DELIVERABLE

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D5.4 - 3D/VR Training materials

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Contents

1 Executive Summary

This training manual describes how to make 3D resources for Europeana through the use of 3D PDF files. Chapter 2 refers to deliverable D5.1 and describes the requirements and possibilities of PDF as a 3D delivery platform as well as other solutions for 3D delivery that could be used instead of or in addition to 3D PDF when specific opportunities or issues are present for certain 3D content providers. This manual provides a detailed description of the workflow for creating 3D PDF resources through Adobe Acrobat X Pro which is a commercial but not so expensive software application. Appendix 2 lists the 3D file formats commonly used for cultural heritage applications that can be converted to 3D PDF. Appendix 3 provides links to other PDF authoring environments.

The capabilities of the 3D PDF are described in technical detail in Chapter 3, which analyses how these capabilities can be used to support typical functionalities for the cultural heritage domain in general, and for archaeological and architectural monuments in particular.

Chapter 4 describes the consecutive steps in the process of how to make the 3D data ready for transformation into a 3D PDF file. This chapter outlines many of the potential issues and provides a general approach to design a specific workflow that each 3D content provider needs to fine tune to their own data, available software and organisation structure. One aspect of this workflow is the conversion of the file formats that are provided by the 3D content provider into 3D PDF. Appendix 2 provides a list of 3D PDF file formats, commonly used in cultural heritage, which can be imported directly into Acrobat X Pro. Other formats need an additional conversion step.

Chapter 5 provides a step-by-step guide to creating different types of 3D PDF resources. This is supported by the large amount of examples that are available in the section Resources/Virtual Reality of the CARARE website (see overview in Appendix 1).

Chapter 6 discusses the preparation and creation of metadata for the 3D resources, which is a parallel process to the creation of the 3D resources itself.

Finally, Chapter 7 outlines the different steps and issues of delivering the 3D resources to Europeana.

Appendix 4 describes a Case Study for the Hellenistic-Roman theatre of Paphos, Cyprus.

To road test these materials, a two hour training session was been provided twice for CARARE partners at the Plenary meeting in Vilnius at the end of September 2011.

2 Introduction

As explained in detail in the D5.1 deliverable, the creation of 3D resources for Europeana is in fact a process of publishing existing 3D content to a 3D resource that can be used by the public at large. Most of the 3D content within CARARE will be made available as 3D PDF files. Some 3D providers will use other 3D technologies to provide certain functionalities that 3D PDF does not have. These alternatives are, for example, based upon WebGL that allows viewing of 3D content directly in a browser without use of a plug-in. WebGL is currently supported by Chrome, Firefox and Safari[1], but not by Internet Explorer (about one Europeana user out of three uses IE). A case study implementation by STARC can be found in Appendix 4.

Several presentations of this approach have shown that the cultural heritage community support it because it provides a simple but robust workflow and implementation. Recently, the take-up of 3D PDF has been increasing in the heritage community and PDF publications with integrated 3D are appearing on the Internet[2]. 3D PDF also meets the following requirements by Europeana:

- available on every computer platform and every major operating system,
- standardised and open format (current PDF format, i.e. PDF 1.7, is ISO 32000-1 standard),
- easy to use, including VR,
- no software install needed (90% of all computers have a 3D PDF enabled reader installed).

The first small caveat here is that those 10% of computers that do not have a 3D PDF enabled reader (i.e. the free Acrobat Reader) are mostly Mac users that rely on the free PreView application that is preinstalled on every Mac but that lacks 3D capabilities as it is still based on a much earlier version of a PDF reader. Most Mac users, however, will be willing to install Acrobat Reader as it provides a lot more functionality than PreView and is also free.

The second caveat is that – although good PDF readers are available for mobile devices – none of them yet supports 3D visualisation. As high-spec graphic chips start to be integrated into those mobile devices, this should no longer be a technical problem. As 3D PDF is by many people still considered as a tool for engineers and product designers, the use of 3D PDF on mobile devices is probably considered to be too marginal at the moment to be provided as a mainstream application.

This training manual outlines the production of 3D digital resources in PDF format (see D5.1) based upon Adobe Acrobat X[3]. In Appendix 1 is a list of 3D PDF examples that are available on the CARARE website under the section Resources[4]. There are other PDF authoring environments that allow the creation of 3D PDF documents (see Appendix 3) in a similar way.

Creation of PDF files with 3D functionality with the Acrobat application requires the Pro version or Suite[5] version. If conversion of 3D files into PDF is needed (see details in Chapter 3), then the

[1] WebGL is available in Safari under OS 10.6 but not enabled by default, as it is still in test phase. Go to Preferences, click the Advanced Tab, check Show Develop Menu and select Enable WebGL.

[2] www.nino-leiden.nl/doc/Annual Report NINO-NIT 2010_3D.pdf

[3] http://www.adobe.com/products/acrobat.html

[4] http://carare.eu/eng/Resources/3D-Virtual-Reality

[5] http://www.adobe.com/products/acrobatsuite.html

Tetra4D plug-in called 3D PDF Converter[6] is also required. If you don't have Acrobat X, you can buy the combined package (Acrobat X Pro + 3D PDF Converter) at Tetra4D. The 3D Reviewer application comes with the 3D PDF Converter software and allows the preparation of 3D data (editing, merging and animating 3D data plus advanced light control). This training manual will not go into the 3D Reviewer functionality since this covers advanced 3D operations that in most cases will not be needed for 3D heritage data.

The software described in this manual is Acrobat X Pro with 3DPDF Converter 3.2. The list of supported formats commonly used in cultural heritage applications can be found in Appendix 2, the full list is available at Tetra4D. Other 3D PDF authoring tools may have other formats that are supported (such as SketchUp).

[6] http://www.tetra4d.com/products.html

3 The 3D capabilities of PDF

The CARARE D5.1 Deliverable described in detail the 3D capabilities of PDF and how they can be combined to support functionality that is useful in the context of cultural heritage such as evolution through time, the structure of a monument, cross sections through a site or annotated views with measurements or restoration notes. In this chapter, we go through the basic capabilities of 3D PDF and how they can be used to construct this useful functionality. The advanced capabilities such as animation and Java scripting are not covered in this training manual as there was up till now no requirement for these from any of the CARARE 3D content providers. Additionally, the use of the 3D Reviewer software that allows advanced preparation of the 3D data such as merging or editing of 3D files or setting up specific lighting conditions is also not included but we indicate in this manual where this software could be useful. If the need arises later on in the project to create training for these advanced capabilities, specific training material will be provided.

In this chapter we will cover the following basic capabilities:

- conversion of a range of formats to PDF,
- texture mapping,
- layering,
- named views,
- actions,
- cross sections.

3.1 Conversion of 3D file formats to PDF

3D PDF files use two different internal file formats, PRC and U3D. From the technical specifications and from testing several 3D objects, we have learned that the U3D format is much more suited for cultural heritage data than the PRC format, which specifically has been designed for the CAD/CAM/CAE domain (see D5.1).

Within the current authoring environment of Acrobat X, you can integrate 3D into your PDF file if you have your 3D model available in either U3D or PRC format. Free 3D processing software, such as MeshLab[7], allows the transformation of many 3D formats into U3D format. You can insert any U3D (or PRC file) in a PDF file through Acrobat X (see Chapter 5) without going through a conversion process. Note that the conversion process (see Chapter 5) does a little more than conversion only (it performs compression, omits unnecessary data, etc) so your U3D file needs to have the right characteristics before insertion.

If this doesn't work, because you are unable to convert into U3D format, or because the converted U3D file has some issues, you need to follow the general workflow in which you convert your 3D file through the 3D PDF Converter plug-in into a 3D PDF file with U3D structure.

[7] http://meshlab.sourceforge.net/

The 3D PDF Converter software supports a long list of file formats[8] for which an intelligent conversion into U3D or PRC is available. This list incorporates formats such as AutoDesk 3D Studio, Collada, VRML and Wavefront OBJ, and results in a one-step conversion process.

On the other hand, there are about 130 3D formats which are in use at the moment. This means that it is possible that the format that you use in your organisation is not supported by the 3D PDF Converter software. This can be solved in one of three ways and results in a two-step conversion process:

1. Most applications that create 3D models, through digitisation or modelling, provide a range of export formats, so you can save your 3D model in another supported format.
2. You can use separate converter applications that convert your format into a supported format. Most of these converter tools are available on the internet for free or at a very low cost.
3. You can use other third party applications that convert other formats than listed above to PDF (see Appendix 3).

It is required that you do some research and testing to find the most optimal conversion workflow from your 3D file format to PDF. This workflow will depend on the characteristics of the 3D model (texturing, layering, etc) as explained in the next sections.

In this conversion, you need to make sure that all required functionalities (layers, textures, …) and properties (units, layer names, …) of your original 3D model are preserved. Features that are unnecessary for the envisioned 3D PDF functionality (such as auxiliary lines, lights and cameras, …) can be easily removed in the conversion process to PDF. This is explained in detail in Chapter 4.

3.2 Texture mapping

A major advantage of 3D PDF is that it encapsulates everything you need for your 3D model into one file. Many 3D applications use separate material files and texture files in addition to the 3D shape data, etc., and use a convention where these auxiliary files need to be located (same directory, special subdirectory, …) . The conversion module has the intelligence to look for each file format for the right files in the conventional location, so in most cases little or nothing needs to done before conversion, as long as the location of the files after creation has not been altered.

There are several methods for texturing a 3D object, but we limit our discussion here to the two most commonly used methods which are *image mapping* and *vertex colours*. For image mapping, the 3D model has extra information about what part of a texture file maps to a certain zone of the shape. For example, in the case of uv-mapping[9], each vertex of a 3D model contains 'u' and 'v' co-ordinates of the texture image. For vertex colours, each vertex contains simply colour information, there is no texture image connected to the 3D model. Vertex colours are quite common for digitised objects while texture mapping is used for both digitised objects and modelled objects.

[8] http://www.tetra4d.com/products.html
[9] http://en.wikipedia.org/wiki/UV_mapping

3.2.1 Textures by image mapping

There are two types of texture image mapping: *continuous* and *triangular*. In the case of a continuous texture, the image is typically a photograph (for example of a brick pattern) that is mapped upon the 3D model. Continuous texture mapping is typically used when the 3D objects have geometrical shapes such as blocks, cylinders, … The kind of mapping hence refers to these geometrical properties (planar mapping, cylindrical mapping, …). For example, we don't want the brick texture to deform, so we have to map it onto planar objects. Additionally, these textures can be repeated (or "tiled") to cover large areas. This requires the texture to be created in such a way that it can be repeated seamlessly (see example of a roof tile texture below). As these textures in most cases represent physical materials[10], the scale factor of the mapping onto the object is crucial and should be preserved through conversion processes.

In case of a triangular texture, the texture of each triangle of the 3D model is more or less randomly stored in an image file (software which creates such a map sorts the triangles more or less by size to obtain an even resolution of the texture over the object). This kind of texture map is used for more complex objects that have no obvious or geometrical mapping. Textures are typically derived from photographs that are mapped upon the object through photogrammetric techniques.

