CLOSE-RANGE PHOTOGRAMMETRY APPLIED TO ARCHITECTURAL RESTORATION

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KEY WORDS: Digital Photogrammetry, CAD, 3D-Modeling, Extensible 3D, Scalable Vector Graphics, Internet/Web

ABSTRACT:

Close-Range Photogrammetry applied to architectural restoration has a long tradition. Basic ideas were formulated 1860 by Albrecht Meydenbauer addressed to the Prussian Conservator. First results have been presented four years later. More than 100 years the photogrammetric process has been carried out by experts, using high sophisticated optical and mechanical equipment for recording and evaluation. Evaluation is the process to convert the perspective photo into a true scale orthographic drawing.

Development of digital photography and PCs transferred the workflow to the desktop of the architect. The end user is now in charge of his evaluation. He can formulate his requirements. Recording, plotting and further processing is in one hand. According to this change, the Izmir Institute of Technology is setting up a Laboratory for Photogrammetry. This project is accompanied by the co-operation between IYTE and the University of Applied Sciences, Bielefeld.

Taking into consideration the development of second-generation Web applications, the project scope is beyond the production of 2D drawings. Today we focus on structured storage of information, apart from the application. The data basis should be presented in Scalable Vector Graphics drawings and Extensible 3D models for virtual walkthroughs. Media for data exchange is the Web.

This contribution introduces the concept of the new laboratory in Izmir, formulates the requirements to photogrammetry from the point of view of an architect and finally describes a complete workflow of the modern concepts applied to heritage documentation.

1. THE PROJECTED PHOTOGRAMMETRY LAB AT IYTE

The MS Program in Architectural Restoration at IYTE aims at establishing an interdisciplinary approach for education, research and application in the field of conservation of historical buildings. It is open to graduate students in architecture holding a bachelor degree. In the future years, however, the program will permit the training of architectural conservation professionals with different backgrounds such as architects, engineers, planners, conservators, archaeologists, historians, surveyors and managers. The tools necessary for the measured survey of historical buildings are being provided from the Central Surveying and Topography Laboratory of the Faculty of Architecture at present (*http://likya.iyte.edu.tr /arch/restoration/department.htm*).

The projected Photogrammetry Laboratory at IYTE aims at the improvement of the quality of conservation education and practice in the country. The establishment of the laboratory will evoke consciousness on the necessity of accurate cultural heritage documentation and allow the creation of a platform for research on the discipline of documentation for architectural conservation purposes. It will promote multi-disciplinary approach and teamwork. The production of accurate information on architectural heritage stemming from an understanding of the values, which are the reasons of conservation of that specific heritage, is desired. Therefore, it is important that the documentation phase should be considered as a part of the whole conservation project and be carried out by the same conservators who will be in charge of the conservation decisions. In other words, the ones who will use the knowledge should be responsible of producing that knowledge.

In order to reach the mentioned objectives, the laboratory is structured around three main themes:
- Recording techniques
- Documentation theory
- Information management

The recording techniques include practices with wide variety of tools and their integration options under different conditions. Conservation experts with sufficient skills of metric survey techniques to historic buildings and sites will be trained. In the later years, mid-career opportunities will be provided. The documentation theory includes the history of architectural documentation, the key concepts of metric surveys, the principles for determination of the level and method of recording necessary; and the related international guidelines. The importance of selecting a documentation method in accordance with the conservation needs of a specific case will be underlined. Information management includes classification, access and dissemination of end results.

2. ARCHITECT'S VIEW TO PHOTOGRAMMETRY

Closing the gap between information users (architects, planners, archaeologists, art historians, managers, etc.) and information providers (photographers, photogrammetrists, surveyors, etc.) is considered as a challenging activity in cultural heritage practices (Letellier, R. and Gray, C., 2002). While interdisciplinary research is aimed in the projected photogrammetry laboratory at IYTE, the training will be provided for the candidates of conservation experts who have a bachelor degree of architecture in the first hand. Therefore, it is important to present the key issues in the management of the

documentation phase and the documentation tools used in the field of architectural conservation.

