3D standards for scientific communication

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Abstract: This paper aims at verifying some of 3D modeling and VR visualization techniques in archaeology and cultural heritage management and at testing their use for scientific communication. The monument chosen for this research is the eighteenth century great staircase of SS. Niccolò and Cataldo Monastery in Lecce, that was modeled by means of CAD, VRML, X3D forthcoming standard.

In this way, it was possible to examine every method's advantages, evaluating the economic and intuitive use of WYSYG *tools versus the dimension of generated files, and the possibility of expansion and of updates. A particular focus was made on under-definition X3D standard, and on its possibilities in archaeological applications, in particular to build up 3D-DBMS, Virtual Reality scenes and Augmented-Reality applications.*

Key words: X3D, XML, VRML, Virtual Reality, 3D, Internet, Scientific Communication, Augmented Reality

Introduction

This research aims at applying and verifying some of 3D modeling and VR visualization techniques in archaeology and cultural heritage management and at testing their use for scientific communication.

It is well known that lately 3D models and virtual reality visualizations of artifacts, sites, environments and archeological, historical and artistic monuments have been increasingly used, mostly over popularization and didactics (for educational use see Mitchell – Economou 2000; for use of VR to give a public access to archaeological data see Pringle 2000; Bonfigli – Guidazzoli 2000 propose the use of VR for increase the knowdledge of the History of Bologna; Frischer – Abernathy - Favro - Liverani - Blaauw 2000 show various kinds of scientific, didactical, educational disseminations of a scientific model of Santa Maria Maggiore), but, recently, also in scientific applications. For instance Forte 1993 develops an application of scientific visualization for the topographic exploration of Reno Valley next to Bologna; Ozawa 1993 uses VR techniques for the 3D reconstruction of ancient Japanese villages of Yoshinogari in IV-VI centuries DC; Gottarelli 1995:101 analyses methods and techniques for 3D record of archaeological data, and outlines a virtual model of the archaeological excavation; Carafa – Laurenza – Putzolu 2000 propose a GIS based integration of 3D data in archaeological record and documentation.

An important laboratory for scientific visualization is CINECA VIS.I.T laboratory, a supercomputer sistem for developing real time 3D experiences, and to focus visual components of Cultural Heritage information (Guidazzoli 2000). An other important Laboratory for visual information for archaeological research is the SHAPE Lab, that has developed the ARCHAVE sistem, a software sistem that utilizes VR as an Interface to access scientifical data (Vote - Acevedo– Laidlaw – Joukowsky 2001). The Virtual Model is specifically defined an "extension of the record" in the Virtual Vilars Project. In the general project of record, documentation and reconstruction of an Iron Age Fortress in Catalogna, the authors state that "The three-dimensional and individualized restoration of the different features must also constitute an instrument for the study and typological analysis of the aforementioned structures" (Junyent – Lores 2000:228).

Goodrick – Harding 2000 use VR to solve a specific archaeological problem: the authors demonstrate the orientation of the site of Thornborough creating a virtual model of the site and of the stellar constellations.

An interesting application of VR to the analysis of pictorial information of the "Cristo Sole" Sepulcher in Vatican Necropolis is shown in Forte - Tilia - Bizzarro - Tilia 2001.

In the above applications VR tools are considered as a kind of archaeological and historical documentation, in addition to traditional two-dimensional ones.

This use of VR has lead to pay more attention on methodological aspects.

A first definition of virtual archaeology is given by P. Reilly in 1990 (Reilly 1991), who stresses the concept of "virtual" as related to a replica, or model, whose realism depends on the quality and quantity of data included. This paper opened a debate up to date till today, with interesting consequences both on methodological and technical aspects.