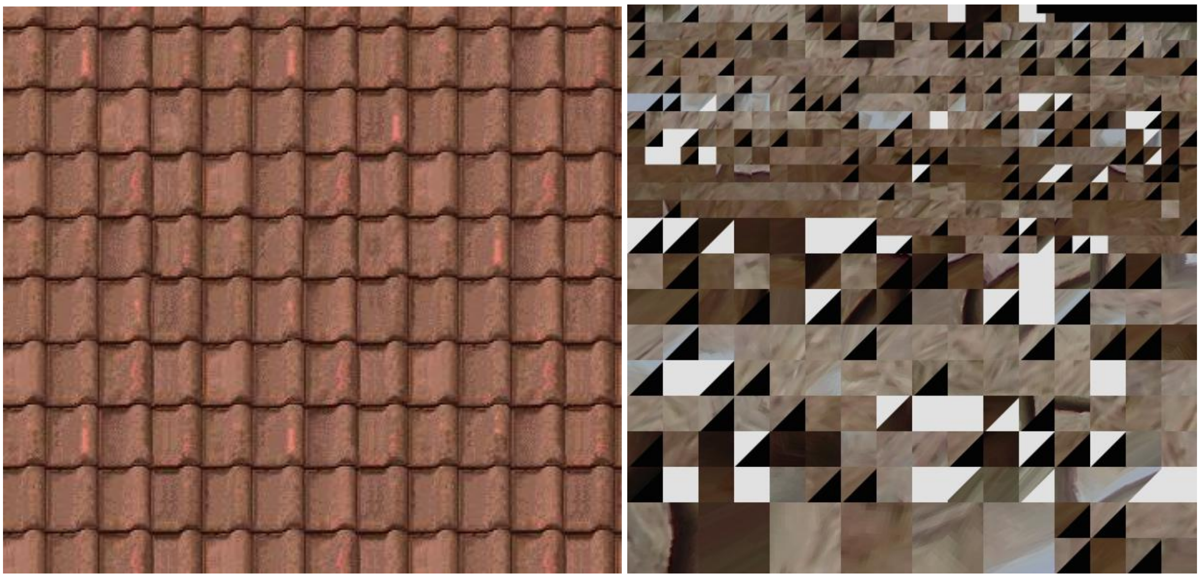


Fig.1: Continuous (left) and triangular (right) textures

In case you have *images mapped* onto your 3D object, you need to take care that the characteristics of the image mapping are not lost in the conversion process. As far as we have tested, the one-step conversion process by the 3D PDF Converter plug-in preserves very well all image mapping characteristics for the various formats. This is to be expected, as file format conversion is the core business of this application. The two-step conversion process however is prone to problems such as losing the scale of the image texture or losing the texture mapping altogether. This is especially the

[10] http://www.archibase.net/articles/2587.html/

case when optimised texture images (for example, through mip-mapping[11]) are used. This means that sufficient testing needs to be done before a certain conversion trajectory can be considered as appropriate.

3.2.2 Textures by vertex colours

In the case where you have *vertex colours* in your 3D model, and you have a one-step conversion to PDF, both PRC and U3D conversion preserve these vertex colours. When you have a two-step conversion process, however, you will need to use an intermediate file format that supports vertex colours, which limits your choice to Collada and VRML. In our tests, VRML proved to be the most reliable format.

3.2.3 File compression

When converting to U3D or PRC, you have the option to *compress* the resulting 3D file. Although very little documentation can be found on this topic, it is quite clear that compression does not alter the shape information (only lossless compression is done on the xyz information) while U3D compression mostly works on the image compression of the texture file (most probably JPEG image compression). Practically, this comes down to the fact that 3D models with many and/or large texture images show a significant reduction of 3D PDF file size without visible quality loss when compressed during the conversion process. However, if the texture file is not a continuous image (which you can check easily by visually inspecting it), significant compression is not a good idea as the quality of the resulting 3D PDF deteriorates.

3.3 Layering

Several 3D image formats, such as 3D Studio, allow layering which is preserved when converting to 3D PDF. These layers show up in the *model tree* of the 3D PDF file (typically shown in the left hand column). This layering, when designed properly while creating the 3D file, is extremely important for implementing VR functionality in 3D PDF. For example, you can show evolution by turning on and off the different phases, or you can show interactively the structure of a building by putting the different parts of a building in the appropriate layers. You can also compare the 3D model of a ruin against its virtual reconstruction by putting them in different layers and switching between them.

Hence, implementing certain VR behaviour in PDF does not come for free. It may require that the original 3D model is restructured into the right layers (see Chapter 4). Creating simple VR behaviour in 3D PDF is based upon *named views* that are linked to key words or images through *actions* (see following sections).

[11] http://en.wikipedia.org/wiki/Mip-mapping

3.4 Named views

Creating named views is the next step after conversion to PDF. A *named view* consists of a *camera viewpoint*, a set of *active layers*, a *render mode* and a *lighting mode*. Once these different parameters are chosen, they are saved as a *view* with a certain *name*.

The first step is to *select the appropriate layers* (if the 3D model consists of more than one layer) and hiding those layers that do not contribute to the view we want to create. By switching on and off layers, great functionality can be implemented. But such functionality does not come for free; it needs some thought and design. For example, we want to show how a building was made, layer by layer. This means that the 3D model of the building needs to be structured in layers that follow the construction process. Don't turn off layers that will not be visible from a certain point of view to optimise visualisation. As the users of the 3D PDF have the freedom to explore the full model at any time, the visibility of layers should be chosen from a conceptual point of view and not be related to the camera viewpoint.

The second step is to *position the camera* in the required way to visualise a certain part of the object in a certain way. To do this efficiently, there are different camera modes such as *rotate, spin, zoom*, etc., which are very intuitive. One camera mode of particular interest in scenes is *walking*, which is basically a horizontal movement throughout the scene. Just position your camera at the right height through, for example, *rotate* mode, switch to *walking* and walk to the required position. Alternatively, you can use the *Camera Properties* dialogue window to adjust your camera, including the lens angle. Normally we use a *perspective* camera but if needed you can switch to an *orthographic* camera.

When converting the object, you can choose to create automatically special named views such as *top, front, left*, … in perspective or orthographic mode. Such views are useful as quick overviews to assess the object. As most people in cultural heritage are used to such views – especially in orthographic mode – this is a very useful feature.

Normally, we will show 3D models in the *solid* render mode. If useful, the render mode can be changed for each named view. The *illustration* render mode shows the 3D object as a hidden line drawing. The *solid outline* render mode combines the *solid* and *illustration* visualisation and has the big advantage that the underlying structure of the model is also shown. The *shaded illustration* render mode is basically the same as *solid outline* but puts more focus on the line drawing and less on the solid shading.

When converting, a default *lighting mode* was chosen (see Chapter 4). But, if needed, every view can have its own lighting. Inside views, for example, could have a different lighting mode to the default outside lighting mode.

You can also define views that contain *measurements* or *3D annotations*. First define your measurement or 3D annotation in 3D, then chose the other parameters as described previously.

It is recommended to plan which named views are useful for visualisation and interaction. If the 3D model is just going to be visualised as an object, without any accompanying context information, the named views are simply helping the user to have an efficient assessment of the object (for example: top, front, …). If a link with images or text is envisioned, the named views result from the *interaction design stage* prior to the creation of the named views (see Chapter 5).

3.5 Cross Sections

A very useful functionality in 3D PDF is the visualisation of cross sections. This allows the definition of a transparent plane that deletes everything on one side of the plane and highlights the cross section by use of extra coloured lines if needed. Cross sections can be made through the X, Y or Z plane or through a random plane.

A cross section allows the user to assess the structure of the object and should be constructed with care. A good strategy is to use the named views *top*, *front*, … in orthographic mode to have a perpendicular view upon the cross section. The user can still look at the object from all sides, but a perpendicular view on the cross sections is most informative and follows existing practices in the documentation of cultural heritage.

3.6 Actions

Actions are used to link 3D visualisations to text and images to create simple VR behaviour. After definition of the full set, the named views can be linked to a zone in the document and one or more actions can be defined that will be performed when the zone is clicked.

The most basic use is to link a keyword or image in the text to a named *3D view*. In this way, the 3D model can highlight an aspect that is explained in the text, optimally viewed by the named view. In this way, the 3D model can be aligned with a photograph of an archaeological site or an old gravure of a building, showing how the building looked originally or how it looks today when compared to older depictions.

Other useful actions are *go to page* to show a 3D model on another page, or *go to document* to show another document containing, for example, site photographs or technical drawings.

Actions in a 3D PDF document are a simple and efficient way to create basic VR functionality without the need for animation or navigation. When changing from one named view to another, the 3D PDF visualisation module automatically creates an animation from one viewpoint to the other.

This has advantages for both the creator and user. Through actions, the creator of a 3D PDF file designs a flexible exploration mechanism that can be updated and expanded easily. For the user, actions provide a very simple way to navigate through the 3D models, creating an easy access to 3D for people that have little or no experience of 3D. This is a crucial element in our strategy to stimulate easy take-up of 3D resources in Europeana.

Experience shows that it is certainly possible to create actions on the fly, based upon a certain text that describes the 3D object. Nevertheless, we recommend that some effort is invested in designing the interaction with the 3D through *named views* and *actions* before starting the authoring of the 3D resource. This consists of defining the *keywords* that will trigger the actions, defining the *views* that are linked to the actions and defining the *overall structure* of the document.

A useful approach is to turn each 3D model into a 3D PDF file without any context information and make a first draft version of the named views per 3D PDF, based upon the available text and images. Once there is a clear relation between the keywords and the named views, the full 3D document can be assembled (see Chapter 5).

4 3D Data preparation

As the CARARE project focuses on creating 3D resources from existing 3D data, this chapter deals with the preparation of the data before the creation of the resources.

The **first step** checks if the available 3D data is complete and correct concerning:

- shape data,
- textures,
- layers.

This is not a trivial task. 3D data made for research or technical purposes can have small missing areas as this is not always important for the scientific or technical task it was created for. For example, laser scan data of a building could miss the top part of the walls if the laser was not able to reach these parts of the wall, but this could have been unimportant for the original technical use of the 3D data. However, a layman seeing the 3D resource, without knowing about the limitations of the scan data, could be puzzled or mislead by these apparent imperfections.

In most cases, there is too much data in the original 3D file. This should be removed as it will not serve any purpose in the final 3D resource for Europeana but nevertheless still take up space within the file. In the conversion process to PDF (Chapter 5), some types of unnecessary data can be eliminated. Other unnecessary 3D data needs to be removed manually. Sometimes, small corrections are needed to make the data work. If you show, for example, several phases of an excavation in 3D, you need to make sure that each phase of the excavation lies deeper than the previous phase.

Texture and material files need to be present and in the required relative position to the shape file (for example in the same folder). Some 3D applications still use absolute pathnames for textures and material definitions, which is an issue when being copied outside their traditional creation environment. It is important to understand that the conversion to PDF encapsulates all these files into one single file so that the 3D PDF file becomes perfectly portable.

As described in Chapter 3, the required layer structure needs to support the "storytelling" by the Europeana 3D resource, so it can be different from the original layer structure. For example, if you want to show how a certain monument has expanded over the years, you will need to put the different phases of the building into different layers which possibly is not the case in the original 3D file showing the building.

A **second step** in preparing the data for public use is reduction of the complexity of the shape data and texture files. In most cases, there is no need to provide highly detailed shape and texture data if the goal of the 3D data is to provide an overview of a monument or site. There is also a practical aspect in that most professional 3D files tend to be too large for satisfactory Internet delivery Practice shows that it is quite feasible to keep Europeana 3D resources in the form of PDF files under 10 MB, while the original 3D shape files are typically as large as 1 GB or more. Please note that texture files can significantly contribute to this data volume. As a concrete example, the finalised digitisation data of the Hagar Qim prehistoric temple in Malta is 4,2 GB in size, of which the shape data takes 1,2 GB (in '.obj' format) while the textures takes 3 GB (in '.bmp' format). It is recommended to keep Europeana 3D resources under 20 MB.

Although PDF can handle large 3D files (over 5 million polygons), we recommend keeping the number of polygons of each 3D model in a 3D PDF file below 0,5 million polygons to keep the load time of the 3D model within acceptable limits.

To reduce 3D models to this target size, good and free applications such as MeshLab[12] are available. Special care needs to be given to 3D models with vertex colours. Reducing the number of polygons in such 3D models reduces also significantly the texturing quality of these objects. Therefore, such objects should be converted from vertex colouring to texture mapping (by a process called *retexturing*). This can also be done by MeshLab.

As a **third step**, we need to verify orientation, scale and origin of the original 3D model.

First of all, we need to understand that the definition of what is *vertical* is not standardised for 3D models. If a model is processed in a computer graphics application (such as for example MeshLab), the y-direction is shown as vertical. In many other 3D applications, including PDF readers, the z-direction is considered to be vertical. This means that 3D-models that originate in a computer graphics application need to be rotated through 90 degrees around the x-axis. Getting the vertical correct is quite important for 3D PDF. *Walk* mode in 3D PDF is in fact a displacement in the horizontal plane so it only works properly if your vertical direction is correctly defined. The same holds for the *Spin* (look from all sides but keep the vertical) and *Fly* (flying movement that keeps the vertical) mode. As explained before and detailed in Chapter 5, the import of 3D files into PDF allows you to generate automatically *named views* such as *top* and *bottom*, and this only works properly if the vertical is correctly defined.