2.1 Management of the Documentation Phase in an Architectural Conservation Project

The conservation project starts with the definition of the scope. In turn, the context, scale and presentation format of the documents to be produced is determined in accordance with the scope of the project (Mediterranean Action Plan, 1992). It is known, that measured surveys can be prepared more accurately and in a limited time, when the state-of-the-art recording tools and technologies are utilized. Nevertheless, the documentation phase should be planned considering both the low-cost recording methods and the state-of-the-art recording methods in accordance with the aim, budget, time schedule, technical opportunities of the conservation project (Letellier, R. and Gray, C., 2002). At this point, the article sixteen of Venice Charter, which is an important international document in the field of conservation, should be underlined (ICOMOS, 1964). The article sixteen implies that the activities of heritage recording, documentation and information management should be integrated into a conservation management process. It is also known that the documentation should not be considered only as a guide for the conservation project, but also as a scientific document presenting the condition of the resource before, during and after the conservation applications, if one wants to measure change over time (Kuban, 2000).

Preliminary studies should be conducted in order to identify the outstanding values and to determine the physical condition of the building (Feilden, 2001). When the values are classified, it is possible to examine them under the two main subheadings as historical and aesthetic (Riegel, 1996; Kuban, 2000; Jokilehto, 2002). For the preliminary evaluation of the values and the physical condition, basic orthogonal drawings (plan, section and elevation) in scale and photographic survey providing information about the current situation of the resource may be sufficient.

However, for the preparation of an application project, analytical documentation is a must. The analytical documentation has the aim of determining the spatial alterations and structural damages of the building. The data collected set a base for the precise ranking of values and the determination of the related conservation design; definition of the strengthening techniques and materials that will be used, and the technical staff needed for special applications. In the analytical phase, the resource should be recorded by sensitive metric survey. A precise measured survey supported with excavation, wall and ground drilling, examination of materials, etc. is desired (Feilden, 2001; Ozkut, D., 2004).

2.2 The Documentation Tools Used in the Field of Architectural Conservation

Sustainable techniques of documentation for conservation purposes should be searched in accordance with the realities of each country (Almagro Vidal and Almagro, 2005). Training of local conservation experts with practical and low cost tools of documentation is important for Turkey. So, in the structuring of the photogrammetry laboratory, tools of low cost and simple handle are considered. There are many examples of sophisticated recording works carried out by skilled scientific institutions. However, the key element here should be to train candidates of conservation experts with simple, easy and low /

medium cost systems, which they can benefit from in their future careers. These documentation tools of architectural conservation can be grouped as recording tools, evaluation tools and representation tools.

2.2.1 The Recording Tools: The tools of recording are analogue, digital and video cameras for photographic recording of the current state; manual measurement tools such as hand tape, bubble level, etc.; topographic measurement tools such as electronic theodolites and photogrammetric measurement tools such as precise cameras and laser scanner. The close-range photogrammetry is a tool of high potential to document constructions graphically. The fieldwork is realized in a rapid way and the office work is relatively simple once you are familiarized with the technique. (Nunez, et. all, 2005).

The aim in the related laboratory training is to provide effective understanding of the techniques involved in the application of metric survey to historic buildings and sites. For example, a demonstration on three dimensional laser scanner can be carried out. It is difficult, however, to access this technique in regular applications because of its price in Turkey for the time being. Therefore, the real effectiveness of the data collected in relation to its cost should be underlined. Another demonstration can be carried out on camera calibration. The importance and principles of correcting distortion in cameras should be basically understood, although a conservation- architect will often get help from a photogrammetry engineer for this task in his / her future career. As general rule, the scale from modest to sophisticated should be followed in the training process.

2.2.2 The Evaluation Tools: Evaluation of the data collected starts with information management. Thus, prior to any further activity, the collected data should be cataloged. Data structure and internal organization should be provided in order to facilitate future retrieval and access. Today, the primary tool of information management is a cataloging software such as PostgreSQL, Open Office, etc. Another software that should be introduced at an introductory level is Geographic Information System, which is a computer based system designed to manage, retrieve, display and analyse complex data necessary for conservation plans for cultural heritage sites.

An indispensable step in data evaluation is oriented to graphical documentation. These can be drawings or photographs. From the drawing point of view, the results of the conventional measured survey can be hand-drafted or they can be evaluated in the computer environment. From the photograph evaluation point of view, rectification and photogrammetry processes should be considered. The control points necessary for rectification process can be provided from topographic survey or direct measurements. The results of photographic rectification can be evaluated by a variety of softwares such as ASRix, Pictran, Rollei, etc. The tools of close range photogrammetry are a PC, an evaluation software such as Rolleimetric, Pictran, etc. and a stereoscope, if they are making stereo-photogrammetry. The students should use the evaluation software to acquire some practice in orientation and bundle adjustment, if they are making multi-image photogrammetry; stereo viewing and stereo plotting, if they are making stereo-photogrammetry; and three dimensional measuring. They should understand the amount of time needed to get a good plotted drawing.

