL experiment. It has to be noted that not all scenes are used this way. VALIDEUR is a tool that we develop and experiment in order to allow interpretative modelling of edifices, meaning the building up of visualisations in which we want to show *what we know* of an edifice at a time in history, *and only this*. This key issue, raised for instance in [1] on the city of Heusden (Netherlands), is particularly important in researches about built heritage. The use of scenes produced through this tool as interfaces is therefore only one aspect of our research, but it shows that a theoretical modelling of elements of architecture can widen the possible uses of visualisations. CGI handling modules are written in Perl 5, a version of the language that supports object orientation [2]. Scenes are written in VRML 2.0 both for Cosmo and Cortona plug-ins. The use of VRML 2.0 for architectural scenes is investigated in various researches, see for instance [3]. Although often considered too heavy, the language provides several features that appear particularly relevant in our context:

- Easy to write freeware ASCII format
- Routing of events using interactive or automatic sensors that can be used for instance to switch between alternative representations or to allow the modification on the client side of appearances, positions, etc...
- Multiple URL anchoring of individual shapes.
- Graph structure that allows dependencies between shapes
- Insertion of text scripts that can be targeted at the scene as a whole (lighting conditions for instance) or at individual shapes (i.e. in our architectural concepts).

The *combination* of technologies that we have chosen corresponds quite closely to our research methodology since we are focusing on the interface between knowledge modelling and visualisation issues, more than on the building up of a global, "*does everything*", application. In other words, we believe working on a theoretical model, producing VR scenes, querying an information system are essentially *different* tasks, most often carried out by *different* people. Our position is that our research should result in the development of a *set* of tools, among which the VALIDEUR and SOL experiments that will be described hereafter.



ill. 2 : Constraints and technical solutions adapted for the visualisation of the concepts

5. IDENTIFYING AND ORGANISING ARCHITECTURAL CONCEPTS

A broad area of research has been opened in the past decade on object orientation as an implementation of the reasoning by classifications paradigm. In Architecture, theoretical classifications can be dated back to the work of the roman architect and theorist Vitruvius who analyses edifices both in terms of composition and in terms of morphologies. He organises individual elements of the corpus inside stylistic classes [4]. His approach has set a strong methodological background for the theorists of architecture throughout the classical period. A major

ambiguity however appeared on which concepts should be organised: physical objects or spaces they enclose and their purpose [5]. Social division lines tended to replace or complete morphological division lines as proven by Serlio's theoretical work [6]. The works of Viollet Le Duc in the nineteenth century, both as an architect and as a writer, strongly reintroduce morphology and structure of the edifice in its analysis [7]. By doing so, the architect brings to the fore the idea that physical objects can be considered as basic concepts to deal with when studying patrimonial edifices. We consider that object orientation provides a relevant formalism in representing the corpus of physical objects [8]. Classifications of such elements along with a non-ambiguous definition for each concept involved, such as those provided by [9] and [10], are the guidelines we use. Basing on the relevant sources, we analyse the edifice as a composition of individual physical objects. Elements of a building will be described as such *entities* providing that they meet three requirements:

- An entity is a unique "object " identified by a single element of the vocabulary.
- An entity has an obvious role in the physical structure of the building.
- An entity intervenes independently of any other in the building's system of relations.

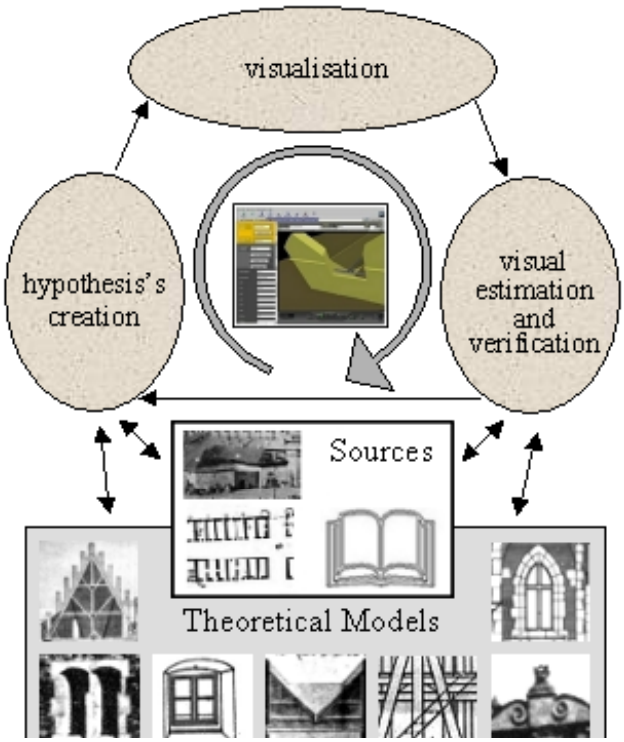
Object Orientation is today applied to the field of architecture both in terms of knowledge representation (see for instance [11] or [12]) and in terms of programming technique (see for instance [13] or [14]). Still, in works on the architectural heritage, such experiences are more rare, although contributions from D. Donath and F. Petzold [15] can be quoted, that give a good example of the multidisciplinary aspects of researches on the architectural heritage.