This concept is investigated in Sarti-Forte 1995 and it seems to be accepted in Forte 1997; Gillings and Goodrick (Gillings-Goodrick 1996; Gillings 1999; Gillings - Goodrick 2000) analyse the various techniques grouped under the term "VR" in archaeological studies. The authors consider the imprecision of the term itself a cause of the use of various alternative notions and techniques. So they emphasize the need for a framework for archaeological VR applications. Gillings analyses the problem of an "uncritical" enthusiasm in archaeology for VR, that caused a lack of interest for methodological issues, such as the definition of the actual meaning of the term VR for archaeologists and again the relationship between the reality and the virtual model. The authors come to the conclusion that VR has to stress the process more than giving passive images to be really useful for archaeological research and to help the data interpretation. With this more critical approach Gilling proposes the incorporation of VR into everyday archaeological study (see before, note 2) (Gillings 2000). One of the steps to reach this goal is considered the "development of an archaeological-VRML in its own right"(Gillings-Goodrick 1996, 2.6).

Barcelò 2000 deals again with the relationship between reality and model, and comes to the conclusion that "Visualization can be defined as the mapping of abstract quantities into graphical representations (geometric representations of lines, surfaces and solids) as an aid in the understanding of complex, often massive numerical representations of scientific concepts or results". He points out that "future advancement of Virtual Reality techniques in archaeology should not be restricted to "presentation" techniques, but to explanatory tools", thus envisaging the need for integrated visualization and data management tools. Analysis of present and possible or future applications in archaeological research are outlined in Borra 2000; Forte 2000a; Forte 2000b; Forte - Beltrami 2000.

Frischer – Niccolucci – Ryan – Barcelò 2000 point out a history of the diffusion of VR and of its applications in cultural heritage sites representation. The authors come to the conclusion that much of the past failures in CVR were caused by a lack of scientifical contents of high-tech experiments. They think that in the future VR will be much more present in archaeological research and practice, in collaborative and interactive worlds, but that this will be possible only by stressing the importance of scientific contents, by using a "philological" approach and by creating a set of standards that will allow interopeability, testing and validation.

Sanders 2000a - 2000b describes the status of archaeological uses of VR in archaeology, also envisaging in the future the use of multi-user, interactive worlds. Particular attention is paid on the need for shared communication standards, focusing on the role of VRML for developing scientific libraries, interactive worlds, data dissemination on Internet.

Zuchovsky 2001 deals again with the concept of realism, and proposes to refer the realism to the integrity, homogeneity, volume and quality of initial data, rather than on the realism of the VR final model, that will never be "real".

To sum up one of the key issues for the development of future archaeological VR applications seems to be the definition of widely accepted, flexible and transparent standards that allow the archaeologists to manage their data with no technical intermediation and to develop specific set of archaeological components.

Therefore, the first purpose of this research is testing and using VR as a tool for archaeological and historical scientific documentation and communication.

The monument chosen for this research is the SS. Niccolò and Cataldo Monastery in Lecce, in the South of Italy (fig. 1): a complex building, characterized by an interesting stratification in building phases through centuries (Photos by author, if not specified. For the historical and artistic aspects of Saints Niccolò and Cataldo Monastery see Wackernagel 1911; Infantino 1973; De Leo 1978; Bucci Morichi 1983; Fagiolo Cazzato 1984; Calò Mariani 1985; Storia 1993; Calò Mariani 1994; Kemper 1994; Pepe 1994; Vetere 1994; Palumbo 1996; Pellegrino-Vetere 1996.).

In this construction, the eighteenth century great staircase was selected (fig. 2).

So this analysis purposes are: 1 - the great staircase structural study; 2 - building stratification observation and recognition; 3 –VR tools applied test.

SS. Niccolò and Cataldo Monastery in Lecce

As we said, this research focuses on a part of SS. Niccolò and Cataldo Monastery in Lecce, the eighteen-century great staircase and the barrel vaults system that carries it.

The Monastery built by Tancredi, earl of Lecce in 1180, situated out of Lecce, had various building phases, rebuildings and restorations, until today, when it is the Department of Medieval and Contemporary History and of Cultural Heritage Studies of Lecce University.

In 1494 king Alfonso D'Aragona committed the monument to Monte Oliveto monks, who deeply changed its structure and decoration.

After this classicist moment, new architectonic and decorative manieristic changes were made in XVII sec., and in XVIII century, when the great staircase was built up, dated between 1733 and 1738.

After 1870, the monastery received poor and mad people, with very bad consequences for decoration and architectural features of the building.