Secondly, it can be useful to change the *orientation around vertical axis*, to obtain a correct definition of the width and depth directions. This is not only important for easy definition of cross sections, but also for a correct definition of automatically defined named views such as *front*, *back*, *left*, *right*. As Europeana currently does not as yet provide "Google Earth"-like 3D functionality, the orientation of the 3D object should focus on the presentation aspects of the object rather than on its spatial orientation in the geographical sense. The same holds for the origin of the 3D objects in the 3D PDF file. It is better for visualisation purposes to choose the origin to be in the middle of the object than have a correct origin in the geographical sense.

Finally, it is required to *verify the scale and unit of scale*, as measurements can be provided (see above) while the user has always the option to measure the object directly. As we focus on international use and as we mostly deal with buildings and sites, the metre is the most obvious unit for Europeana 3D resources.

Before we can start importing our adapted 3D model into Acrobat X Pro, we possibly need a final **fourth step** which is the translation into U3D format or another file format that can be read by Acrobat X Pro or the 3D Converter plug-in of Acrobat X Pro (as explained in detail above).

The first step of this data preparation phase is typically done in the 3D application that created the original 3D file, while the other steps can be done together in software applications such as MeshLab.

[12] http://meshlab.sourceforge.net/

5 Creating the 3D PDF file

5.1 Document design and creation

As explained in the D5.1 deliverable and above, there are two kinds of 3D PDF files. If we deal with museum objects or archaeological finds, we could just apply a file format conversion to PDF. If we deal with scenes, we need to provide context information to understand and support exploring the scene. In both cases however, it is good practice to provide at least some information about the organisation that is providing the 3D PDF and some identification or background information on the object. After all, the 3D resources are designed to have a high visibility at Europeana and national heritage level and should be considered as a major communication tool.

This means concretely that a 3D PDF file should have a well-designed *template* containing the logo, name and address of the organisation plus some standard information why the organisation makes this information available in 3D. Using a template will create some uniformity and consistency between the 3D resources of a 3D content provider, and supports the professional image of that organisation.

5.1.1 Museum objects and archaeological finds

Museum objects and archaeological finds typically do not need any VR functionality besides visualisation of the object from all sides. So they can be generated as a file conversion to 3D PDF, just using a standard template file. This template file is a normal PDF template.

To convert a certain file, in a supported format, to PDF, simply open that file in Acrobat. The 3D Converter plug-in will give you a window to provide the right parameters for the conversion. This window has four tabs: General, Document, Import and Optimise.

The **General** section allows you to define the display defaults and the configuration of the navigation tools. The display default for *Lighting* is "lights from file" but if you haven't defined specific lights within your 3D model, you should take any other type of light source that works well for your model.

The default *Rendering style* "solid" works best for most 3D models, but you can change if you like to other rendering styles, if this is useful.

If *Animations* are defined, you can also define how they are visualised. This manual does not go into the more advanced topic of animations.

To help exploring the 3D model, it is good practice to add automatically *default views* such as top, left, front, ... and to have the *toolbar* visible.

For the kind of visualisation processes for Europeana that we envisage here, it is not useful to have the *model tree* shown in detail or to execute *scripts* when opening the 3D PDF file.

All settings that we define here are remembered per input file format. You can name these settings in the top input line of the window (default name: Custom). If you always use the same settings for a certain file format, you can tick the box to have the *dialogue box hidden* for this file format, so the next time that you import such a file, the window for setting parameters will no longer be visible.

The **Document** settings allow the use of a *template file* (see above), to define the *layout* (size and orientation) of the page you are designing, and allows the setting of *restrictions* on the use of the file.

In the *Permissions* section, you can protect the document for copying and editing by ticking the box for restricted editing and copying, providing a password and leaving the box to enable copying unticked. However, be aware that these restrictions can be bypassed by some non-Adobe 3D PDF editing tools. Somebody who really wants to copy the 3D model unfortunately can.

The **Import** section shows you which information is available in your file and allows you to get rid of information that is not needed, such as construction lines or reference points, by unticking the boxes. For 3D models from digitisation, you typically need only *surfaces*. If your 3D models have been created with or simplified to primitives (such as boxes, cylinders, …), you will need *solids* only. It also sets the *units* for your 3D PDF file.

The **Optimise** section allows you to choose between U3D and PRC format. We recommend using U3D ECMA3. It is recommended to use compression, but significant gains are only obtained if the 3D object contains textures. Compression ranges only from 100% (no compression) to moderate compression (50%). If you use a 3D model with vertex colours, you need to avoid compression when using U3D as the vertex colours are lost. In that case, using PRC with compression does work but it provides you only with moderate compression gains.

You should tick the box to *centre your model at the origin* unless you have designed your 3D model to have a specific rotation centre.

When all these parameters have been set, click on OK to perform the conversion. The imported object will take the full page (or the area that has been designed in the template).

If there are specific views on the objects that are useful for the user (besides the standard views such as top, left, front, …), these can be added by positioning the camera as required and creating the views with an appropriate name (see workflow in the next section 5.2). For example, a named view can be created to zoom in on an important part of the object. If the object consists of several pieces, for example two named views can be created, one for the assembled state and one for the disassembled state. It is obvious that the name of the view should highlight its importance. In this way, the user can discover the peculiarities of the object through selecting those additional named views.

5.1.2 Digitised monuments, archaeological sites or landscapes

Digitised monuments, archaeological sites or landscapes typically need context information to be understood and appreciated, and can have some simple VR capabilities through *named views* that are triggered from keywords and images. This context information, with its keywords and images, needs to be designed as a normal text document (for example in Word) which is saved in PDF, leaving open spaces where the 3D models will be shown.

To add the 3D content to such a document, open the PDF text document in Acrobat X Pro. Click the *Tools* button on the top right side of the application window, and select the section *3D PDF Converter* to use the function *Insert 3D*. Drag a window to where you want the 3D content to be visualised, select the kind of 3D file you want to insert and select the file to open. You will get the same kind of 3D Converter window as described above, with the same parameters.

If you are inserting a U3D file, select the section *Content* and use the *3D tool* under *Multimedia*.

Drag a window to the empty space where you want the 3D content to be placed. You will get an *Insert* window to select the 3D content to be inserted. Tick the box *Show Advanced Options* to see all parameters. The insert box has three sections: *Launch Settings*, *3D* and *Resources*.

The *Launch Settings* option defines how the 3D content on the page will behave and look like.

3D in a PDF file is shown through a *Poster Image* until the 3D is activated. The Poster Image can be derived automatically from the default view of the 3D model (option "Retrieve poster from default view") or can be an existing image (option "Create poster from file"). Retrieving the poster image from the default view is by far the simplest solution.

The *Appearance* option defines whether the 3D window has a border or not and if the background of the 3D is transparent or has a flat colour (defined in the section 3D).

A 3D PDF document can contain many 3D objects, and each of these objects can be large and complex. To make 3D visualisation of such a document feasible, 3D PDF uses the technique of "activation". Activation means that only one 3D file is taken in memory and processed to be visualised at a time. The *Activation Settings* option defines when a 3D model becomes active. Experiments have shown that for cultural heritage (where most objects are quite complex) it is recommended to enable the 3D when *The content is clicked* (default value). Activating the 3D content *when the page becomes visible* or *when the 3D content becomes visible* is not a good choice for complex objects as the user needs to wait (to have the 3D loaded) without knowing why.

For disabling the content, leave the default value (when *Disable Content* is selected).

Concerning *Playback Style*, the 3D window can be shown in the window that is *drawn on the page* or in a *floating window* of predefined Width and Height. Either one of the options can be used, depending on the structure of the document. If the context information is on the same page, the 3D should be shown on the page itself. If the context information is spread over several pages, the 3D should be shown in a floating window. When you browse through the document, the floating window will remain visible on top of all pages.

5.2 3D interaction design

5.2.1 Named views

To create the interaction with the 3D models, create first the required *named views*. Typically, each keyword in the text has its related named view. Also images can be linked to specific named views.

Creating a named view is very simple. After converting or inserting a 3D model, click it to activate the 3D and make the appropriate view on the object or scene by moving the camera (use the different visualisation modes such as *Spin* or *Walk* but also the scroll wheel to zoom or the CTRL (CMD on Mac) button to pan, to come efficiently to the right position). In the toolbar, click *Views* and then *Manage Views* to define a named view. Click *New View*, select the properties that the user can change in the View Properties window, and click OK. It is good practice to give views an appropriate name, so fill in the new name, click *Rename* and OK to save the view.

When a 3D file is converted or inserted, the application automatically creates a default view (that is not named) but if you want a more appropriate default view, create the desired view, give it a name and select *Use As Default.* It is useful to make sure that views appear in an appropriate order in the list of views. Use *Move Up* and *Move Down* to reorder before clicking OK. In this way, add the default view and all required named views that correspond to keywords and images.

While defining named views, it could be useful to change the parameters of the camera (for example to make it more wide angle) or to turn off some layers of the 3D model.

To change the camera parameters, just click the top left *Visualisation Mode* button, select *Camera Properties* and make the required adjustments. You can also click the *Perspective/Orthographic View* button to change the type of 3D visualisation, or change the *Model Render Mode* (next button to the right) of change the *Additional Lighting* (next button to the right).

To turn on/off layers in an active 3D model, click the object tree symbol in the 3D toolbar or click on the object tree symbol in the left hand bar of the window. To see the full tree, you need to click on every "+"-sign to open those parts of the tree. By checking or unchecking the boxes of each layer, you can turn on/off the visibility of that layer in the 3D visualisation as needed.

There are some special named views that can be very useful for certain applications, such as *Cross Sections*, *3D Measurements* and *3D Comments*.

To create a *cross section*, turn cross section mode on by clicking on the top right button in the 3D toolbar and click on *Cross Section Properties* to fine tune the cross section. Cross sections can be made by the *X, Y or Z plane* or *parallel to a face* of the 3D model or *parallel to a plane* defined by 3 points. You can turn on/off the cross section line or change its colour, you can make the cutting plane visible/invisible or change its colour and transparency and *align the camera* perpendicular to the cross section. You can fine tune the position of the of the cross section plane through *offset* or *tilt* or *flip* the visibility of the cut part. When done, click *Save Section View* (which you can rename if needed).

To insert *3D measurements*, click the top left *Visualisation Mode* button and select *3D Measurement Tool*. You can now click on the start and end point of a measurement (the cursor locks on the 3D model, and shows different shapes of the cursor when locking on a point, a plane, a line). Click a third time to position the measurement itself (the named view is created automatically at the third click, you can rename it if needed).

You can use *Add 3D Comment* to add annotations in a 3D fashion. Click on the point where you want the annotation to be connected to, position the text window, type your comment and click OK. If you click the 3D text window, you will be able to still change its size by dragging the corners when selecting the 3D text window.

5.2.2 Linking active zones with named views

To create simple VR behaviour, we will now add the links between keywords or images and named views. Select *Tools/Content/Link* so that the cursor becomes a crosshair. Drag a rectangle over the keyword or image so that you get a *Create Link* window. As *Link Type*, you can choose for example an *invisible rectangle* with *Invert* as *Highlight Style*. Choose *custom link* as *Link Action*. Click on *Next* and you will get a *Link Properties* window, in which you leave the *Appearance* as it is and select the *Actions* tab. Add the action *Go to 3D/Multimedia View* and click *Add*. In a window *Select a 3D View*, you will get on the left a list of all inserted 3D models per page and in order of insertion. Select the required 3D model and hit *Select a 3D View*, you will get the list of all named views of that 3D model that you have created. Select the appropriate named view and click OK.

If the 3D model is on the same page as the link, you are finished and can click OK.

5.2.3 Additional actions

If your 3D model is, however, on another page than the link, you need to add another action to go to that page by adding *Go to a page view*. You will get a *Create Go To View* window, go to the right page, if needed zoom in, and click *Set Link*.

When clicking the tab *Actions*, you will see the list of actions that you have defined linked to the keyword or image that you have selected. When all actions are defined, click OK and continue to create all other required links. You can test the links by clicking the *Hand* icon in the toolbar (that leaves the link mode) and clicking the links that you defined.