2.2.3 The Representation Tools: The representation tools of architectural conservation are closely related with the representation tools of architecture. The architectural representation technique as a language of thought has undergone a series of transformations through out the history. Today, the representation of space with all its historical layers has reached to an excellent level with the help of CAD – the data capture, modeling and presentation environment. There are a number of CAD softwares to consider (Autocad, GID, etc.). Orthographic drawings (plan, section and elevation), axionometry and perspective are pioneering tools to express the conservation-architect's survey and analysis of the existing state of a historical resource, and also her / his proposal for the continuity of the survival of the resource (Robbins, 1994). The analytical approach in architectural drawing is an outcome of Renaissance thought. After this threshold, important developments have taken place. In the modern period, reading of architecture as space (Zevi, 1993), being objective and rational in the selection of representation techniques and making use of the concept of abstraction in order to represent reality (Duruk, 2000) have become important. Today, the orthographic drawings are still powerful tools of architectural language. Nevertheless, the true representation of space via three dimensional models in computer environments is investigated extensively as an outcome of the architectural philosophy of the period.

Within this frame, the appropriateness of the representation technique with regard to the concept behind can be claimed as the key point to question, while defining a methodology for architectural conservation drawings. Three dimensional cad models are objective tools of describing three dimensionality (Hanke and Grussenmeyer, 2002). They are measurable. They do not suggest a standpoint; viewing of the resource from many different directions and standpoints is possible. Their construction take time, but the end-result can be used to produce a variety of representations such as orthogonal drawings, axonometries, perspectives; and both two dimensional and three dimensional web graphics. Orthogonal drawings, when enriched with rectified images, will help the analysis of building elements and problems on each building surface. Axonometric views will be helpful in the analysis of the historical space. Perspective views are provided from the model; if pictorial representation is desired. Web graphics are effective for archiving and dissemination of data. Interactive viewing by the user becomes possible. Therefore, the model makes it possible to structure the desired correspondence between the representation and perception.

3. GRAPHICAL REPRESENTATION OF BUILDING SURVEYS FOR THE WEB

3.1 Conversion from CAD drawings into Scalable Vector Graphic files

3.1.1 Web 2D – Flash or SVG? SVG (scalable vector graphics) is the World Wide Web Consortium (W3C) standard definition for interactive 2D Web graphics. That format includes text, bitmaps, vector graphics, animation and interactivity - everything from one source. SVG formats may be generated with simple text editors, XML tools or converters. SVG files scan be viewed with stand-alone browsers or plug-ins for Web browsers. Flash is a proprietary format for animations from Macromedia. The format far spreads and is supported by Macromedias powerful animation tool. Despite this software there are several good reasons to apply SVG.

SVG can be used without sophisticated authoring software, a simple text editor is sufficient. Easy access via script languages is provided. The format is very well structured, the source is readable as a text format, while Flash is embedded in binary formats. Referencing of external images enables easy updating of SVG presentations. Flash takes advantage from embedded images. But updating means recompiling. SVG references images and supports a much wider colour space and colour management. Flash animations are replayed as a series of single frames. Every image is precalculated and stored in the animation. SVG has extended features by applying interpolations between two positions. This results in a much better structured and shorter code.

The Web community provides resources like tutorials, scripts, software and application samples. Not least SVG benefits from the advantages of a non-propriety standard.

Adobe and Apache offer common viewers for SVG. Adobe's SVG viewer is provided as a plug-in for Web browsers or as a stand-alone version. Downloading from www.adobe.com/svg leads to a quickly and automatically installation. Clicking the right mouse button in a SVG window opens the context menu with access to the functions zoom-in, zoom-out, panning, help and some others. There is no learning curve necessary to handle the Adobe SVG viewer.