During XX century, many restorations took place, sometimes deeply changing monument features and, finally, in 1985 the building was conceded to Lecce University, which made it respectable and usable.

The last restoration also involved the eighteenth century great staircase, examined in this paper, showing the old front door on the surface of the wall, where banister leans.

The eighteeth century great staircase: I PHASE methodology and analysis steps

In the first phase of this research, the great staircase was examined following these steps: 1-Analysis and measurement; 2-Drawing; 3-Photographic documentation; 4-Graphical restitution; 5-3D modeling in AutoCAD and exportation in VRML; 6-3D modeling in VRML.

Firstly the attention was focused on VRML (for VRML standard see Colombo-Marana 1997:145; Colombo-Marana 1999; Hartman-Wernecke 1996. Some uses and possible perspectives of VRML in archaeology are shown in Gillings-Goodrick 1996; Gillings 1999.), because since 1994 this language has been more and more used, to become a universal standard for virtual reality, mainly because it is free, platform independent, expansible, interactive, hyper medial and so on (theorical and methodological aspects in Ronchi 1994; technical issues in Hartman-Wemwcke 1996; Brutzman 1998; http://www.vrml.org/; http://www.lucia.it/vrml; http://www.web3d.org).

In order to test VRML standard advantages for our purposes it was decided to create the virtual scene of the eighteenth century great staircase by using different tools and techniques. The research about our tools for reconstructing, and about how they differently work and benefit our research seemed to be one of our most interesting analysis fields. So the VRML scene was created by means of: manual editing; WYSYG editing; exporting a 3D model made with AutoCAD.

In this way, it was possible defining every method's advantages, evaluating WYSYG tools economic and intuitive use versus generated files dimension, and expansion and updates possibility.

The great staircase was reconstructed, in order to make a 3D structural model to visualize and study building architectural features. The model of Saints Niccolò and Cataldo staircase aims at helping to understand the structure of the building: so high resolution model was not needed, nor particular lights, surface accuracy, detailed decorations modeling (for higher detail level models or lighting, surface and texture problems see Gottarelli 1995:75; Meucci-Buzzanca 1996; Kantner 2000; Lucet 2000; Pollefeys - Proesmans - Koch - Vergauwen -Van Gool 2000). Average measurements were taken where repetitive elements were found, such as staircase steps (the same process is applied in Medrano Marqués-Dìaz Sanz-Tramullas Saz 1991:287-288; Daniels 1997; Lucet 1997; Huggert – Chen Guo - Yan 2000). So the model here presented is a structural model (the word "structural" is not used like Daniels does in Daniels 1997, 3. 1., where the author refers it to the distinction between perception and structural models).

It was important to keep in mind our study purpose since this first step, in order to plan the right data set to use. Soon it was clear that notwithstanding the fact that the traditional 2D graphical documentation, plan and section have been considered sufficient to record a 3D object, such as a building or an archaeological excavation, 3D reconstruction needs a much greater amount of data and measures than the traditional 2D model, and consequently conveys richer information.

So, the 3D wire-frame model was made with AutoCAD (on the use of AutoCAD for archaeological applications see Buzzanca-Giorgi 1996; Messika 1996; Wood 1996; Daniels 1997; Drap – Hartmann –Virnich – Grussenmeyer 2000; Martens – Legrand - Legrand – Loots – Waelkens 2000) (fig. 3). Likewise, in order to test VRML benefits, the monument virtual scene was created by using various tools: exporting a model from AutoCAD to VRML; using a WYSYG VRML interface; hand-writing the .wrl file (fig. 4) (for more informations on this phase of this case-study see Cantone 2000, under press). The main results are: 1 - exporting an AutoCAD 3D model in VRML produces a light file, interactive, and easily usable on the web. But, analyzing the source code of this file, it is clear that this way it is obtained a single Indexed face set node, which is a polygon with the external surface of the whole model as external area. 2 - direct drawing in VRML, using a graphical WYSYG interface. That way we created a virtual world similar to all appearance to the world exported from AutoCAD. But it is just the source code that is completely different. This time in the code we can easily recognize every part of the "building": every wall, every vault has its own node, easily visible in the code, especially by using VRML possibility to name each element. Moreover, this code makes the most of some powerful features of VRML, such as the primitives. This is a double benefit: a - the files is lighter; b – it is possible updating and changing the virtual world every time you want, modeling also only one node - i.e. architectonic element. Nevertheless the GUI seems not completely able to use powerful VRML features, particularly to lighten files: it does not use, for instance, keywords DEF and USE: the result is a still heavy and not clean code. 3 - manual editing. Thus it is obtained a clean and light code, but of course much less easily and quickly. As already noticed, there are many differences between 3D VRML modeling tools, so it seems important to chose the way to model virtual words every time, evaluating how each method works, and which are its benefits for the specific research purposes. In this way, we could test each method advantages and limits, in particular evaluating quickness and intuitive editing versus generated files dimension and updates possibility.