5.3 Local 3D PDF settings

When designing 3D PDF resources, one has to be aware that the user's Acrobat Reader has local settings that can alter or influence the behaviour of the 3D PDF file. In the Preferences of Acrobat Reader X, the following parameters are important:

In the category *3D & Multimedia*, section *Renderer Options*, no changes should be made to the default settings. Double sided rendering is normally not required as most 3D creation workflows ensure that polygons are consistently oriented (inside/outside).

In the category *3D & Multimedia*, section *3D Tool Options*:

- *Enable selection for the Hand tool* can be turned off as there is no need to select objects
- *Consolidate tools on the 3D Toolbar* should be checked to keep the *Walk* mode visible
- *Enable view transitions* should be checked, this creates the automatic animation between viewpoints
- *Show 3D orientation axis* can be turned off as there is no need to see the XYZ axis displayed.

In the category *3D & Multimedia*, section *Auto-Degrade Options*, no changes should be made to the default settings (*Bounding Box* visualisation when a frame rate of 15 fps (images per second) cannot be delivered).

In the category *Measuring (3D)*, it is useful to have scale and units shown for measurements (when allowed during authoring of the PDF file).

6 Creating Metadata for 3D content for Europeana

6.1 Introduction

This training manual is addressed to organisations involved in the CARARE project and those who are preparing metadata for 3D/VR resources which will be published online and made accessible to users through Europeana.

3D resources need metadata which describes the content, the context represented in the 3D model (especially important in cultural heritage), the visualisation (and related information about data capture and processing). For Europeana, the metadata which helps users to find interesting resources is particularly important; this is no different for 3D than for any other type of resource.

The CARARE project has defined a metadata schema[13] to ensure interoperability between the metadata captured by heritage organisations and the metadata required by Europeana. This schema builds on existing standards and best practices and provides a framework for describing 3D and other digital resources in context.

This chapter describes the metadata recommended for 3D PDF and other 3D resources for publication online and access through Europeana. Appendix 4 describes a Cypriot case study provided by STARC concerning the virtual reconstruction of the Paphos Theatre and its metadata.

6.2 General considerations for metadata

Metadata is literally "information about the data" and its purpose is to facilitate the discovery, use, management and reusability of digital resources. The main categories of metadata which you may capture during digitisation, post-processing, publication and preparation of content for Europeana include:

- **Descriptive Metadata:** information about the content and subject of the 3D resource and its intellectual and physical properties.
- **Structural Metadata:** information about the component parts of the 3D resource.
- **Administrative Metadata:** information useful for the storage and long-term preservation of the 3D resource, which includes:
    - Technical information on the creation and modification of the digital resource
    - Information on the original data from which the 3D resource was derived
    - Information about intellectual property rights and copyright.

When you select (or design) a metadata schema to capture information about the 3D objects that you

[13] http://www.carare.eu/eng/Resources

are producing, it is important to keep the following issues in mind:

- Metadata for storage and long-term preservation is typically created during the production process of the digital object and targeted at the storage of the master files, any derivative files and related information within a Digital Library or Repository.
- Metadata for the discovery of digital resources is typically used in web-sites and web portals targeting large audiences (e.g. Europeana, national culture portals etc). Such metadata includes descriptive information along with rights and other information important for the discovery and use of the digital resource, which may be added or enhanced during the publishing process.

6.3 Metadata for 3D: production processes

The production processes involved in creating 3D content involve several stages and possible methodologies and techniques including, for example, capturing data from real objects (digital images, photogrammetry, laser scanning) and creating models using Computer Aided Design (CAD) tools.

It is important to record information (metadata) on the processes which have been used to create the 3D object, registering the digital provenance of the object from the original data, the tools and parameters employed to the final model. This technical and administrative metadata has a fundamental role in ensuring the long-term usability of the object and enabling new formats to be created in the future.

Appendix 4 describes the metadata schema for 3D objects adopted by the Cyprus Institute which is based on the principle of recording every important detail for the identification of the digital provenance of a 3D object including:

- The methodology for data acquisition, the parameters set, the scenario during the acquisition process
- The software used for the post processing (texture mapping, simplification, etc).

This information is important during the production process because it enables the operator to retrace the various phases of the 3D model production and enhance it where appropriate.

It is recommended that the information relating to the creation process is embedded in the 3D content to limit the possibility of losing it. This is because modification of some of the parameters used for production will produce different final results. For example, with 3D models obtained with image-based dense matching software (such as Arc3D), it is important to record which kind of lens was used to record the images and the weather conditions as these determine the final result.

The London Charter[14] defines “paradata” as information about human processes of understanding and interpreting data objects. For example, the method used in a laboratory analysis and the results on which an interpretation was based; or how data and evidence were used to create a 3D reconstruction.

To conclude, it is recommended that you document in metadata:

- the different phases of 3D model production, from data acquisition to post processing,
- all the software used,
- the instrument(s) used for data acquisition,
- the methodologies adopted,
- the pipeline followed to achieve the final result, and
- the interpretational processes and reconstructions (the paradata).

This metadata will support the storage, preservation and re-use of your 3D content.

6.4 Metadata for 3D: the CARARE schema

The metadata which is required for the discovery of your 3D resources by the users of your web-site and web-portals such as Europeana supports the typical search facets (what, when, where and who) and enables users to develop their knowledge and understanding, as well as access to and re-use of the content.

The CARARE metadata schema is based on existing standards for the description of:

- Cultural heritage assets (archaeological monuments, historic buildings, museum objects, etc.,)
- Digital resources (including 3D PDF and other 3D content)
- Activities (including fieldwork to survey and digitise monuments and buildings; laboratory analysis and post-processing of field data; as well as historical events)
- Collections (administrative information about the collection whether physical objects in a museum collection or a collection of born-digital 3D models).

The CARARE metadata schema provides a framework for sharing your information with others and with Europeana. The following information is recommended.

6.4.1 The Heritage Asset

The Heritage Asset is the piece of cultural heritage that we want to describe and people to know about, for example the theatre at Paphos described in Appendix 4. The recommended information elements for heritage assets include:

- ID, this is a unique identifier for the record
- Name, e.g. Paphos Theatre

[14] http://www.londoncharter.org/

- Description, a free-text description about the monument and its history
- Heritage Asset type (or the subject), e.g. Theatre, Orchestra, Stage, Archaeological monument
- Temporal information, for example:
    - Period, e.g. Hellenistic-Roman
    - Start Date, e.g. AD 65
- Spatial information, for example:
    - Named location, e.g. Paphos
    - Geopolitical area, e.g. Cyprus
    - Spatial reference system, e.g. WGS 84
    - X coordinate
    - Y coordinate
- Relations to digital resource(s), this is the link between the heritage asset and your 3D content and other digital representations.

This is the core information which you are recommended to include in your descriptive metadata to enable discovery. The CARARE metadata schema defines additional optional elements to enable more detailed description, for example of the condition of the monument, dimensions, materials and inscriptions.

6.4.2 The Digital Resource

The Digital Resource is the digital content that we want to describe and people to discover, for example, the 3D reconstruction model of the theatre at Paphos described in Appendix 4. The recommended information elements for digital resources include:

- ID, this is a unique identifier for the record
- Name, e.g. 3D reconstruction of Paphos Theatre
- Description, a free-text description about the subject content of the resource (i.e. the monument which has been modelled and its history) and the context for its creation (i.e. the paradata)
- Format, this is the file format (generally a MIME type)
- Type, this is the general type of digital resource e.g. 3D, text, image, video
- Created, this is the creation date of the digital resource
- Subject of the content, e.g. Theatre, Orchestra, Stage, Archaeological monument
- Temporal information, for example:
    - Period, e.g. Hellenistic-Roman

- Start Date, e.g. AD 65
- Spatial information, for example:
    - Named location, e.g. Paphos
    - Geopolitical area, e.g. Cyprus
    - Spatial reference system, e.g. WGS 84
    - X coordinate
    - Y coordinate
- Link, this is a URL or URI pointing to the digital object online
- Object, this is the URL where a 2D image representing the 3D is located. This will be used to create a thumbnail which will be displayed by Europeana in its search results.
- IsShownAt, this is a URL or URI pointing to a web-page on which the content is made available
- Relations to heritage assets or to activities, this is the link between the digital resource and the heritage asset it represents and to the activities in which it was created
- Rights associated with the digital resource, e.g. a copyright statement.

The Link element above allows Europeana users to go from the metadata description to the 3D content itself which is held on the originating organisation's own website. The 'IsShownAt' element may also be used to point to the 3D content on an alternate web-page. The 'Object' element can be used to point to a 2D image representing the 3D content for illustration purposes.

6.4.3 The Activity

The Activity theme covers things that have happened. It includes the activities involved in the capture, processing and publishing of 3D content, and allows for the methods and techniques used in each activity to be recorded. You are likely to create several separate activity records for the metadata related to the 3D capture processes previously outlined in section 6.3. The recommended information elements for activities include:

- ID, this is a unique identifier for the record
- Name, e.g. 3D laser scanning of Paphos Theatre
- Description, a free-text description about the activity covering the organisations, methods, techniques and equipment used.
- Event Type, this is the type of activity e.g. 3D survey
- Actors involved in the activity, e.g. the organisation and staff involved in the survey

- Event method, e.g. laser scanning
- Materials and techniques used in the activity
- Temporal information, for example:
    - Start Date of the activity, e.g. 20/07/2005
    - End Date of the activity, e.g. 25/08/2005
- Spatial information, for example:
    - Named location, e.g. Paphos
    - Geopolitical area, e.g. Cyprus
    - Spatial reference system, e.g. WGS 84
    - X coordinate
    - Y coordinate
- Relations to heritage assets or to activities, this is the link between the digital resource and the heritage asset it represents and to the activities in which it was created.

6.4.4 The Collection

The Collection provides administrative and contextual information about the set of resources which your 3D model forms part. The recommended information includes:

- Title of the collection, e.g., STARC 3D collection
- Source, this is the organisation which holds the collection
- Contacts for the collection
- Language of the metadata records
- Coverage of the collection, e.g. spatial (Cyprus) and temporal coverage (Hellenistic-Roman)
- Rights associated with the collection as a whole.

6.4.5 Metadata for resource discovery: considerations

The CARARE metadata schema provides a rich framework for the description of your 3D content contextualised with information about the cultural heritage represented in the model and the activities which lead to their creation. It is designed to provide a common framework for sharing metadata with other cultural heritage organisations and with Europeana, and to support the discovery and use of your 3D content.

To conclude, it is recommended that your metadata for discover includes:

- Information about the heritage asset (the monument or building) and its subject, date and location, and any associated historical events

- Information about the digital resource (the 3D object) and its type, format, subject (including the temporal and spatial coverage), and any rights in the content.

- Information about the activities which produced the 3D object including the organisations involved, the methods and techniques used to produce the model, and any reconstructions or interpretations

- Information about your organisation and its collections.

This metadata will support the discovery of your 3D content in search portals and will provide users with important contextual information about its creation and the cultural heritage which is represented.

Finally, content providers are requested to provide their resource-discovery metadata under a public domain licence (CCO) to enable its use in the Europeana portal and as linked open data.

7 Delivery process

Delivery of 3D resources is no different from delivery of other resource types. Basically, besides the metadata, Europeana needs to know three elements that allow proper delivery of the 3D resources: the *thumbnail image*, the *location of the file* for download and the *landing page*.

The *thumbnail image* of a 3D resource is created from a normal image of sufficient resolution (typically a good JPEG image in screen resolution of at least a few hundred pixels in width). This image is communicated to Europeana through an Internet link in the metadata (<DigitalResource><Object>) where it is processed by special software to create the thumbnail. Choosing a thumbnail image is a bit trickier than for most other resources as we need to define the most representative view on the 3D object, or select the most representative 3D object if the 3D resource contains several 3D models. As a thumbnail needs to represent the 3D resource in a single view with limited resolution, we need to make the thumbnail image simple and powerful. If we have, for example, a 3D model of a large, complex castle it may be better to choose the tower or the main gate of the castle to be depicted on the thumbnail image than the complete castle to avoid ending up with a cluttered thumbnail that does not represent the castle properly.

A second piece of information to be delivered is the *location of the 3D PDF file*, this is provided as a permanent Internet link through the metadata (<DigitalResource><Link>). Although the user interface is not finalised yet, there will be the option to download the 3D PDF file directly from the Europeana page, so the link to the file to be downloaded needs to be provided.