3.1.2 Converting from CAD to SVG: For CAD files (DWG, DXF) and bitmaps (BMP, WMF) are converting tools existing. I downloaded SVG Factory, ACME CAD Converter and CAD2SVG for test purposes from the Internet. Despite some useful functions, all converters did not meet our requirements. The major disadvantage of all tested converters is the loss of the source coordinates in the target file. In result to that investigation we decided to write our own conversion software from DXF to SVG.

The drawing exchange format is separated into sections. The entities section contains the drawing elements like points, lines, polylines, arcs and block insert statements. The blocks geometry is stored in the blocks section. Appearance attributes are bundled in the layer information. The conversion software parses the blocks and entity sections and translate the accepted objects into the SVG structure and mainly in path information. Layer belongings will be converted to class names for later use with style sheets.

The SVG specification is separated into graphic elements, container elements, graphic referencing elements and text content elements. The file starts with the XML prologue as parsing information:

```
<?xml version="1.0" standalone="0">
```

The root tag for a SVG document is <svg>. The attributes width and height define the visible area for the document starting in the lower left corner of the frame. The attributes *viewbox* and *preserveAspectRatio* define the area of the graphic scaled to the width and height values. The concept is well known from basic graphic programming libraries. Identification of name space for xml is referenced by the xmlns attribute.

```
<svg xmlns=http://www.w3.org/2000/svg
    width  = "400" height="300"
    viewBox="0.0 0.0 1024.0 764.0"
    preserveAspectRatio="xMinYMax meet">
```

The code is continued in gruous:

```
<title>exposure arrangement </title>
<defs> for definitions referenced
         later in the code </defs>
<desc>    Descritption like:Converted
         from DWG to SVG </desc>
<g>
  <!-- the graphic content is embedded
  here -->
</g>
</svg>
```

The tags <title> and <desc> are used for descriptions and are ignored by the render engine. Tag <g> is for grouping graphic elements. Transformations or attributes defined for a group will affect all the child elements of this group.

Graphic content consists of predefined primitives like rectangle <rect>, circles <circle>, ellipses <ellipse>, lines <line>, polylines <polyline> or polygons <polygon>. Appearance of the objects is defined by style-attributes like *fill* or *stroke*, which can be set by style sheets or as particular shape properties. Arbitrary lines are constructed from the definition given in the <path> tag. The notation is similar to Postscript. A list of points starts with the letter d followed by a string including the co-ordinates with a letter in front. The letter indicates the characteristic. M stands for move to, L for line to, C stands for curve and so on. A z at the end of the list indicates a closed path. The co-ordinate pairs are separated by blanks. The following code shows a path with two straight lines rendered in black colour.

```
<path d="M499.93 340.11L499.91 340.06
499.88 340.00 " fill="none" stroke="black"
stroke-width="0.2"/>
```

SVG is disposed to animation and interactivity. An anchor marks objects as sensitive areas. Defining a hypertext reference guides to other documents. Objects can act in response to events. SVG treats Xlink as an own namespace. This namespace is referenced with xmlns:link. The elements providing a link are covered with the tag

```
<a  xlink.href="url"  target="_blank">  <g>
graphic elements </g> </a>
```

Where url is the reference to a document in the web and can pass parameters to that source. Target points to the target window where the new document has to be rendered. Code that is not included in the XML or SVG specification like JavaScript or CSS, must be terminated between

```
<![CDATA[ <!- - script code or CSS code --
> ]]>
```


Figure 3.1: Façade drawing in SVG format applying style
sheets

The project mentioned in this paper, is a documentation of a watermill, refer to *www.imagefact.de/wassermuehle-kalletal*. Section drawings are formulated in SVG as well as the interactive map of the photogrammetric exposure arrangement. Symbols for photo positions contain a link to a PHP software. Clicking a ling creates a page displaying the image and according values from the XML data base and enables the user to make single image measurements on-line.
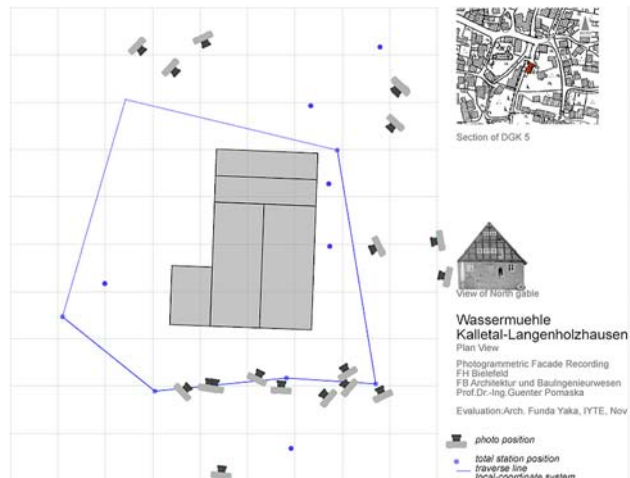