I PHASE: Results

The analysis made this way brought out many observations on the monument studied, which was recorded and examined by means of the photographic and graphical documentation collected.

3D model interactive visualization enhanced the monument analysis enabling a better and quick test of the data set collected. In particular it was possible analyzing: 1-the great staircase architectural features; 2-the building phases stratification.

This shows that a monument VRML model is an additional tool to record, document, and study data, in order to achieve powerful and useful benefits. Indeed VRML allows: immersivity; individual interaction with the model; updating - work in progress; networking.

Individual interaction with the model enables much more completely and directly data studying, communicating and transmitting, also in modeling still existing monument reconstruction. Moreover, constant updating possibility make our graphical information more flexible and useful than traditionally.

The same features enhance networking and interacting during the whole research, introducing interesting and useful changes in the methodology of our work.

II PHASE: X3D

During the first phase of our research, we could notice VRML standard powerful possibilities. However, it was possible too noticing some limits in this standard use.

First of all, probably the inadequacy itself of efficient standardized, and widely known GUI, limited, somehow, an intensive application of VRML as a common tool for archaeological documentation.

Furthermore, VRML is a complex and heavy language. This feature has two consequences: 1-it is difficult developing error-free applications; 2- it is necessary downloading heavy client-plug in (> 3Mb), and this dramatically reduces Internet users who can visualize a VRML scene (about 10% Internet users). Moreover, VRML expansions are possible only by using PROTO (http://www.web3d.org/technicalinfo/specifications/vrml97/index.html).

These limits are remarkably strong for archaeology and cultural heritage management study purposes: for instance, it is not easy making VRML 3D model interact with other applications and, first of all, with DBMS (but this feature is under development: http://www.web3d.org/TaskGroups/dbwork).

These are some of the reasons that induced Web3d consortium to develop X3D, a new and powerful language, which is likely to be the 3D standard for Next Generation Web (Locatelli 2000; http://www.web3d.org/TaskGroups/x3d/faq/index.html) (fig. 5).

X3D stands for Extensible 3D, a next-generation, extensible, XML-compliant 3D graphics specification that extends the capabilities of VRML 97. The name X3D was chosen to indicate the integration of XML.

In short, X3D main goals are:

1. Integration with XML (X3D expresses VRML 97 capabilities using the Extensible Markup Language);
2. Componentization. (X3D enables a lightweight core that can be easily extended to provide new functionality);
3. Extensibility. (X3D uses components to add fundamentally new nodes and corresponding implementation code to the core).

The integration with XML is a powerful feature that enables easy pages re-hosting, better pages technology integration, and,. finally integration in Next Generation Web, which will be based more and more on XML.

Componentization feature means that the new standard has a light core, in which only 23 nodes have been included: Anchor ; Appearance ; Background; Color; Coordinate; CoordinateInterpolator; DirectionalLight; Group; ImageTexture; IndexedFaceSet; IndexedLineSet; Inline; Material; NavigationInfo; OrientationInterpolator; PointSet; PositionInterpolator; Shape; TextureCoordinate; TimeSensor; Transform; Viewpoint; WorldInfo.

This core can be extended with Components, sets of related nodes. Various Components constitute a Profile, i.e. subset of related Components that provide a set of task-specific functionalities. Different Profiles are useful to fulfill different users needs: Base, Core e Full are examples of Profiles.