It is also good practice to provide a *landing page* which is the page where you are directed to when clicking *View in original context* on the Europeana object page (metadata field (<DigitalResource><IsShownAt>)). This landing page could provide some description of the 3D resource, but also why or how the resource was made.

A landing page provides also the option to provide alternative ways of displaying the 3D content. In some cases, 3D PDF is not the right solution for showing the 3D resource appropriately. In other cases, 3D PDF files will be complemented by other, new 3D visualisation solutions that provide more added value but have the disadvantage of not being compliant to all Europeana requirements (see the Paphos case study in Appendix 4).

Landing pages can be existing Internet pages on which the download of the 3D PDF file is added. For example, the CATA reference collection of Iberian pottery[15] has a page (with tabs) for each vessel in the database which can become a landing page by simply adding the 3D PDF download link to this existing page. Besides the 3D PDF, there is a rendered image plus a short video of the 3D model of the vessel, plus a large variety of context information (location of the excavation, typology, material, decoration, …).

In upcoming versions of the Europeana portal, there will be an indication of the file type of the resource so clicking on the PDF file type symbol will bring you to the help file for 3D PDF if the content is 3D. This central help file will deal with all aspects of installing 3D PDF capable readers,

[15] http://cata.cica.es/cata.html

basic techniques for displaying 3D PDF files and remarks about setting local preferences (see Chapter 5.4).

8 Conclusion

3D PDF is a good solution which is currently being documented as an ISO standard and is being used widely by several communities. But other good techniques are in the pipeline. It is its good practice to document in detail the process of creation of the 3D PDF from your existing 3D data so that future alternative 3D publishing methods can be applied as soon as they become available. This also includes storage of the 3D data in future proof formats such as X3D to create independence of the authoring environment in which they were created.

Interesting new views on digital preservation of complex cultural heritage objects, such as 3D models, can be found on the website of the POCOS consortium[16], including webcasts of the presentations and resulting papers as an e-book publication, to appear end of 2011. Another very useful resource is the new Competence Centre on digital preservation, called Open Planets Foundation[17].

[16] http://www.pocos.org/
[17] http://www.openplanetsfoundation.org/

Appendix 1: List of example 3D PDF files

An extensive list of 3D PDF examples has been made to support the 3D PDF creation process by showing the PDF capabilities as described in Chapter 3.

All examples are available at http://carare.eu/eng/Resources/3D-Virtual-Reality

CARARE 3D PDF examples for public use, single objects (no context or VR):

- Capitel 1, St. John Abbey, Biograd, Croatia
- Capitel 2, St. John Abbey, Biograd, Croatia
- Column, St. John Abbey, Biograd, Croatia
- Pulpit column, St. John Abbey, Biograd, Croatia
- Head of Tutmoses III, Allard Pierson Museum, Amsterdam, Netherlands
- Interior portada, Seu Vella cathedral, Lleida, Spain
- West portada, Seu Vella cathedral, Lleida, Spain

CARARE 3D PDF examples for public use, curated objects (with context and VR behaviour):

- Traditional Polish building at Bogatynia, Poland (template and basic information)
- Church at Lipnica Murowana, Poland (template and short text)

CARARE 3D PDF examples for specialist use:

- Dobra Nowogardzka Castle, Poland (with links to extensive technical drawings and photo documentation in separate PDF files)
- South spur from the Castle of Bouvignes, Belgium (with cross sections, for restoration)
- Statue to be restored, Ath, Belgium (with 3D comments and measurements)
- Sanctuary of the public Lares, Pompeii, Italy (archaeological assessment)
- Bowl from Jaén, Spain (archaeological reference collection)

CARARE 3D PDF examples for tourism use:

- Castle of Bouvignes, Belgium
- Ename Abbey, Belgium
- Macellum at Pompeii, Italy
- St. John Abbey, Biograd, Croatia

Appendix 2: List of 3D file formats, used in cultural heritage, that can be converted to 3D PDF

A 3D PDF file uses internally the U3D format version 3 so importing a U3D file (.u3d) is in fact only providing a PDF wrapper around the U3D file, no real conversion needs to be done (same holds for the PRC file format but this is of less importance in cultural heritage).

The following formats are directly imported by Acrobat Pro, through the Tetra4D Converter plug-in:

- Autodesk 3D Studio (.3ds)
- COLLADA (.dae)
- Google Earth (.kmz, .kml)
- VRML (.wrl, .vrml)
- Wavefront Object Format (.obj)

Tetra 4D specialises in this conversion business and enlarges its list of supported formats with each new version, the above list refers to version 3.2. One format that is certainly of interest is SketchUp (.skp) which is said to be included in the next version (but supported already by other authoring applications, see Appendix 3).

See the full list of supported file formats at http://www.tetra4d.com/products.html

Appendix 3: Other 3D PDF authoring tools and websites

Here is a short list of alternative authoring environments and useful websites for 3D PDF information and tips.

Authoring environments:

- PDFTron (http://www.pdftron.com/)
- Visual Technologies Services (http://www.pdf3d.com/)
- PDF Xpress (http://www.accusoft.com/pdf.htm)
- pdfTEX (http://www.tug.org/applications/pdftex/)
- Quick PDF Tools (http://www.debenu.com/quick-pdf-tools/)
- Deep Exploration by Right Hemisphere (http://www.righthemisphere.com/products/dexp/)
- SimLab Composer (http://www.simlab-soft.com/3d-products/), animation
- SimLab 3D Plugins (http://www.simlab-soft.com/), SketchUp conversion
- TechSoft 3D (http://www.techsoft3d.com/)

Other useful websites when using 3D PDF:

- Baker Communications (http://acrofacts.donnabaker.ca/)
- PDF Association (http://www.pdfa.org/)
- Chemical Structure Model Rendering Demonstration (http://85.214.71.72/pdf3d/)
- PDF Expert Corner (http://www.aiim.org/Resources/Standards/Articles/PDF-Expert-Corner)
- Planet PDF (http://www.planetpdf.com/)
- Acrobat Ninja (http://acrobatninja.blogspot.com/)
- 3D PDF Consortium (http://www.3dpdfconsortium.org/)

Appendix 4: Case study - The Hellenistic-Roman Theatre of Paphos

Introduction

This case study describes the methodology adopted by STARC for the publication on the web and harvesting by Europeana of the virtual reconstruction of the Hellenistic-Roman Theatre of Paphos (Cyprus).

STARC, in collaboration with the University of Sydney archaeological mission, Department of Antiquities of Cyprus, the Institute for Technology Applications to Cultural Heritage of the National Research Council (CNR-ITABC), Italy and the University of Naples "L'Orientale" (CISA), Italy, produced a high-quality three-dimensional terrestrial model of the theatre by using state-of-the-art photogrammetric and laser scanning acquisition technologies.

The 3D model represents the current physical state of the theatre and its surroundings. The obtained 3D mesh (figure1) was used as a reference model for the digital reconstruction of its five architectonic phases.

Figure 1: *The digital model represents the actual physical state of the theatre as it is at the present moment.*

Methodology

The virtual reconstruction was based upon the London Charter (LC) guidelines for documenting computer-based 3D visualisation of Cultural Heritage.

The pipeline from the virtual reconstruction to the publication on the web is summarized below:

- Documentation and study of the available scientific resources about Greek and Roman history of architecture, archaeological documentation from previous excavations (plans, sections, unpublished notes, photographs)

- Composition of hypothetical hierarchical modelling diagrams of the architectural components representing each of the five identified phases of the theatre and transformation in the local metadata schema (STARC metadata schema) (Figures 2 and 3)
- Alignment with the CARARE metadata schema
- 3D implementation of the virtual environment based on based on architectural blueprint plans, modelling, texturing, lighting and rendering
- Superimposition of the 3D reconstructed models on the 3D model of the real asset resulting from the integration of aerial photogrammetry and laser scanner digital acquisition
- Export of the models into interchangeable, portable, sustainable and interoperable digital formats
- Visualisation of the output using multimedia or hypermedia techniques for communication on the web with interactive systems, video animation, film, photo gallery, 3D PDF.

The information and digital resources (pictures, 3D models, maps, texts) used for the virtual reconstruction of the different phases of the Paphos Theatre are documented through the STARC metadata schema which relies on the LIDO and CARARE schemas. The online content, mapped to the CARARE schema, is available for harvesting by Europeana.

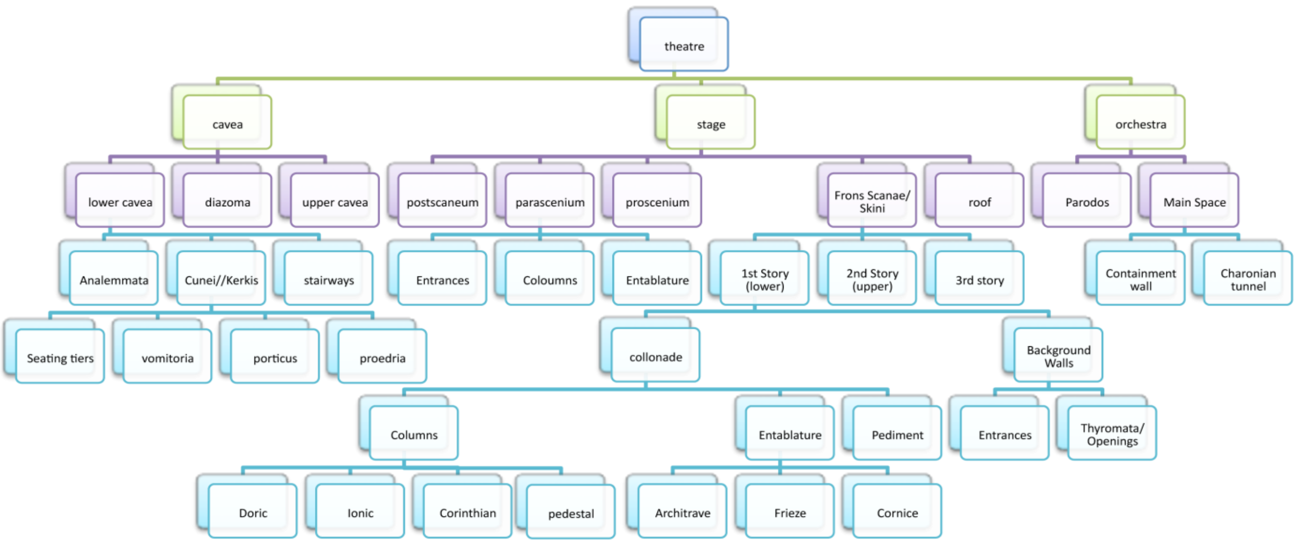


Figure 2: *The representation of the native XML schematical modelling as an aggregate diagram of the components-per-total that composed a typical Hellenistic-Roman theatre having characteristics of both periods. The theatre as the "parent" having six orders/levels of sub-children; logically more orders can occur, with higher complexity than the diagram created, resulting a relative bigger error for the reliability of the visualisation outcome; nonetheless revealing more architectural detail that makes it more pleasant to see is a potentially risky operation*.

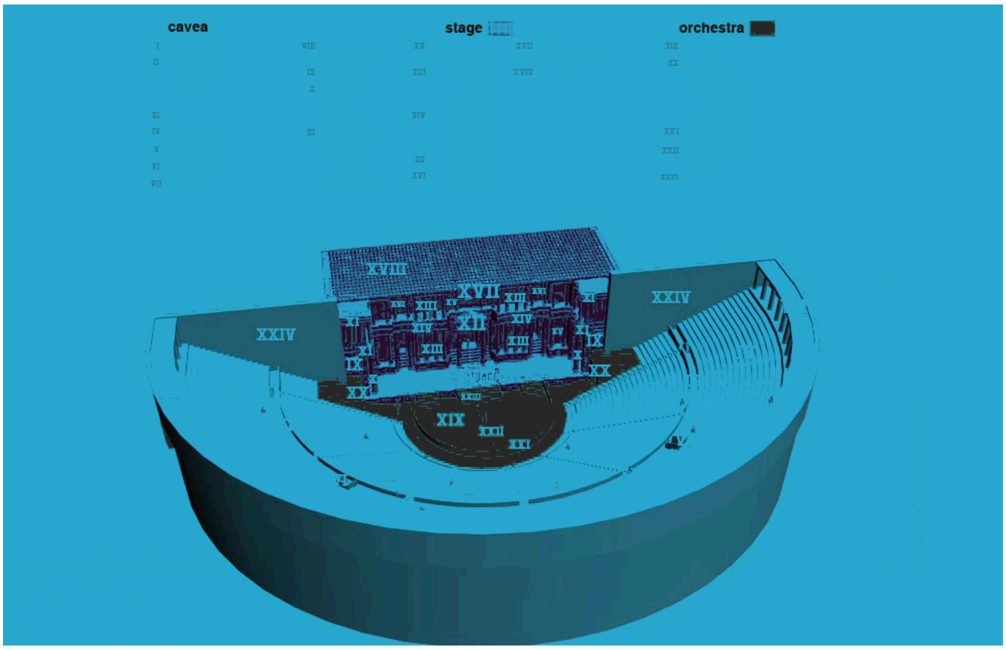


Figure 3: visualisation of hierarchical components of the Theatre

Metadata

The metadata schema for 3D objects adopted at the Cyprus Institute is based on the principle of recording every important detail for the identification of the digital provenance of a 3D object ranging from the data acquisition to the dissemination to the public.

