New experimentation of a generic framework for architectural heritage data visualisation

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ABSTRACT

When studying patrimonial edifices or sites, documentary sources, may they originate from archives or from contemporary survey campaigns, provide partial evidences from which the researcher will infer possible scenarios on how an edifice or site may have evolved throughout the centuries. Documentation analysis and visualisation are therefore vital to the understanding of the architectural heritage. They are the only scientific basis from which virtual renderings can be proposed and justified. Still, the making of 3D scenes in our field of experimentation is most often only in relation with communications goals. Virtual renderings, although presented as visualisations of an edifice, totally mask the semantics behind the scene, meaning the reasons behind the shapes and in definitive any kind of scientific analysis since they provide certainty where only probability should be considered. Such seducing results may be of great use, they may be considered as a visualisation of geometrical shapes, but in no way can they be considered as visualisation of architectural heritage data. We propose an approach of data visualisation in which 3D scenes act as interpretative interfaces to the documentation, and in which the objects represented are given appearances that show what can be stated form the reading of each object's documentation. We have defined a methodology in which the documentation is analysed and attached to architectural concepts with respect to the notion of scale, and in which the concepts are given representations that are used both as visualisations of the documentation's analysis and as interfaces in the documentation's database. Our experimental set is the centre of the city of Kraków (Poland).

We introduce in this paper several recent developments of our research : a combination of persistence mechanisms that includes XML parsing and RDBMS, links between objects and documentary sources, symbolical visualisation of undocumented / non-dimensioned objects. We also introduce a recent experimentation of this framework at structural scale on major edifices in Kraków's city centre.

Keywords

Applications, Scientific visualisation, architectural heritage, virtual reality, VRML, interpretative modelling.

1. INTRODUCTION

In the field of the architectural heritage, documentation and visualisation play essential roles, as established by [Alk93]. But what solutions can one find when wanting to retrieve information on the

former using the graphical signs available in the latter? And how can one mark those graphical signs with indications about the content of the former? These are the two basic questions that our paper addresses.

In the field of geography, or let's say at the scale of territories, GIS platforms have provided formalisms that enable a native connection of the graphical sign to the information it localises and signifies. Such platforms have been used at the scale of architecture notably in archaeological site management or urban planning (see for instance [Bil97] or [Ioa99]). But in the case of patrimonial architecture at its various scales, geometry cannot be considered as a relevant intermediate between the documentation and the edifice, as established by [Bou71]. One of the

difficulties is that dimensional aspects are in most cases hypothetical but in all cases do require the third dimension.

In the field of geometry, and particularly in connection with support for surveying, experiments have been carried out in order to attach information to the geometrical results of the survey campaign, typically 3D points as experimented in [Whi97]. But in the case of patrimonial architecture a 3D point or any other geometrical being is a totally irrelevant concept to attach information to. What historical reference mentions "a 3D point" ? What book, illustration, painting, inventory can be attached to a geometrical being?

In both the fields of GIS and surveying, there have been efforts in order to find theoretical concepts that can serve as interfaces between information and visualisation platforms. We believe that in our field of experimentation the geometrical concepts will fail coping with the complexity of the architectural documentation because they are just not the concepts people who document buildings deal with. Still, we consider that the edifice's shape can be used in order to interface documentary sources. But the information that characterises an edifice or a site can be fruitfully put in relation to theoretical concepts, provided that those concepts originate from the world of those who study edifices: architects, archaeologists, conservators, historians, etc.

Figure 1 : The city of Kraków, interpretative 3D interface, and situation in the city

We introduce a methodology in which theoretical architectural concepts are identified and structured with regards to the Object Orientation classification paradigm. Each such concept can be documented and represented inside VRML (Virtual Reality Modelling Language) scenes that act as 3D, graphical interfaces to the documentation but also as graphical visualisation of the documentation's content.