Research issues in this domain are for most of them strongly connected to independent disciplines such as history, history of art, ethnology, archaeology, etc. They range for example from using GIS in archeology [16] to representing patrimonial edifices through rendering platforms [17]. This may partly explain why object orientation remains uncommonly used in the field of the architectural heritage.

Our experience shows that it is possible to represent elements of the theoretical architectural corpus through a hierarchy of classes and to provide these classes with methods that will generate visualisations. The entity hierarchy represents an intermediate scale in the model. At a wider scale, entities are grouped in so-called "Réseaux" that correspond to compositions such as "the column" (entity *Base* + entity *shaft* + entity *capital*). On the other hand, at a smaller scale each entity can detain concepts called "Attributes" that correspond to generic morphological features.

6. GENERATING VRML SCENES

Architects, historians of art, archaeologists and other professions that deal with the architectural heritage frequently face objects partly or totally destroyed [18]. Most commonly destruction is the effect of time passing, but also of fires, floods, wars as well as ignorance or irresponsibility. A detailed documentation that would provide information about form and structure of a despaired object is often lacking. Therefore any reconstruction either purely theoretical or aiming for reuse of the remains has to be based on comparisons and analogies. Creation of an hypothesis is the result of an author's expertise. The next step is a visualisation of the proposal. Its correctness and probability can then be verified by a visual estimation. This verification process is repeated until the satisfactory proposition is formulated.

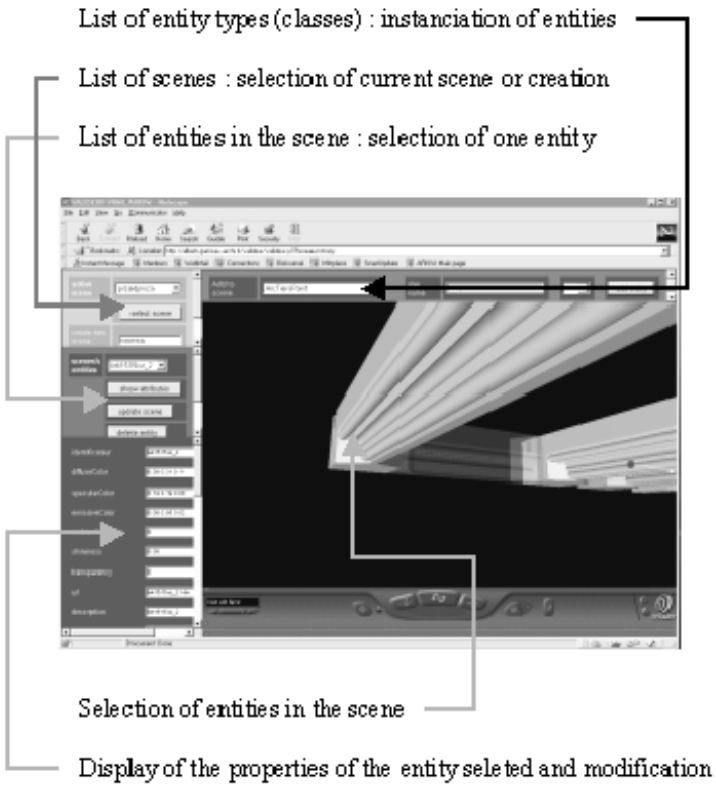


ill. 3 : Simulations of edifices : virtual reconstruction as an iterative task based on the analysis of sources

Visualisation is a most tiresome and time-taking element in this process, it is therefore important to provide researchers with a knowledge-based tool that could help in authenticating the entire process of hypothesis building. Objective of our VALIDEUR tool is therefore to provide an Internet interface for on-line creation of VRML scenes in which each object represented is an instance of the architectural model. VALIDEUR uses two main hierarchies of classes: architectural classes and interface classes. In addition to those two main hierarchies of classes, geometrical classes provide tools for the representation of profiles for instance, and the array class handles the processing of VRML scenes computation.