Some extensions have been already integrated, and, particularly interesting for archaeological applications purposes, also GEO VRML extension (http://www.ai.sri.com/geovrml).

For these reasons it seemed useful applying this new technology to our study, so the great staircase was modeled in X3D, by using X3D-edit, a scene-graph editor, developed by the same working group that is defining the standard.

X3D-Edit uses the XML tagset defined by the X3D Compact Document Type Definition (DTD) <x3d-compact.dtd> in combination with Sun's Java, IBM's Xeena XML editor and an editor profile configuration file <x3d-compromise.profile>.

X3D-edit processes X3D scene graph using different XLS to generate .html, .wrl files and, possibly, other kinds of outputs, such as .pdf and so on (fig. 6). A X3D browser is being developed too by the same group, called XJ3D, tested under Linux, Solaris and soon Win 32 (fig. 7)(http://www.web3d.org/TaskGroups/x3d/faq/index.html).

Use of X3D makes it possible to figure out more structured data managing, integrating a XML DBMS with the X3D model. Besides, the generated core is extremely readible and transparent, allowing a flexible management and quick control of data. Moreover, XML enables using output independent data: it is possible using data collected and analized in various ways: from the site, with PDA, to the study, with 3D DBMS, to the dissemination. Furthemore, this standard is lighter than VRML, so we can figure out a dramatic increasing in data availability.

X3D Code specimen

```
<?xml version="1.0" encoding="UTF-8"?>

<!DOCTYPE X3D PUBLIC "http://www.web3D.org/
TaskGroups/x3d/translation/x3d-compromise.dtd"
                               "file://localhost/C:/
www.web3D.org/TaskGroups/x3d/translation/x3d-
compromise.dtd">
"file://localhost/C:/www.web3D.org/TaskGroups/
x3d/translation/x3d-compromise.dtd">
```

The file heading informs the browser the file language: xml, version 1.0. The encoding used is the one defined by utf8 abbreviation, the transformation format UCS (Universal Multiple-

Octet Coded Character Set) at 8 bit, ISO/IEC 10646-1:1993 Information technology , including also not ascii characters.

This part indicates too the location of document type definition.

```
<X3D>
```

This is the beginning of the X3D code.

```
<Header>
<meta content="monastery.xml" name="filename"/>
<meta content="monastero dei santi niccol&#242; e cataldo, lecce" name="description"/>
<meta content="francesca cantone" name="author"/>
<meta content="march, 2001" name="created"/>
<meta content="http://www.archeologia.net/monastery.xml" name="url"/>
<meta content="X3D-Edit, http://www.web3D.org/TaskGroups/x3d/translation/README.X3D-Edit.html" name="generator"/>
</Header>
```

The file header includes meta tags, with various additional informations about the file, the author, the date of creation, etc.

```
<Scene>
<NavigationInfo type="&quot;EXAMINE&quot; &quot;ANY&quot;"/><!-
      Scene graph nodes are added here -><Group>
      <children>
        <Shape>
          <appearance>
            <Appearance>
              <material>
                <Material ambientIntensity="0.033"
                        diffuseColor="0.0 0.0 1.0"
emissiveColor="0 0 0"
                              shininess="0.100"
specularColor="0.8 0.8 0.8"/>
              </material>
              <texture>
                <ImageTexture url="ultimo.jpg"/>
                </texture>
        </Appearance>
       </appearance>
       <geometry>
         <IndexedFaceSet ccw="true" convex="true"
          coordIndex="0 1 2 -1 &#10;
1 3 2 -1 &#10;
...
(skipping coordinates)
...
6 22 28 -1 "
          creaseAngle="1.222" solid="true">
         <coord>
             <Coordinate point="6.04496 -56.09990 -45.89980&#10;
                        37.14500 -56.09990 -54.89980&#10;
2.07639 -56.09990 -45.89980&#10;
...
(skipping points coordinates)
...
25.14500 -67.90000 -18.89980&#10;"/>
         </coord>
        </IndexedFaceSet>
       </geometry>
      </Shape>
     </children>
    </Group>
      <Group/>
      <Shape>
        <appearance>
          <Appearance/>
        </appearance>
      </Shape>
      <Group/>
      <Shape>
        <appearance>
          <Appearance>
            <material>
              <Material/>
            </material>
            <texture>
              <ImageTexture url="ultimo.jpg"/>
            </texture>
          </Appearance>
        </appearance>
```