Preservation of the architectural and urban heritage includes a concern for the edifice itself, but it also includes a concern for the edifice's documentation for which we lack appropriate visualisation platforms. In our research area, the meaning of the word *visualisation* is often narrowed to this of *virtual reconstruction*. But an undocumented virtual reconstruction can hardly be considered as something more than as a dead-end (see [Kan00]). Although realistic 3D models prove relevant with respect to communication goals [Bur97], we favour an approach in which what is "beyond" the image is more important that the image itself, in line with contributions like [Ste91] or [Alk93]. What we try to visualise is a momentary state of knowledge on the edifice's evolution. In previous contributions, we have introduced our position on interpretative modelling in the field of the architectural heritage with regards to visualisation issues [Dud01] and on the use of 3D models as interfaces with regards to documentation issues [Dud02]. We will in this paper very briefly sum up these aspects, and focus on data visualisation issues, meaning how can we provide support for the visualisation inside 3D scenes of a qualitative analysis of the documentation. We will discuss the main elements and recent developments of our methodological framework and will also detail the following aspects:

− The combination of persistence mechanisms, including XML parsing and RDBMS, that we have developed in order to handle the persistence of the architectural model's instances and of the documentation.
− The links between the architectural model's instances and the documentary sources
− The symbolical visualisation of undocumented / non-dimensioned objects.
− A recent experimentation of this framework at structural scale on major edifices in Kraków's city centre.

2. VISUALISATION ISSUES

As mentioned above, architectural heritage is an application domain in which both documentation and visualisation play essential roles. Moreover, ensuring their interdependence has clearly been acknowledged by authors as a key issue (see for instance [Ste91] or [Nak99]):

- Visual results such as VR scenes can in no way be considered as elements of information in a research process if they are not put in relation with a documentation that authenticates, validates, explains each particular arrangement of architectural shapes the reconstruction proposes.

- Symmetrically, documentation about edifices can very hardly be given a synthetic visual interface when this interface does not refer to what the documentation is about, meaning architectural shapes. There is therefore a clear need to use VR models not only as interfaces but also as filters or views on this documentation. Such models will help the researcher to evaluate visually how precisely shapes are documented, and to retrieve from the system information that have been sorted out thematically.

Finally, it has to be stressed that in our research area a physical object such as "an opening" can have been re-used several times during history, and often inside different edifices. Both the shapes reconstructed and the documentation relate to a moment in time. This introduces a level of complexity for which we lack adequate formalisms since such issues as dynamic data visualisation [Rus01] or time handling in GIS sytems [Bil97], although already addressed, do not bring operational breakthroughs in our application domain. Where [Tos00] writes "*hypertexts are communication*", we would want to write "*3D architectural concepts are information*". This author investigates the problems of links' relevance in a field that is not ours. But there is a clear parallel to draw in our field of experimentation since we want to answer not only to the question -*What did John Smith write?*- but also to the 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?*- allowing searches on what the document is about (edifices at different periods in time).

3. DOCUMENTATION ISSUES

In [Hei00]'s experience, a 3D scene is used to navigate into a set of information about a city. The user may question the system on the localisation of services such as hotels, railway stations, etc.. Our experience differs in three main aspects:

– As shown above, the elements supporting information are architectural elements (gates, arches, etc..) , not localised services .

– The information we deal with, as well as the shapes we represent, are in relation with a period in history.

– The information, or documentation, we interface needs interpretation since it may be uncertain, uncomplete, etc..

In this section we will focus on the problems raised when dealing with such pieces of documentation, and will try to establish what is needed when one wants to visualise such pieces of documentation.

3.1.1 Data collection

The methodology used by historians of architecture and conservators in order to analyse evolutions of an architectural object is based on the interpretation and comparison of various types of documentation, as stated in the [Cra00] charter. Therefore the idea that different *pieces of documentation are in relation to architectural elements* (a building, a portal, etc.), is for them a natural (although often unspoken) part of their work methodology. One key goal of our research is to capture, capitalise and visualise the actual basis of this methodology –relations between an architectural artefact and the wide range of documents that refer to it. What is more, the documentation that we describe is stored in various collections, each of them having its own classification and access policies. Having it in mind we consciously avoid giving a direct access to sources. Our proposal introduces a distributed computer architecture in which we only refer to pieces of information that are detained by various institutions. Our goal to *localise* documents in terms of :