The STARC schema was adapted to the CARARE schema following CARARE's recommendation and Europeana requirements. In particular the section that corresponds to Digital Resources in the CARARE metadata schema was enriched.

Metadata for Paphos Theatre

The 3D model of the Paphos Theatre was created after post processing data, acquired with the integration of two technologies: aerial photogrammetry and laser scanning. The final result was used for the reconstruction of the five architectural phases of the theatre.

A database has been created documenting the overall key structural components and elements that synthesize the architectural space of the theatre during its life span. Each phase has different distinct characteristics resulting in a different component in the database that reflects the contemporary architectural methods of each period.

These components were hierarchically structured and sub-divided. In our case, the top-level component is the Paphos Theatre, which corresponds to the *Collection level* of the CARARE schema. The sub-levels, divided into various levels of *children*, are the several architectural components and correspond to the *Heritage Asset* level in the CARARE schema. All the components are connected to the Theatre and between them through relations. To these 3D models, other digital resources and activities are also connected using relations.

Once the data was completed, the next step was map the STARC metadata schema to the CARARE 1.0.6.1 schema by loading the metadata as XML files to the MINT tool.

Step by step procedure for metadata preparation:

1. First step: log in to the MINT tool

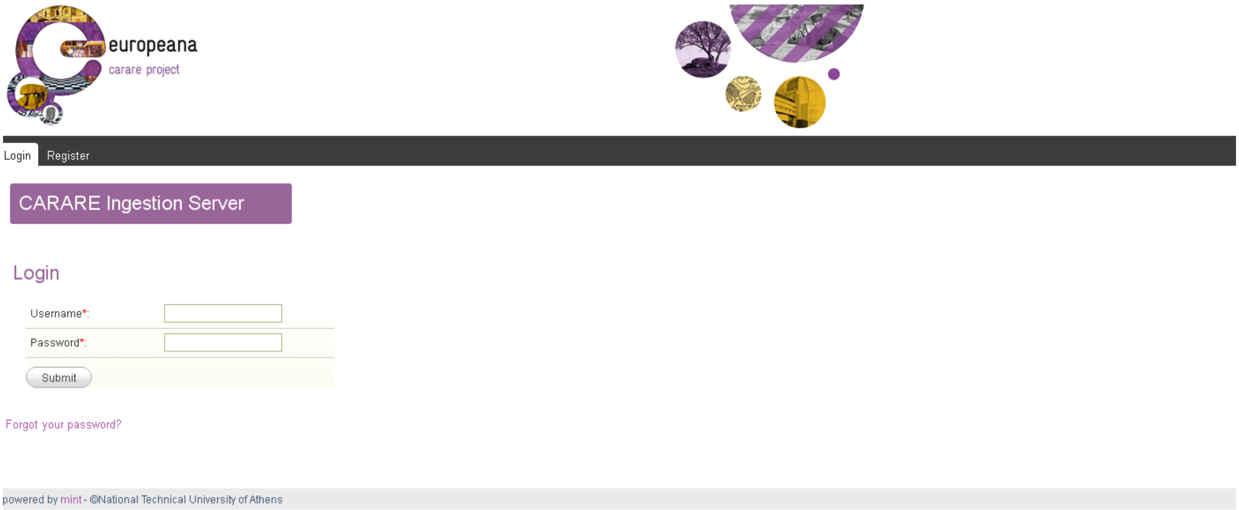


Figure 4: *Registration* screen

2. By selecting the import tool we loaded the metadata as an XML file (through *Browse*).

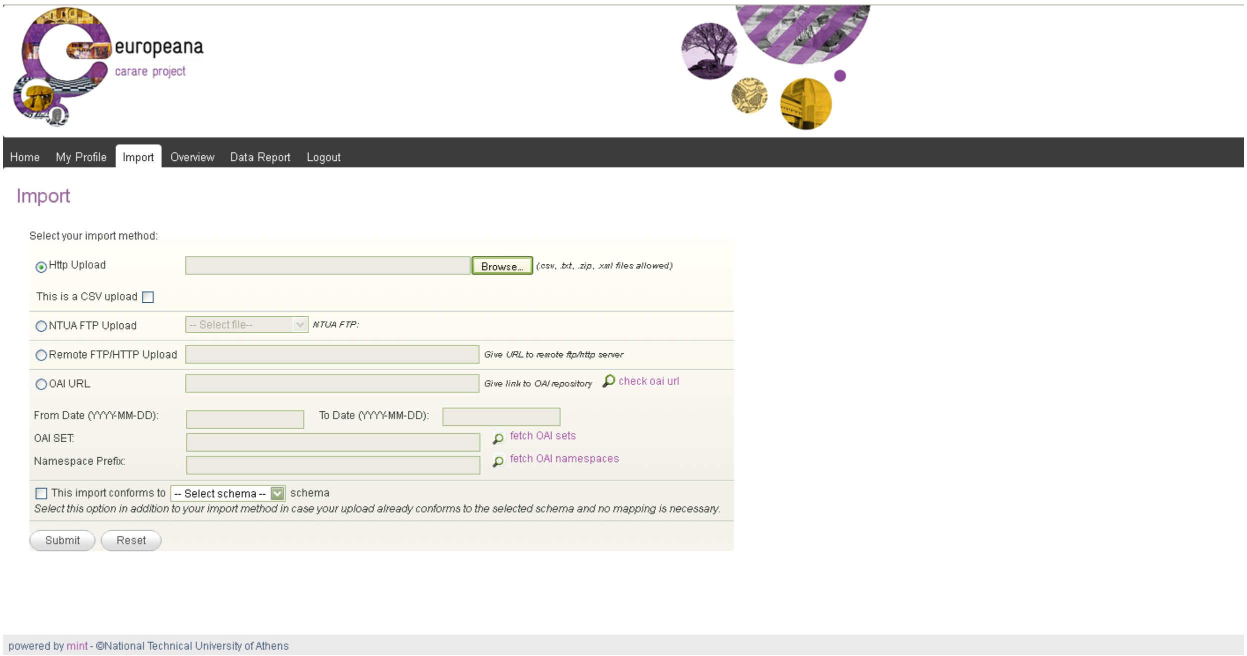


Figure 5: *Import screen*

3. After choosing *Submit*, the *Overview* screen opens. This tool allows the user to browse through items that have been uploaded.
4. By defining the root and label element from the ingested data set we were allowed to proceed with the mapping.