Figure 3.2: Interactive SVG map of the photogrammetric
exposure arrangement

3.2   Modelling Virtual Reality Scenes

Virtual Reality (VR) is a reality near description of 3D worlds enabling interactive viewing by the user. Amongst visual descriptions like geometry and material, physical properties belong to a definition of a virtual world. A user of a virtual world can navigate in the scene, interact with objects and control objects (picking flowers and arrange them) and can communicate with other visitors in the world.

Applying CAD systems enables geometric modelling, material definition and to a certain extend the formulation of VR components. The CAD data structure does not suit to real time rendering. Conversion into a scene graph structure is required.

Rendering a scene to a 2D surface like a monitor, is known under the term desktop VR or "window on world" projection. Distribution of VR worlds in the Web needs client sided a browser plug-in or a stand-alone viewer.

3.2.1   Scene Graph Structure: Due to compatibility reasons of the used software tools, the following text is still based on Virtual Reality Modelling Language (VRML). The newer formulation of VRML that is equivalent to the XML standard, is Extensible 3D (X3D). Extensible 3D defines a system that integrates 3D graphics and multimedia. Conceptually, each X3D file is a 3D time-based space that contains graphic and aural objects that can be dynamically modified through a variety of mechanisms. Standard VRML encoding can be still used in X3D environments. A conversion tool from classic VRML to XML encoding is provided by X3-Edit from *www,web3d.org*.
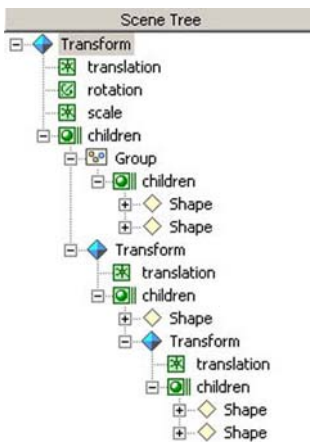

Figure 3.3: Scengraph structure

A scene graph is necessary for optimisation strategies. The VRML tree structure exists of nodes, the objects in the scene. A transformation may be applied to each grouping node in a scene. A grouping node contains children nodes. Children nodes can be simple shapes, the building blocks of a scene, or again grouping nodes. Shapes define the geometry and the appearance of objects. Parameters that distinguish nodes from other nodes of the same type are termed as fields. The grouping node *Transform* defines a coordinate system for its children relative to the parent system. Fields of a *Transform* node are a. o. translation, rotation or scale. Figure 3.3 displays a typical scene graph structure, as it occurs in a VRML editor. VRML files are stored with the extension *wrl* or compressed with the extension *wrz,* for X3D browsers the extension *x3dv* is required, if classic encoding is used.

3.2.2   Conversion from CAD Models into VR Files:
Converting CAD models to VRML scene graphs applying the CAD export function, usually results in unstructured shape nodes. Reuse of geometry and material definition is   not supported in most cases. A first method to structure a complex scene is provided by the *Inline* node. Inline commands complete a scene description by referencing external files. CAD models may be partially converted by selecting layers or objects. The generated code requires in most cases some modifications by editing.
Shapes   consists of geometry and appearance. Material and textures are stated in the *appearance* node. Material can be specified by setting values for ambient intensity, diffuse color,