– In which library(ies) can they be found?
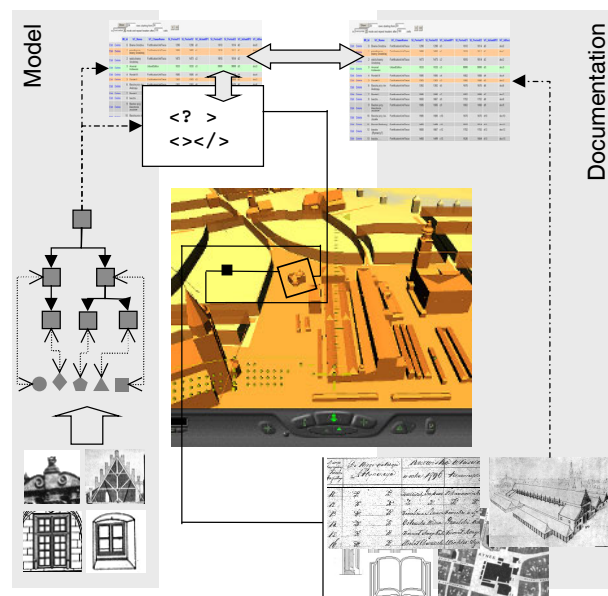– To which architectural objects do they refer?

Figure 2 : The 3D scene, connecting instances of a theoretical architectural model to sets of documents

3.1.2 Data interpretation

In order to interface pieces of information on the edifice, we need to isolate relevant architectural concepts (or shapes) and build out of them 3D models, as developed in [Dud01] or [Don97]. But the documentation that serves as source of evidences is far from being exhaustive or non-ambiguous. What is more it is not structured with regards to the edifices that it documents. We will therefore face several

difficulties when wanting to link documents and objects inside 3D scenes:

1.   Edifices that we study have been widely transformed throughout the centuries when they have not been totally destroyed. This means that we face the challenge to visualise shapes that in all cases are hypothetical, and need to provide scenes with graphical codes marking the hypothesis' evaluation.

Figure 3 : Contradictory sources, illustrations of the same gate at the same period

2.   Investigating an edifice's evolution bases on a documentation and it's analysis. But this documentation varies in type, precision and relevance. We may face partial evidence, contradictory evidence, lack of evidences. We need to propose visual markings of the objects represented in a 3D scene that correspond to the type and content of their documentation .

3.   The documentation about one object does not relate its sub-parts or to its super-parts : each concept should be documented independently from the others. Architectural scale[1] can act as this complementary filter. This notion is oddly absent from the field of 3D modelling although its usability in the studying of the edifice has been established by [Alk93], and although its usage is widely spread among architects.
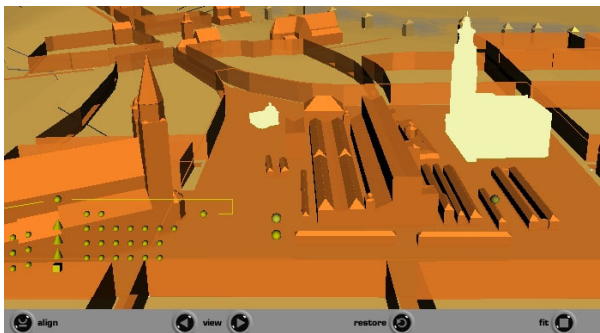
Figure 4 : Scene featuring architectural concepts corresponding to a selection by date (1802) at urban scale. A click on the objects corresponds to a URL query. Two edifices have been highlighted by a click on the documentation typology buttons (bottom left)

4.   Inside an edifice that can be widely transformed, individual elements of architecture can, what is more, be reused or even moved somewhere else in the city, underlining another problem, this of localisation of architectural elements in relation with a given period of time.

5.   In the field of architecture, visualising with the third dimension is clearly established as a necessity. Consequently, we will need to isolate elements of morphology and represent them in order to use them as anchors on the documentation[2].