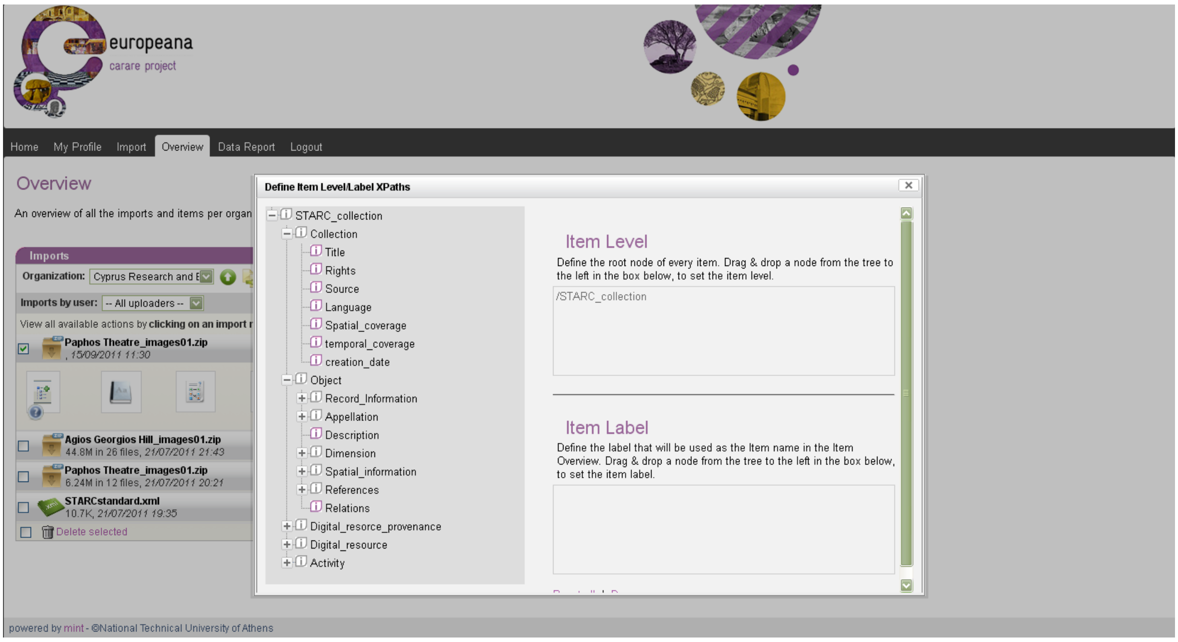


Figure 6: *Definition of the item root element*

5. By selecting the mapping button we could perform the semantic mappings between the source and target schemas.

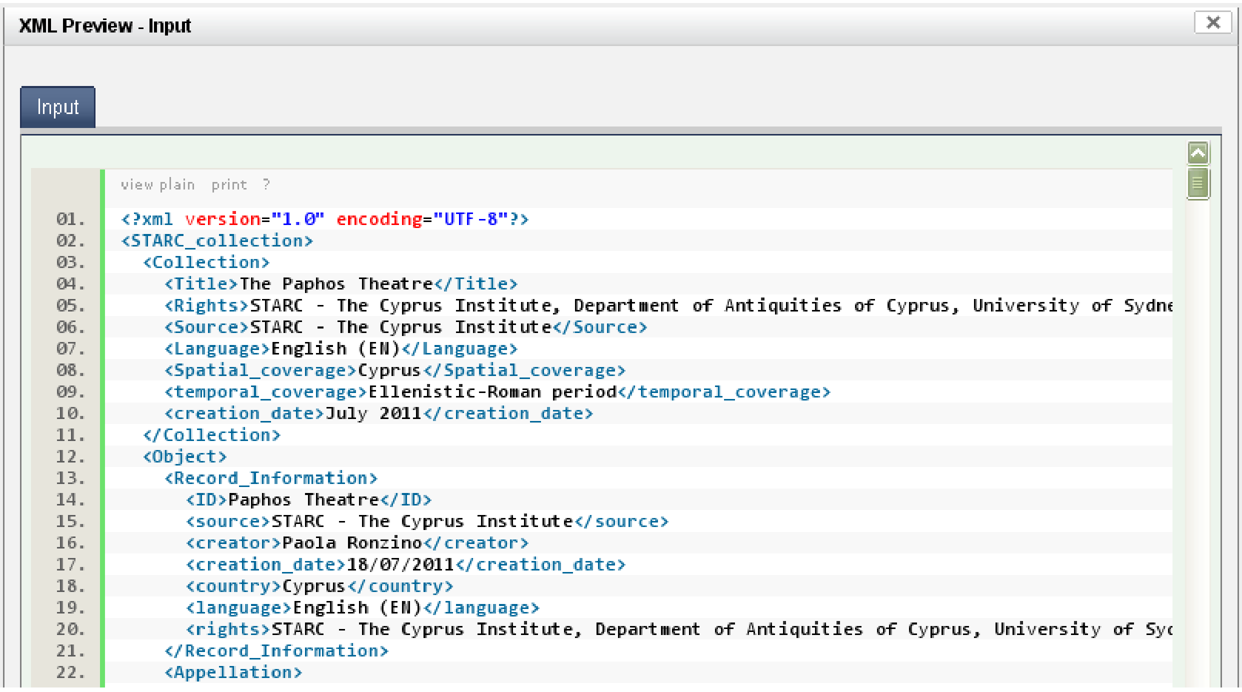


Figure 7: *Input XML*

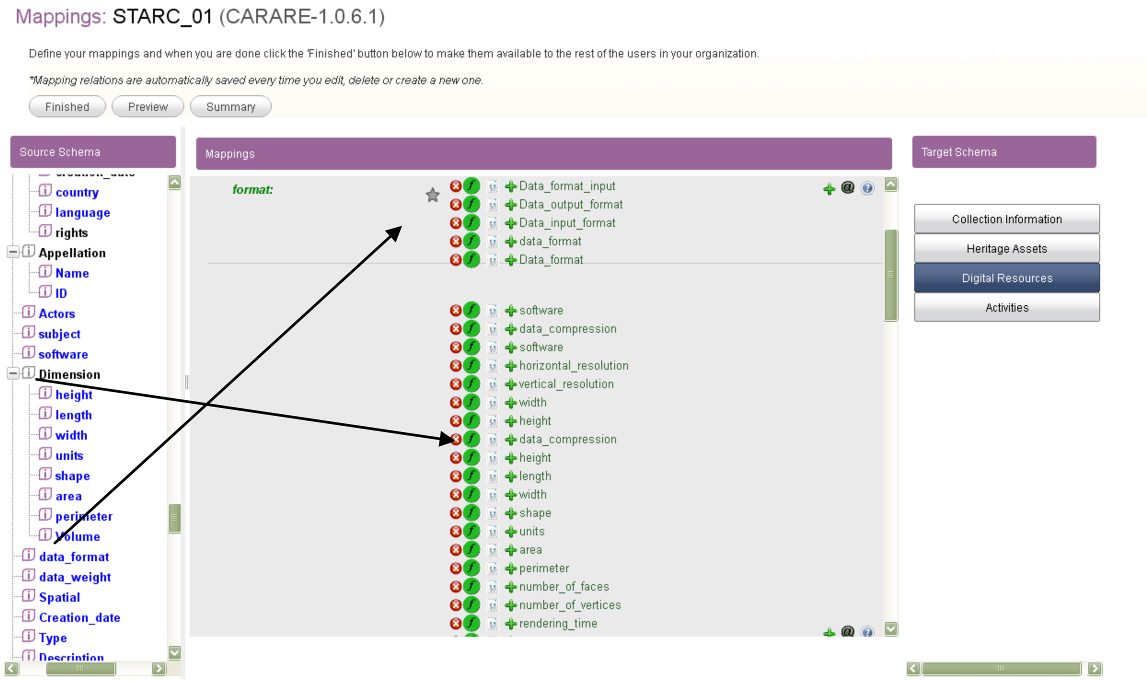
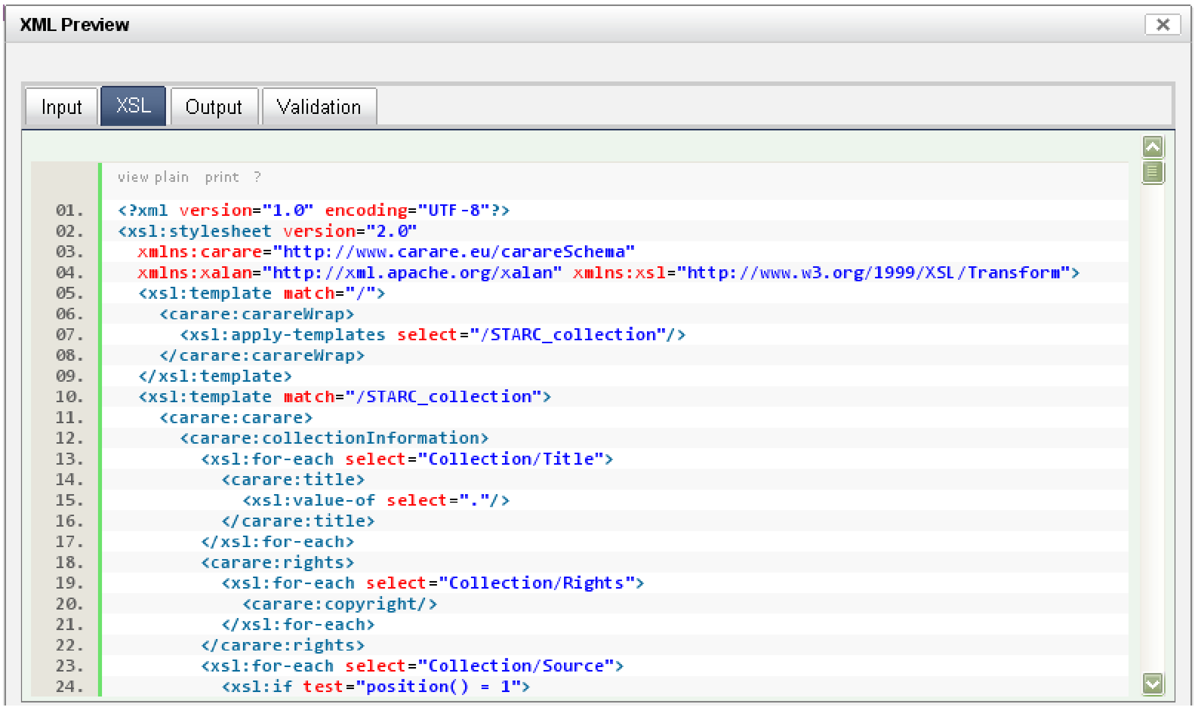


Figure 8: *Screen shot of an example of mapping from STARC schema to CARARE schema*



```
XML Preview
Input | XSL | Output | Validation
view plain  print  ?
<?xml version="1.0" encoding="UTF-8"?>
<xsl:stylesheet version="2.0"
  xmlns:carare="http://www.carare.eu/carareSchema"
  xmlns:xalan="http://xml.apache.org/xalan" xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
  <xsl:template match="/">
    <carare:carareWrap>
      <xsl:apply-templates select="/STARC_collection"/>
    </carare:carareWrap>
  </xsl:template>
  <xsl:template match="/STARC_collection">
    <carare:carare>
      <carare:collectionInformation>
        <xsl:for-each select="Collection/Title">
          <carare:title>
            <xsl:value-of select="."/>
          </carare:title>
        </xsl:for-each>
        <carare:rights>
          <xsl:for-each select="Collection/Rights">
            <carare:copyright/>
          </xsl:for-each>
        </carare:rights>
        <xsl:for-each select="Collection/Source">
          <xsl:if test="position() = 1">
```

Figure 9: *XSL generated from the mapping*

6. Once we mapped our metadata schema to CARARE 1.0.6.1 schema we applied the transformation to the data set uploaded. The metadata were uploaded as multiple XML files, each one containing one item, in a zip folder.

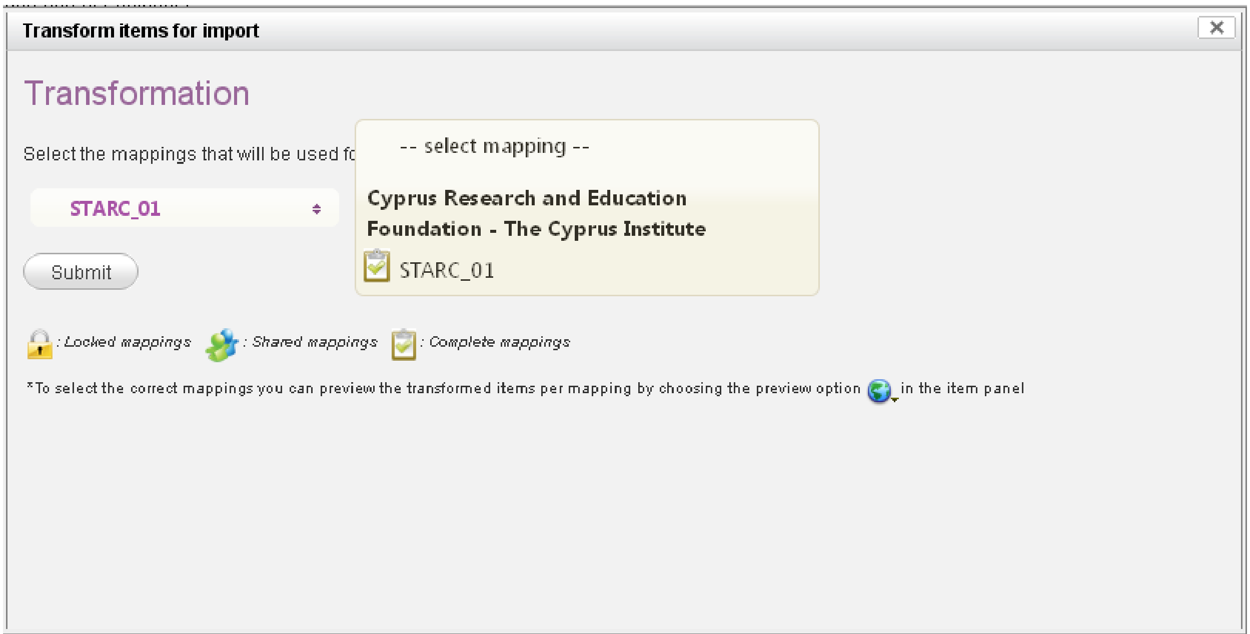
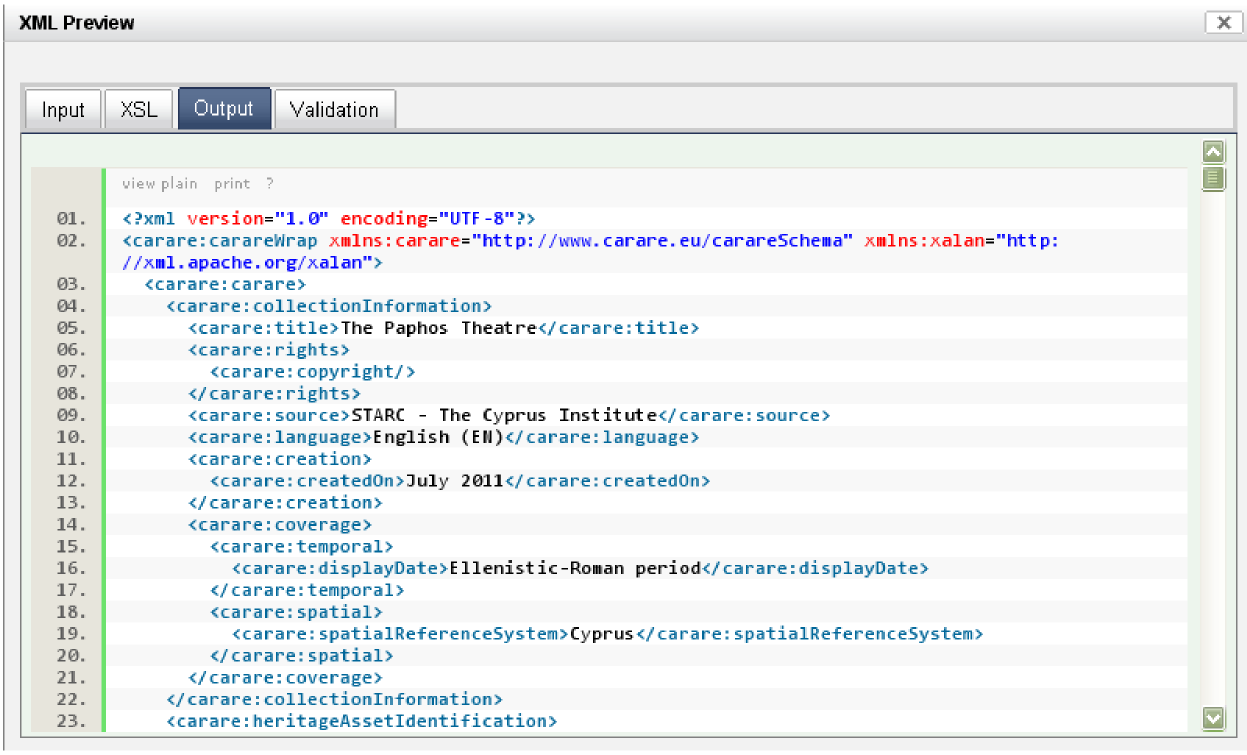


Figure 10: *The transformation modal window*




```
<?xml version="1.0" encoding="UTF-8"?>
<carare:carareWrap xmlns:carare="http://www.carare.eu/carareSchema" xmlns:xalan="http://xml.apache.org/xalan">
  <carare:carare>
    <carare:collectionInformation>
      <carare:title>The Paphos Theatre</carare:title>
      <carare:rights>
        <carare:copyright/>
      </carare:rights>
      <carare:source>STARC - The Cyprus Institute</carare:source>
      <carare:language>English (EN)</carare:language>
      <carare:creation>
        <carare:createdOn>July 2011</carare:createdOn>
      </carare:creation>
      <carare:coverage>
        <carare:temporal>
          <carare:displayDate>Ellenistic-Roman period</carare:displayDate>
        </carare:temporal>
        <carare:spatial>
          <carare:spatialReferenceSystem>Cyprus</carare:spatialReferenceSystem>
        </carare:spatial>
      </carare:coverage>
    </carare:collectionInformation>
    <carare:heritageAssetIdentification>
```

Figure 11: *The output of the native metadata transformed to the CARARE format*

An example CARARE record is shown below, at the end of this case study.