These code lines describe various aspects of a geometrical form: its appearance, material, color, shape. The geometry is defined by the series of vertex, and by their coordinates. Then a texture is applied to the geometrical form. The ambient illumination and features are described too. This example refers to a part of a wall of the staircase.

```
...
(skipping code)
...
        <Viewpoint DEF="vp" description="vp"
fieldOfView="0.785398"
      jump="true" position="0 0 300 "/>
  </Scene>
</X3D>
```

There is a definition of the viewpoint, then the end of the scene and of the X3D file.

Perspectives

Besides the advantages described before, the language structure itself seems to be useful for archaeological applications: there is a standard core, which can be extended with specific profiles. Therefore, an archaeologist can trust on a worldwide diffused language and in the same time can expand it to fulfill his research needs. Besides X3D code is flexible and transparent, so it can be easy for archaeologists themselves to control and update their data with no intermediation.

X3D seems helpful in various steps of archaeological research, from data-entry to data managing and to dissemination and publication.

In data collecting, it is possible to get a richer documentation, integrating 3D model in DBMS.

In data analyzing, X3D allows networking, simulations, building up augmented reality (for an introduction to the use of Augmented Reality in archaeology see Barcelò 2000; Ryan 2000) and achieving cognitive enhancement (Forte 2000a; Forte, M.-Beltrami, R., 2000 for the concept of VR in archaeology as related to the Cognitive Archaeology). Furthemore, GEOVRML profile integration enables using and analysing geo-referenced data, such as maps and 3-D terrain models.

Finally, in data publishing, this standard allows not only data web publishing, but also various outputs and visualizations generation from the same data set.

To sum up it seems clear that X3D will enhance the advantages of the present VRML standard.

It promises wider data dissemination, easier and more effective use of task-specific profiles, immediate interaction with other applications and DBMS.

So X3D seems to be a powerful tool, useful for several applications: excavation data 3DBMS, eventually also making the most of on site data acquisition devices; studying buildings, artifacts, sites, environments, making territorial analysis, etc.

Obviously all that will be possible after this definition phase. It is easy to suppose that the next step will be the developing of GUIs, that may be useful to archaeologists to manage their data themselves.

At the same time, in hardware developing, XML-based devices are going to be worked out, enriching possibilities in data entry, managing, dissemination.

One of the most important fields of research for archaeologists will be developing archaeological profiles and archaeological primitives libraries, to make the most of this powerful standard.