The solution we currently investigate introduces client-side graphical disposals nested inside a VRML 2.0 scene in order to show our analysis of the documentation. Scenes are here given four roles:

–   Represent an interpretation of the morphology.
–   Visualise each object's documentation's analysis through a graphical marking.
–   Retrieve information on any object in the scene.
–   Visualise, as a 3D scene, the result of a query on the documentation.

4. EXPERIMENTAL FIELD : THE CITY OF KRAKÓW

Former capital of Poland, the fourth largest city in Poland, Kraków has one of the best-preserved medieval city centres in Europe. Years of conservation actions, examinations and research conducted in this place produced a very significant quantity of various documents (descriptions, analysis, drawings, photographs, maps, reconstructive hypothesis, etc.) that should be gathered, organised and visualised. Kraków's heritage is a particularly relevant application field since its morphological evolution has been constant and complex, and the documentation gathered on each stage is very rich. The understanding of Kraków's urban development, and the management of data collections in relation with it, therefore closely addresses the main issues of our contribution, information and visualisation.

People involved in the preservation of Kraków's heritage face today, with the development of computer technologies, two major challenges : adapt existing data collections, and moreover exploit the potential benefits of these new computer technologies. It should be stressed that computers may help in the recording and preservation of existing data collections (for instance by preventing a constant direct contact of users with the sources). But what should be stressed even more is that computer technologies can intervene in a better organisation and capitalisation of the conservator's experience, know-how and university researches. This can be

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[1] With regards [Bou71]'s notion of scale, roughly the idea that it takes various points of views to understand the edifice

[2] This we believe can only be achieved if we build a theoretical model of architectural elements, acting like modelling primitives, that will serve as intermediate between the user and the set of documents to interface.

done we believe by centring the organisational effort on the description of the architecture at various scales. Our experiences are carried out in the framework of a Franco-Polish bilateral co-operation[3].

5. METHODOLOGY

In this section we will discuss what the theoretical architectural model really is by introducing briefly concept identification and the resulting hierarchy, and will then describe how instances of this model are represented and stored.

5.1.1 Concept identification

Architectural concepts are formalised by a hierarchy of classes with the root class factorising the attributes responsible for representing the documentation's analysis. This identification step is based on the analysis of respected scientific works[4] in which a careful attention to a non-ambiguous definition of the architectural vocabulary that can be exploited for implementation in an object oriented programming language. Each concept isolated detains several blocks of attributes, five mainly qualitative – and nested inside the root class –, one related to the class' morphology - class specific. Qualitative information blocks store the identification of the object and its localisation in the city, but also:

- A set of attributes called Evolution block fixing the dating of the object by an interval and a qualitative justification attached to the interval.
- A set of attributes called Typology block that provides a qualitative justification of the object with regards to three themes (shape, structure, function).
- Finally, a set of attributes called Documentation block that states what are the type of documents related to the object.

Evolution and Typology information blocks detain **justification attributes** : they are used to represent objects with a graphical code that indicates how credible the information we detain is.

Documentation information block detains **existence attributes** : they are used to represent objects with a graphical code that indicates whether or not we have documents about the object with regards to specific media types.

5.1.2 Concepts Hierarchy

The sixth piece of data encapsulated in each architectural class, the Morphology block, serves as the main division line in the model's organisation.

More precisely, our classification is based on a morpho-structural analysis. The first level of derivation defines families of objects that share a structural role (ex: covering, opening, circulation, etc..). The corresponding classes are mainly abstract ones, they exploit the inheritance mechanism but do not fix morphological features. The second level of derivation defines individual objects or families of objects that share a morphological specificity[5].