The interface shown on ill 4 gives access to the morphological definition of the entity, to its localisation inside the scene and to VRML-specific properties such as colours, lighting, etc. Default values, stored in template objects at system level or scene level, are assigned to new

instances of the architectural objects. Profiles or more generally elements of decoration are not relevant in isolating new classes of entities. With whatever profile a regular beam has been carved, it is still an instance of the beam class, with a unique VRML representation method. We have in accordance with the theoretical work of [10] developed a generic formalism for profile handling in which the *rhythm* of the profile is given as a property of the entity, and in which its *morphology* is generated so as to fit the entity. As it is a rule in patrimonial architecture, profiles are specified in 2D in relation with their type (fillet, ovolo, etc.) and control points specify curve inversions.



ill. 4 : Web Interface of the VALIDEUR VRML modelling tool (browser : Netscape 4.5, plug-in Cosmo Player 2.1)

VALIDEUR is a VRML modeller using an underlying architectural model that can be seen as an object-oriented typology library. It is in keeping with current researches on web platforms and VR in architecture such as [3] and [19].

It however is dedicated not only to the representation of hypothesis but to connecting a 3D VR model to sources giving information notably on its genesis. We will now introduce this aspect of our research with the example of the SOL documentary database. Finally, it has to be noted that in both cases visualisations produced stand *as one more element of information* in the understanding of the edifice. We consider that they are not final stages of a study on the edifice but that they may contribute to the continuing analysis of its morphological evolution.

7. VRML SCENES AS AN INTERFACE IN AN INFORMATION SYSTEM

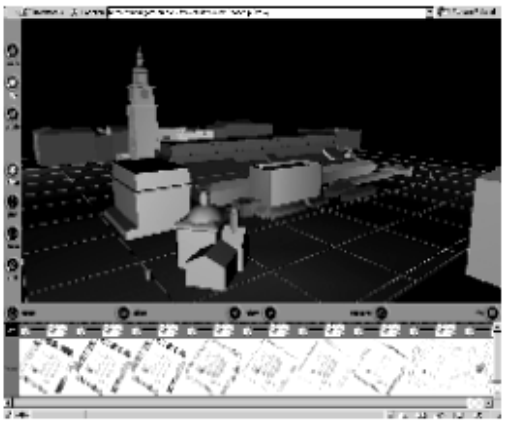
On GIS (Geographical Information Systems) platforms, maps are used as an interface inside spatially determined data: the information is attached to geographical concepts. In the CART experiment [20], a CAD tool-dependant representation is used as an interface inside spatially determined data; but the information is attached to topological concepts (in act, points surveyed on the surface of existing objects).

Our contribution tries to introduce an architectural scale that would stand in between those two propositions. Whereas GIS naturally use maps as navigation interfaces, 3D visualisations of edifices are most often used only as a definitive graphical result. However, defining an architectural corpus along with its visualisation methods raises the opportunity to use 3D models as interfaces inside architectural data.

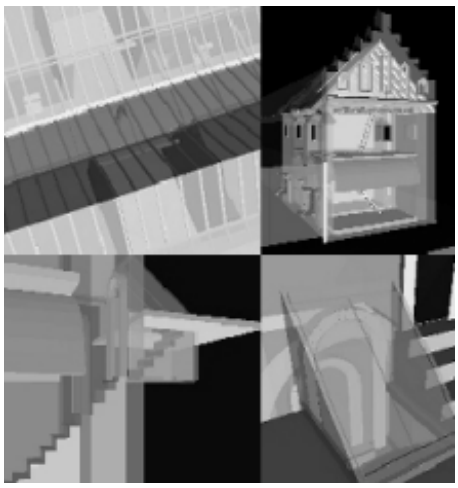
Our approach can be compared to this of GIS, but with two important constraints: representing the spatial concepts in 3D and taking into consideration the morphological evolution of the edifice during its history.

We believe that drawing a link between visualisation issues and database management issues can contribute to a better global understanding of the city and its edifices. Our research only contributes in raising this question on real cases, and in experiencing a possible methodological and technological approach that we will now describe. This approach is based on complementary computer tools: RDBMS, Object Oriented programming languages, Internet platform, VRML modelling. The VRML scenes constructed using VALIDEUR become naturally the basic entry points in questioning the database on architectural entities. Up to now, due to the cost in downloading time of VRML scenes, successive scenes are used to query the database on different periods in time. This approach is experienced on the buildings that were erected (and for most of them are destroyed now) in the central market square of the city of Cracow. SOL (Sources On Line) is a bibliographic, iconographic and cartographic database search tool for the web. It references data connected to the urban fabric of Cracow's Main Square (Rynek Główny) or to problems related to the architectural conservation and protection discipline. As an addition to standard bibliographical data identification (author, edition, etc.), it features additional information that connects each entry to data concerning for instance building considered, architectural detail, historical period mentioned, etc. Specific query interfaces (textual, cartographic, 3D) allow the questioning of each point of view. Since its relevancy relies on the researcher's analysis of references, such a tool can prove useful only if it mirrors the constant evolution of his sources. An updating web-based interface is therefore proposed in order to allow distant interventions on the database itself. In addition, the VRML authoring tool presented above gives an opportunity to figure different moments of the site as well as different hypothesis on these moments. Although the

system remains experimental, and does require more developments, it provides a representative example of what 3D visualisations can bring to the interfacing of databases.