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Figures

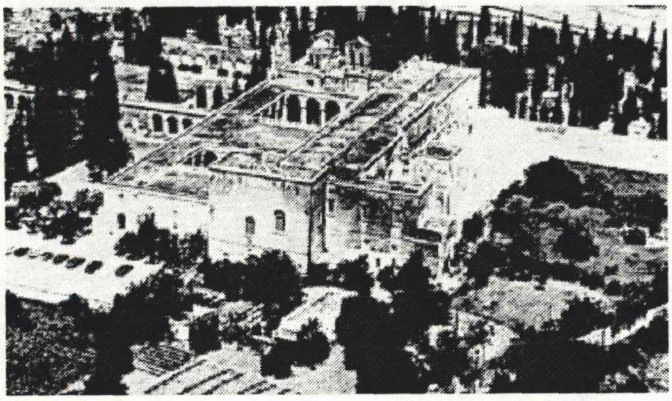

Figure 1. SS. Niccolò and Cataldo Monastery – from Pellegrino - Vetere 1996

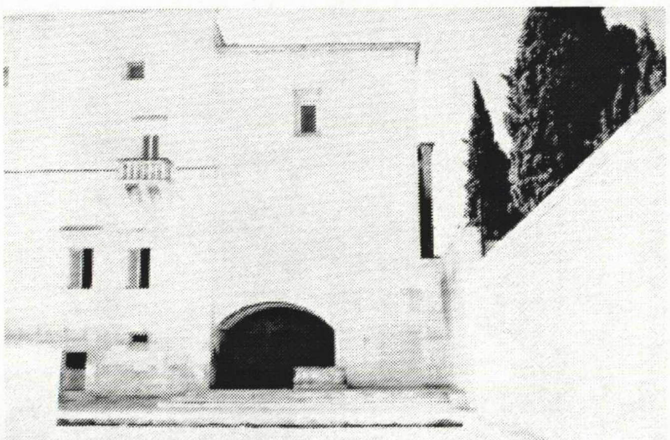

Figure 2. the part of the building in which the eighteen century staircase is built:view from internal court