5.1.3 VRML Representation

Applications of the VRML standard for architectural modelling have often been discussed , see for instance [Cam98] or [Oxm99], we will focus its relevance in relation with our research issue. Our scenes are written in VRML 2.0 [Ame97] both for Cosmo and Cortona plug-ins. Several key aspects of VRML are exploited in our development, and some of its capabilities remain leading-edge ones with regards to *interpretative modelling* issues. The language provides features that are relevant in our context, notably its events routing mechanism that we use in order to write client-side interaction disposals that are nested inside the scene and therefore not dependant on an application or an applet (see [Hol00])[6].
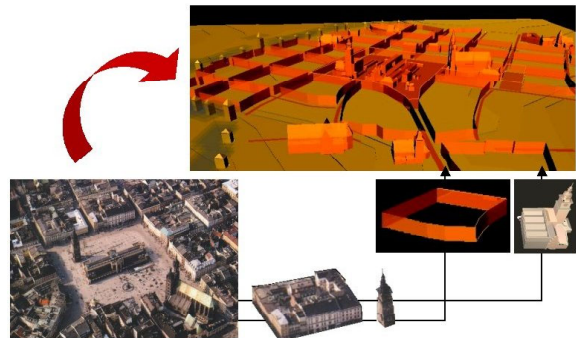

Figure 5 : From the city's morphology to its interpretation, illustration on urban blocks and edifices

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[3] ARKIW PICS 1150 CNRS/KBN, APN 2001 CNRS - SHS

[4] J.M Pérouse De Montclos [Per88], J. Tajchman [Taj89] , M. Łukacz [Łuk98].

[5] In our field of experimentation, it is not credible to expect that a theoretical model will be reusable enough to exactly match each particular edifice or ensemble, its quotidian variety in the words of [Low01]. Our model defines a tree of classes to which we may need to add new individual concepts when the particular edifice or ensemble requires it. The model's existing structure provides the methodological tools to its extension, and the inheritance mechanism notably accelerates the process of integration of new concepts.

[6] We have stressed the need to create autonomous scenes. By saying this, we rejected the possibility of investigating JAVA/VRML solutions that various experiences such as [Lan98] or [Bru98] have proven efficient; but that seem too exposed to versioning problems for use in our application domain (See for a discussion on this point [Dud01]).

Each concept detains methods relevant for scene appending in VRML files. Scenes feature instances of the model and the current state of their properties, among which the justification and existence attributes mentioned in the previous section. An indication of the documentation's analysis (levels of certainty, type of documentation, typologies, etc…) can thereby be displayed natively or interactively inside the VRML scene. 3D scenes are used as a query mode (predefined time-related scenes) by object selection or as a visualisation of the query's result, by instancing the objects corresponding to the search and calling their VRML representation method. Model and RDBMS platforms are chosen independent, the interfacing is carried out using Perl CGI Interfacing modules [Con00] and PHP modules that monitor the RDBMS links.

The system's client/server architecture uses standard CGI programming interfaces, the various tasks are described in the following figure.
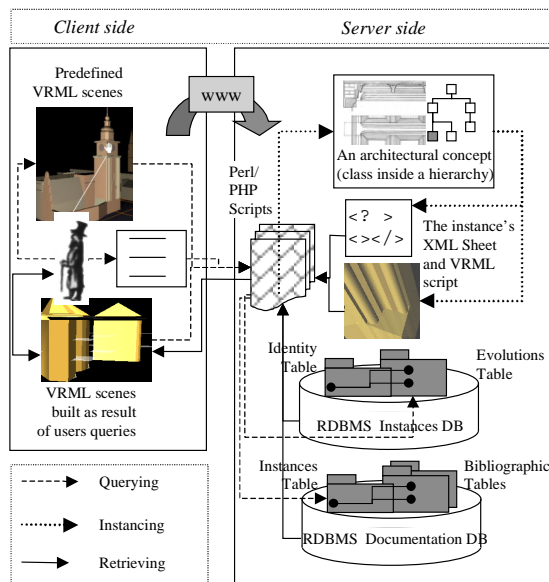

Figure 6 : System architecture

5.1.4 Persistence mechanisms

In our application domain objects are often reused or partly destroyed. This problem has been raised in works like [Łuk98]. We have as a consequence provided each object with persistence mechanism that store independently the object identity (identity + concept documentation + position in the model's structure) and its various states of evolution.