ill. 5 : VRML visualisation used an interface in the SOL database



ill. 6 : Visualisation of interpretative VRML scenes, a step in the understanding of architectural evolutions (Simulations of Cracow's Kramy Bogate, an edifice destroyed during the XIXth century)

8. CONCLUSION

In the field of the architectural heritage, modelling and visualisation techniques are often restricted to the production of comprehensive representations of edifices that are graphically satisfactory but scientifically dead-end. Still, numerous contributions such as [21] or [1] have been defending a wider usage of models as means to interpret and put together pieces of knowledge we have on edifices that are destroyed or transformed. Our research is in line with this position and derives from it a three-step analysis process (Identification of architectural concepts, modelling and documentation of scenes). Our work uses a combination of technologies for the Internet that are here confronted to the specific issues of patrimonial studies in which documentary aspects play a major role. They are questioned on how they can contribute in the step by step process of analysis that architects, historians, archaeologists or conservationists undertake when investigating the evolutions of an edifice.

In this approach, there is a clear connection between visualisations of an edifice and the reasoning that gave birth to it. In that sense, a field of experimentation and a combination of computer formalisms are put in the position to complement one another.

It shows that a lot can be gained in the global understanding of edifices by an appropriate modelling effort and by the use of interpretative 3D visualisations.

REFERENCES

[1] P. Alkhoven, *The changing image of the city. A study of the transformation of the townscape using Computer Assisted Design and visualisation techniques*
PHD University of Utrecht (Netherlands), dec 1993.

[2] Damian Conway, *Object Oriented Perl*, Manning Publications, 2000.

[3] Rivka Oxman, Visual Emergence in creative collaboration, *Proc 17th eCAADe Conf*, Liverpool, UK, 1999, 357-363.

[4] Vitruve, *Les dix livres d'Architecture*
Editions Pierre Mardaga, Brussels, 1988.

[5] F.Fichet *La théorie architecturale à l'âge classique* Editions Pierre Mardaga, Brussels, 1979

[6] Jean Cuisenier, *La maison rustique: logique sociale et composition architecturale*, PUF, Paris, 1991

[7] E-E Viollet Le Duc, *Entretiens sur l'architecture*, Editions Pierre Mardaga, Brussels, 1977,

[8] M. Florenzano, J-Y Blaise, P.Drap,PAROS, Modèles objet appliques à l'architecture construite, *L'OBJET*, 1(3)

[9] J M Pérouse De Montclos, *Architecture vocabulaire - principe d'analyse scientifique*, IN, Paris, 1972-88.

[10] Jan Tajchman,.*Stropy drewniane w polsce. Propozyca systematyki*, ODZ, Warszawa, 1989.

[11] C.Branki, A.Wallis, I.Aird, A.Bridges, Collaborative design objects as experts agents, *CAAD towards new design conventions*, TU Białystok, 1997, 63-74.

[12] Ekholm, A,.A Conceptual Framework for Classification of Construction Works, *ITCON* 1, 1996

[13] Brown, A., Rezgui, Y., Cooper, G., Yip, J, Brandon, P,.Promoting Computer Integrated Construction Through the Use of Distribution Technology, *ITCON* 1, 1996

[14] Lars Line, Virtual Engineering Teams : Strategy and Implementation, *ITCON* 2, 1997.

[15] Dirk Donath, Frank Petzold, Towards a building information system based on computer-supported surveying system, *CAAD towards new design conventions*, TU Białystok, 1997, 141-164,

[16] C.Ioannidis, H.Chlepa, Spatial information system for the geometric documentation and restoration studies of monuments: an application to the wall of ancient Messene, *Proc ISPRS WG V/5* Workshop, Thessaloniki, Greece, 7-9 july 1999, 203-209

[17] C. Ogleby, From rubble to virtual reality, a reconstruction of the ancient city of Ayutthaya using modern photogrammetric techniques, *Proc CIPA Symp 1997*, Göeteborg, Sweden, 1-3 October 1997, 75-80,

[18] Marek Łukacz, Metrologia i pierwsza faza zabudowany staromiejskich blokóz lokacyjnego Krakowa, *Proc ICC*, Kraków, Poland, 22-24 November 1998, Tom 3, 92-100

[19] Andrew Roberts, Virtual site planning, *Proc 17th eCAADe conf*, Liverpool, UK, 1999, 442-448

[20] D Whiting, S Nickerson, Computer aided recording tools automate the creation of a site information system, *Proc CIPA Symp 1997*, Göeteborg, Sweden, 1-3 October 1997, 121-130

[21] Ronald Stenvert, Constructing the past: computer-assisted Architectural-Historical Research PHD of the