emissive color, shininess, specular color and transparency. We don't discuss in detail the meaning of the fields here. But it is obvious that diffuse colour is the object colour, formulated as components of red, green and blue in a range from 0–1, and transparency is a value for the opacity of a surface. A shape is reads as follows:
```
Shape {
  appearance Appearance {}
  geometry Box {}
}
```
We can predefine the *Appearance* in an external file (in the expressed example named *mill_material.wrl*) as a prototype. Here the identification is *WATER*:
```
#VRML V2.0 utf8
PROTO WATER []{
  Appearance {
    material Material {
      diffuseColor 0.189 0.197 0.266
      transparency 0.6
    }
  }
}
```
Referencing the *apperance* node in the shape file writes as follows:
```
#VRML V2.0 utf8
EXTERNPROTO WATER[]
"mill_material.wrl#WATER"
Shape {
 appearance WATER {}
 geometry Box {}
}
```
The parser interprets that *WATER* is coded as a prototype in the external file *mill_water.wrl* under the name *WATER*. The external definition will be used every time the appearance node refers to *WATER*. Applying a material library provides a couple of benefits. In case of changing the appearance of a material, it has to be done only once in the material file. Furthermore it can result in memory savings and performance gains. In the same manner prototype geometry can be referenced including transmission of current parameters. The following code defines a simple tree, stored in the file *mill_shapes.wrl*.
The name of the proto is *TREE* and receives field values for translation and rotation. The field Type is *SFVec3f*, one of the different data types used in the language. While calling the proto, parameter transmission is coded by the statement *IS*.
```
#VRML V2.0 utf8
PROTO TREE [ field SFVec3f transParam
                0.0 0.0 0.0
           field SFVec3f scaleParam
                1.0 1.0 1.0 ]{
Transform {
  translation IS transParam
  scale IS scaleParam
  children [
    Transform {
 # Tree definition at position 0.0 0.0 0.0
    }
  ] # end children
}# end transform
}#end proto
```

Positioning the proto in a scene is than coded by the statements:

```
#VRML V2.0 utf8
EXTERNPROTO TREE [field SFVec3f transParam
             field SFVec3f scaleParam
             ] "mill_shapes.wrl"
```

```
Transform {
  children [ TREE {transParam
                    102.0 10.0 -101.
                    scaleParam
                    0.75 0.75 0.75 } ]}
Transform {
  children [ TREE {transParam
                 105. 10.0 -103.0
                 scaleParam 1.0 1.0 1.0 }]
```

The above mentioned procedure is comparable with the AutoCAD *Insert* command, positioning blocks into a drawing. Our DXF to VRML translator reads the *blocks section* from AutoCAD DXF-files, constructs the VRML shapes and afterwards reads the *Insert* commands from the DXF *entities section* for referencing the protos as shown.

A conversion workflow from CAD to VR, that recognizes 3D shape libraries and external material definitions will lead to an efficient model structure with memory savings and high rendering performance.

3.2.3 **Modeling of Animation:** Interpolator nodes are used to drive the behaviour of objects. To make things simple, look at the water wheel (Figure 3.4), centred in the origin of the local co-ordinate system, parallel to the y-z plane. Interpolator nodes have two fields, the *key* for input values and the *keyValues* that are interpolated by the key field.
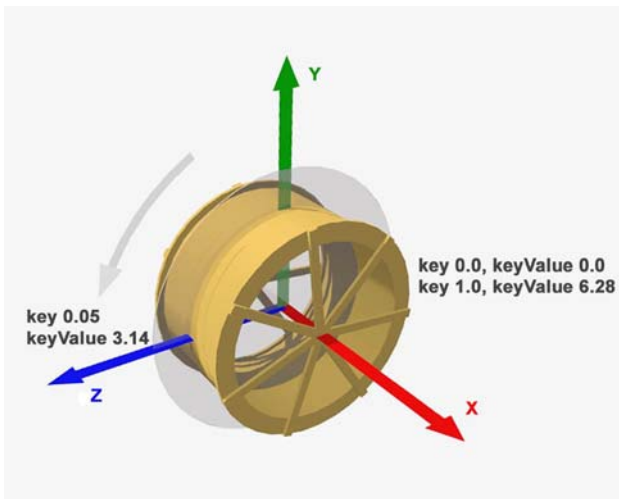

Figure 3.4: Key frame animation

```
DEF wheel Transform {
  translation 117.4602 10.3024 -116.0009
    children [
    DEF ori OrientationInterpolator {
      key      [0.0 0.5 1.0]
      keyValue [ 1 0 0 0.0,
                 1 0 0 3.14,
                 1 0 0 6.28]}
Shape { #definion of the wheel }
  ]#end of children
} # end of transform
```
We define an *OrientationInterpolator* named *ori*. For every value in the *key* field, a *keyValue* for the interpolator is needed. The wheel should rotate around the x-axis in one time unit a full turn. The rotation value at the time 0.5 is 180 degrees, at the time 0 and 1 zero degrees, noted in radians. A time sensor is requested to generate rotation. Changing time fraction has to be routed to the *OrientationInterpolator*.
```
DEF wheel_timer TimeSensor {
    loop TRUE
```

```
    cycleInterval 10
#one full turn of the wheel needs 10 sec
}
ROUTE wheel_timer.fraction_changed TO
     ori.set_fraction
ROUTE ori.value_changed TO
     wheel.set_rotation
```