Instances are stored in an RDBMS context (MySQL) as well as in XML sheets. Class-specific data (mainly morphology) is stored inside XML sheets. Each concept detains methods relevant for persistence handling in XML files and RDBMS context. The Parsing of XML sheets in order to re-instance and visualise objects selected by a query on the Database is done thanks to the Perl XML::SimpleObject

Module [Ham01]. It has to be stressed that autonomy and durability of the data sheets are of crucial importance in our application domain. We store the textual results (XML sheets) inside files that can be used independently from the system as a whole. Good elements for a discussion on the XML one input / several outputs paradigm can be found in [Wal02]. We propose in line with this author a solution based on the idea that a unique input- the instance's XML sheet; will have several outputs.

5.1.5 LINKS BETWEEN INSTANCES AND DOCUMENTARY SOURCES

As mentioned before, the architectural model's instances are stored both inside a database and as XML sheets. References on the documentation are stores in yet another database that describes what the data is: a book, a plan, a cloud of digitised points, etc. and attaches this data to what it is about : an edifice, a part of an edifice, i.e. the instances of the architectural model. In this database we have distinguished *standard data identification* and *interpretation of data content*, in line with the contribution of [Ste91]. In other words, the database contains tables supporting a standard indexing of documentary sources: document identification, author identification, graphics description, but also tables which support the interpretation phase. The following figure summarises links between the two databases we have implemented:
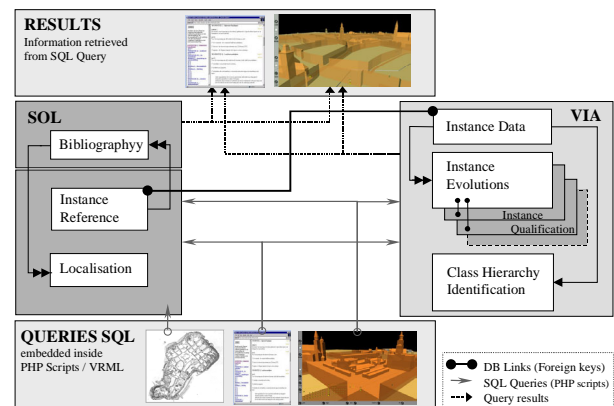

Figure 7 : Roles and links of the SOL (documentation) and VIA (instances) databases

6. UNDOCUMENTED OR NON-DIMENSIONED OBJECTS

The instances and their documentation being described independently, we need to tackle two possible inconsistencies:

- We have instanced an object but have not completed its documentation.
- We have documented an instance but have not yet provided it with dimensional information.

In both cases, how can we still visualise something, and moreover how can we stress the lack of information by a visual sign in the 3D scene? We have implemented two different answers. In the case of undocumented objects, we use a particular level of transparency. The object is marked with an indication not of what we know, but of what we ignore; and we believe this can be a fruitful attitude in the context of historical investigations.
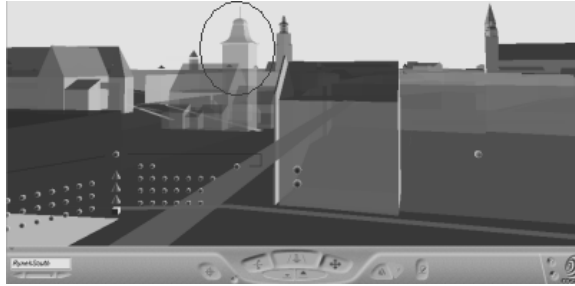

Figure 8 : transparency used to notify of documentation absence

In the case of object that we have documented but for which we have not yet given morphological properties, we use a library of graphical 3D signs that bear three indications. The bottom lineSet indicates the belonging to a hierarchy of concepts. The vertical line height indicates a scale (relative to other concepts in the same scene). Finally, a textured cube shape bears the same transparency/colour coding mechanisms used on all the instances in the scene in order to visualise the documentation's analysis.
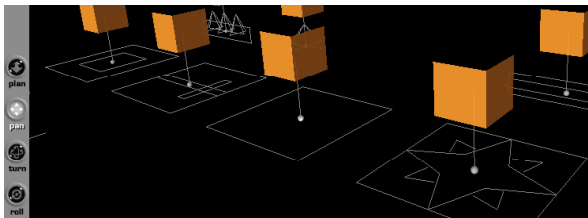

Figure 9 : Library of symbols (subclasses of Edifice)

7. PROTOTYPED EDIFICES

VRML's PROTO nodes are widely used in the writing of the files. Of course an important aspect is that they help reducing the weight of the file. Their role in our development is to control interaction disposals, but in recent experiences we extended it to this of supporting a generic description of complex shapes, thereby gaining again file weight.