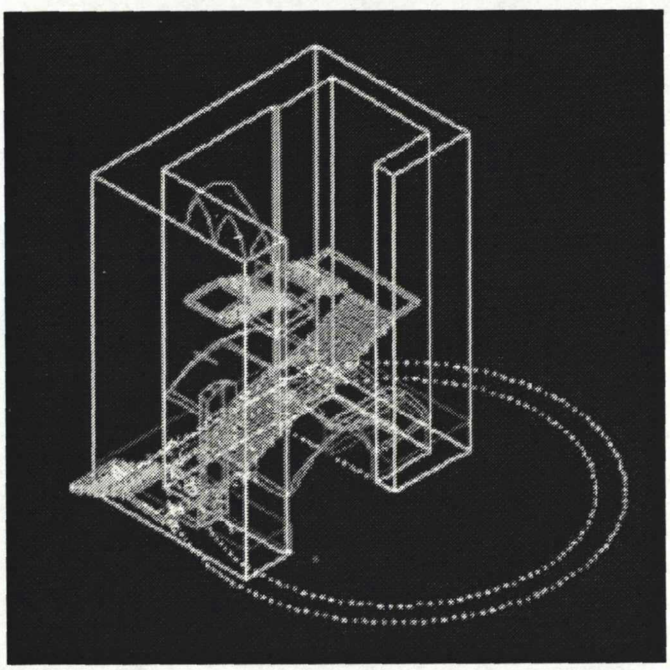

Figure 3. The wire frame model: isometric view

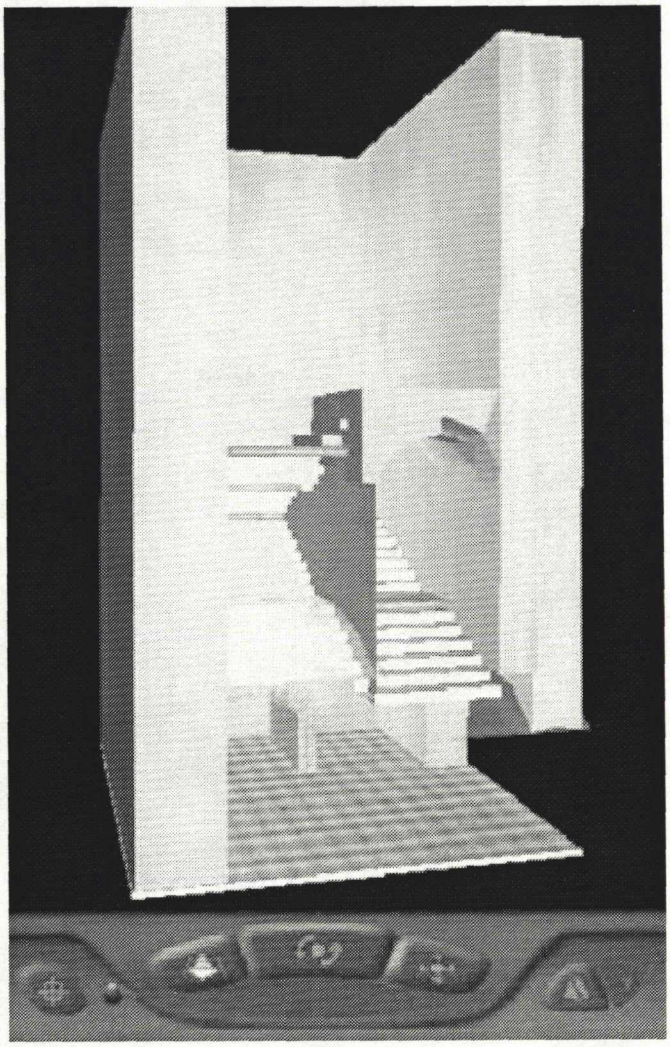

Figure 4. The VRML scene: front view

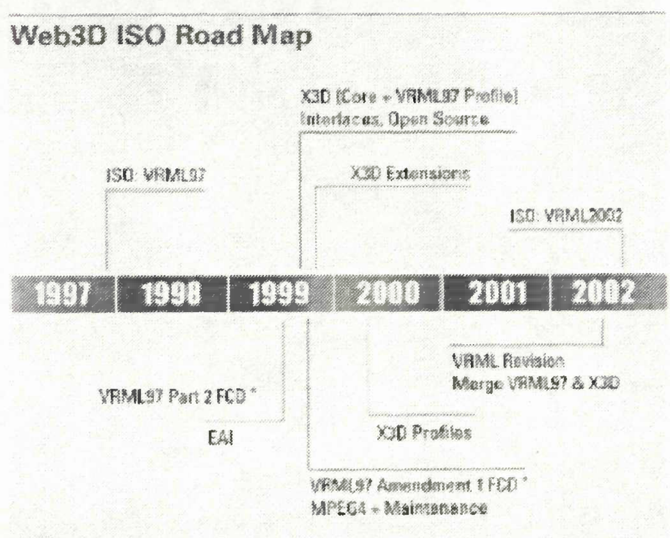

Figure 5. The road-map for the consortium to develop X3D standard

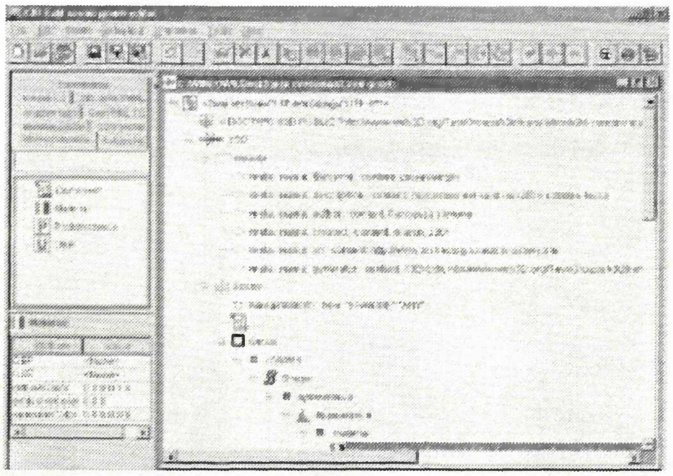

Figure 6. X3D-edit

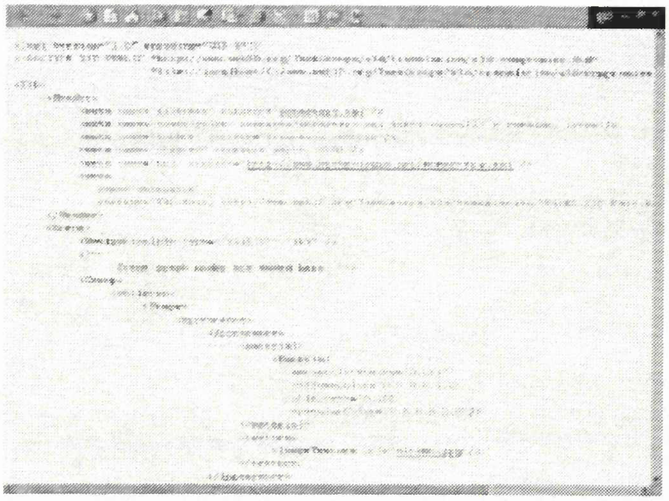

Figure. 7 The pretty-print generated applying a XLS