3.2.4 Navigation and Translation to X3D: All wrl-files, translated from the CAD model, are collected in a subdirectory and referenced by the *Inline* node from the file *index.wrl*. Navigation information is coded in the *NavigationInfo* node. The fields define the avatar (visitor in a VR world), it's size, type of possible navigation (walk, fly, examine), speed and headlight. Some viewpoints may be predefined, and can be selected form the context menu of the browser (right mouse click). The *Background* node defines the environment settings. Illumination of the scene comes from the *DirectionalLight* node and the headlight setting.
```
#VRML V2.0 utf8
#    Watermill index.wrl gp 01.2006
NavigationInfo {avatarSize [.3, 1.8, .5]
speed 1 type"ANY" headlight TRUE}
DEF NORTH_WEST Viewpoint { position
125.09540 14.24956 -93.97775
orientation 0.02054 0.99979 0.00000 0.67126
description "NORTH_WEST" }
#    environment information
Background { skyColor [ 0.0  0.0  1.0,
1.0 1.0 1.0,0.0  0.0  0.0,  0.0 0.0 0.0 ]
skyAngle [ 1.5, 2.0, 3.14 ]}
DirectionalLight { ambientIntensity  1.0
color 1 1 1
direction 0 -1 0
intensity 0.5}
#    import objects
Inline {url "mill_terrain.wrl"}
Inline {url "mill_water.wrl"}
Inline {url "mill_fluting.wrl"}
Inline {url "mill_wheel_rot.wrl"}
Inline {url "mill_building.wrl"}
Inline {url "mill_people.wrl"}
Inline {url "mill_trees.wrl"}
```

Parallelgraphics offers with Cortona a plug-in viewer for Windows PC, MAC OS and Pocket PCs, download from *http://www.parallelgraphics.com*. With Octaga a VRML-client is available, that can display VRML 2.0 and X3D files as well as a browser plug-in or stand-alone viewer. One can download the software from *http://www.octaga.com*.
Standard VRML encoding with the X3D header:
```
#X3D V3.0 utf8
#PROFILE Interactive
#META "filename" "mill_building.x3dv"
```
runs in x3d browsers if the file extension is x3dv.

Software for converting VRML 2.0 files to X3D formats is available from the National Institute of Standards and Technology. The software starts from the command line in a Java environment and translates VRML encoding into the XML encoding conform X3D language definition, see the references for a download location. It is also available with the X3D-Edit tool, provided by *www.web3d.org*.
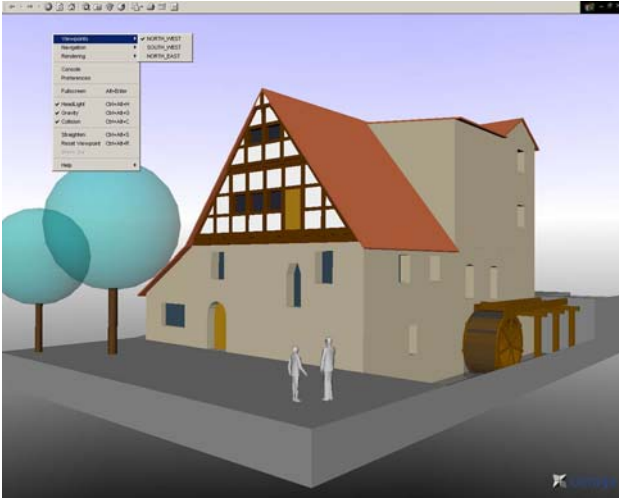
Figure 3.5: Case study watermill: Conversion from CAD to VRML displayed with Octaga, showing the navigation context menu

A zip-file of the watermill VR model can be downloaded from *www.imagefact.de/watermill-kalletal/vrml/mill_wrl_x3d.zip.* After extraction start the index.wrl or index.x3d file, located in the appropriate subdirectories. The files *mill_material* and *mill_shapes* can be altered to use textures and alternative tree symbols.

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