7.1.1 Interaction disposals

They are used either for object control (choice of the database to query on when selecting the object, autonomous rotation of the object around himself for shape investigation, …) or for scene control (lighting conditions, ground anamorphosis, …). The main

families of interaction disposals nested in the VRML scenes are:

° Highlighting buttons : they are used in order to visualise presence or not of each type of documentation on each edifice represented.
° Transparency cones : they are used to show on each edifice inside the scene how precise the documentation is : it in fact is a graphical interpretation of the justifiers.
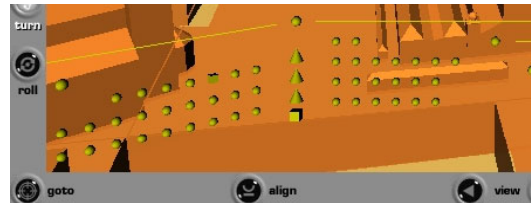

Figure 10 : Highlighting buttons and cones

° Viewpoint controlled actions : actions are nested in the viewpoint list that acts as a menu.
° Global scene control sliders : they provide a client-side control on ground elevation and lighting conditions inside the scene. .
° Anchor selection : we provide each scene with a control that sets which URL will be required when a click on an object is done.

7.1.2 The Edifice Class' PROTO

Although most objects represented are given a geometrical definition inside their section of the VRML file, some complex shapes are defined as PROTOS and only instanced inside their section of the VRML file. It is the case of the Edifice Class for which we developed a PROTO that produces Extrusion shapes basing on two MFVec3f fields (spines) and four MFVec2f fields (two sections, two scales). The Edifice PROTO also contains fields in charge of supporting the various interactions (appearance changes, position changes, anchoring).

At structural scale, each edifice is described as a combination of elementary volumes for each of which an instance of the VRML PROTO is nested in the
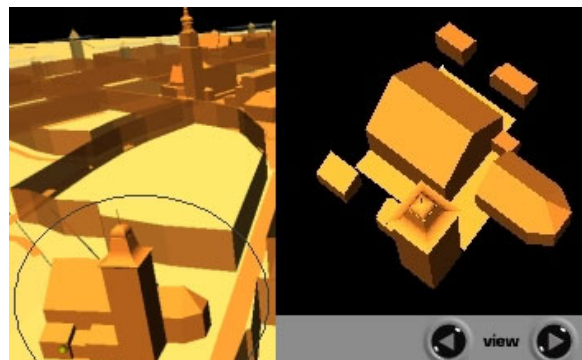

Figure 11 : Various elementary volumes, instances of the same PROTO, the case of the Wszystkich Świętych church

edifice's section of the VRML file. The edifice can contain an unlimited number of elementary volumes, helping to cope with a reasonable level of morphological complexity. Each elementary volume is positioned and oriented independently of the others inside the Edifice's local co-ordinate system, but it bears the same appearance control mechanism as the Edifice as a whole.

8. CONCLUSION

Our work clearly positions visualisation in our application domain as an *interpretation*, with an ambition not for realism but for the better documentation readability and access, in line with contributions such as [Alk93] or [Kan00]. We believe that it is possible to greatly enrich the usefulness of 3D representations provided that some attention is put to the semantics behind the rendering. A lot more work needs to be done in order to develop a vocabulary of 3D signs that would help understanding 3D scenes in the way a legend helps the reader to interpret a geographical map. We believe that only with respect to the preceding points 3D scenes can become a tool for scientific visualisation.

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