Overview of the Paphos web site platform

The online platform aims to promote, understand and share knowledge about the methodology and the output of the virtual reconstruction process of the Paphos Theatre. The prototype platform can be found at http://www.3dtheater.teletronltd.com.

The characteristics of the website built on open source software are:

- Content Management System based on Joomla, installed on a local server using Apache environment, based on PHP server-side scripting language and connected with MySQL open source database
- Dynamic Web design and development of a user friendly interface
- Use of virtual 360 navigation tool (Panotools) for visualisation of real and virtual environments
- Use of VRML (Virtual Reality Modelling Language) for 3D navigation.
- 3D engine based on Flash and Flex will improve, in the next future, the existing technologies for real-time navigation through the Web.

User scenario

Searching in Europeana for the Paphos Theatre, a user will have the possibility to visualise images, 3D models, texts and videos which are related to the Paphos Theatre.

Choosing the 3D icon, (which will be added to the Europeana interface), the user will be able to visualize the thumbnail of the 3D PDF document which will be linked to the original context where the 3D PDF is stored on the content provider's server (in this case on the web site http://www.3dtheater.teletronltd.com). The user will be able to read about the methodology adopted, interact with the multimedia/hypermedia content, products of 3D reconstruction process, explore the 3D object and the descriptive metadata embedded into the 3D PDF.

The thumbnail will be directly created by Europeana through the link, provided by the content provider, to the server or web site where the 3D PDF (for 3D objects) and the images are stored.

The website interface is structured in two sections:

1. The upper part describes the case study objectives and the methodology followed for an efficient 3D online visualisation.

2. The lower part of the interface allows the user to choose the digital resource which he/she is interested on (2D and 3D information):

a. Photos
b. Geolocation
c. Architectural Layout
d. 3D Rendering
e. Interactive
f. Video Augmented Reality

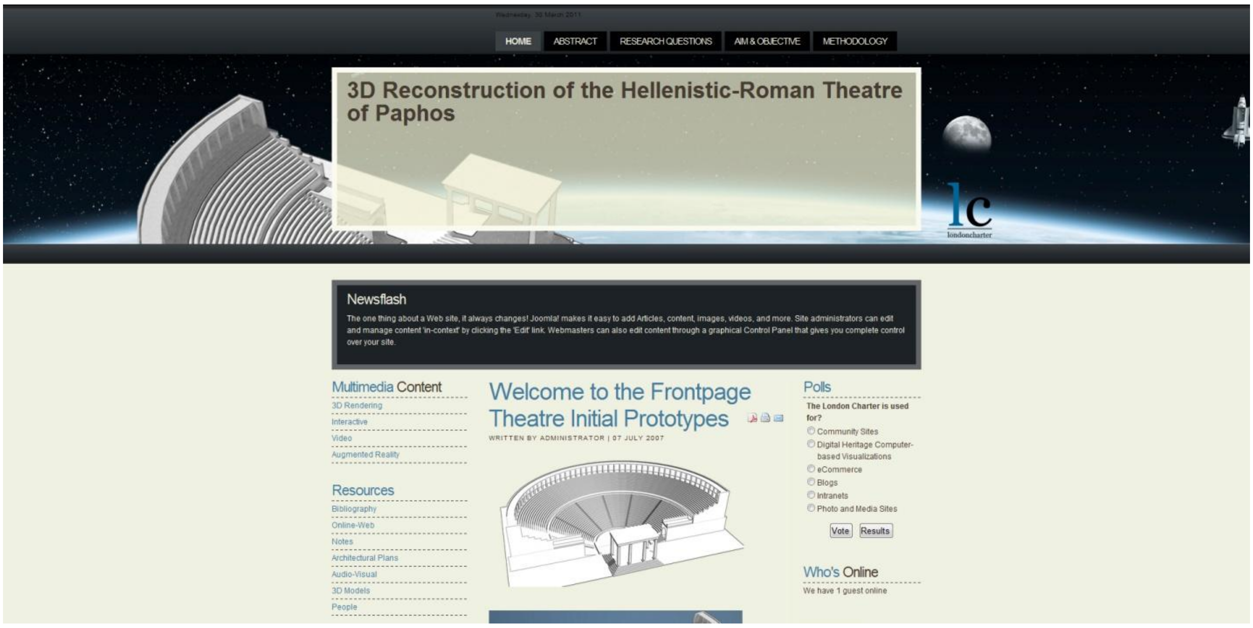


Figure 12: *Website interface*

a. Photos

The photo gallery is interactive and is created on high level communication languages such as **JavaScript** (**CSJS**) (client-site scripting) based on PHP (Hypertext Pre-processor) Server-side HTML embedded scripting designed for web development to produce dynamic web pages.

Inside the gallery image thumbnails will be presented, and, by clicking on it, a pop-up window will show to the user high-resolution images of on-site photos, snapshots and panoramic views with the related description.

b. Geolocation

This tool enables the spatial information visualisation of a 3D model or pictures on Google Earth (using Google Sketch-up for the integration of the model into the Google Earth's environment). The 3D model (optimized for the web and the desktop application) is exported into the *.kmz file format and it is uploaded on the web server. The user will be able to download the corresponding file and then visualise it on Google Earth.

Figure 13: *Geolocation of the 3D model in Google Earth*

c. Architectural Layout

This section follows the same concept as the photo gallery system (previously described) and will enable the user to view and download architectural plans, cross-sections, elevations, site views.

Figure 14: *Architectural layout window*

d. 3D Rendering

The rendering of photorealistic and non-photorealistic still imagery is published on the web site through a 2D open source interactive application (ZOOM.it). This software is currently used by Europeana web site for exhibition of high-resolution still images.

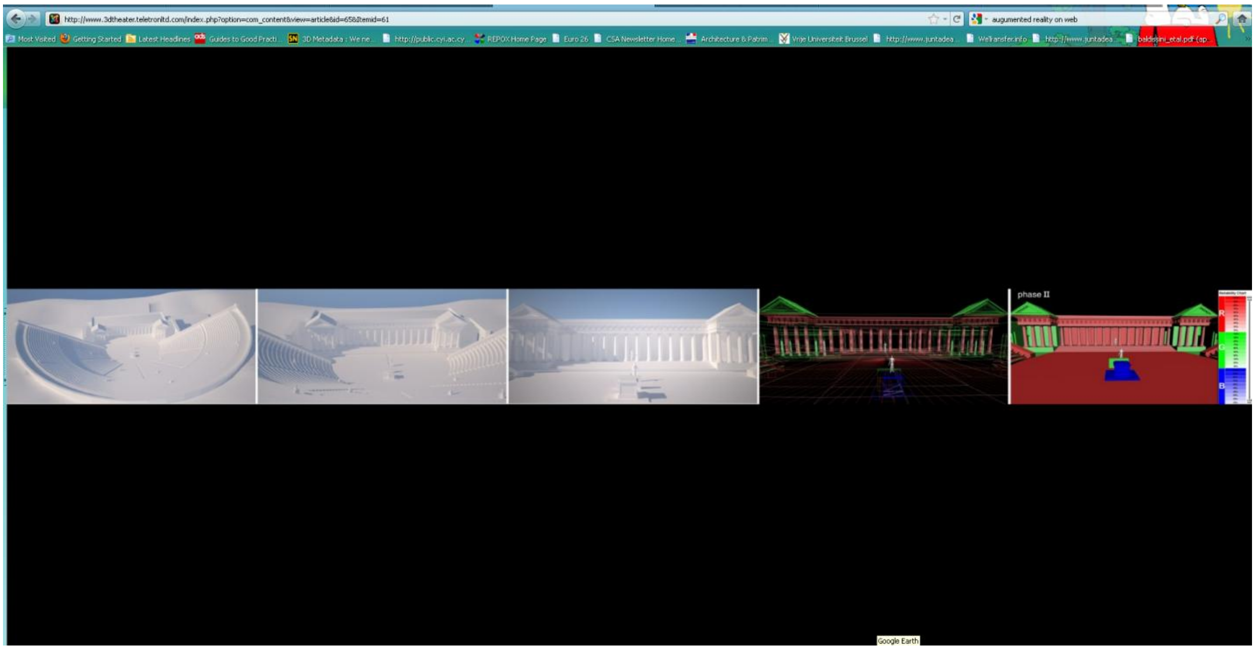


Figure 15: *3D rendering images*

e. Interactive

The 3D models of the whole area of the theatre and its architectural components can be interactively explored by using ISO standard and experimental application (leading to standardisation) for the integration of 3D geometry, textures and light information. In order to have an interoperable (cross-platform) and durable interactive content, the format that we use for publishing our content is 3D PDF. We plan to use VRML, X3D (xml encoded, X3DOM framework) and COLLADA (xml encoded) in the future, according to the Web 3D capabilities and user needs.

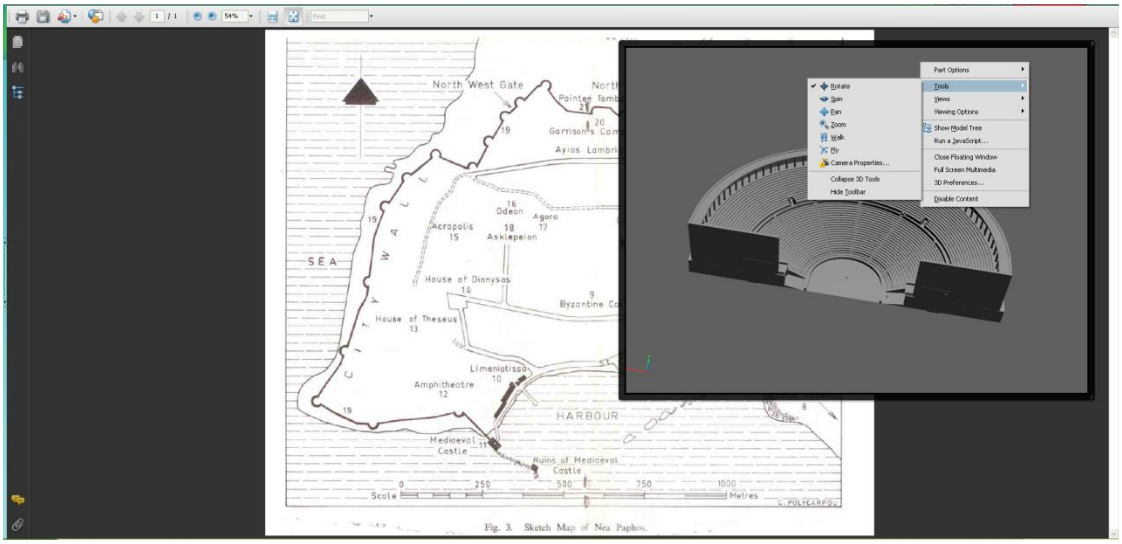


Figure 16: *The 3D model embedded in the 3D PDF*

f. Video

Animated stereoscopic and non-stereoscopic contents can be visualised through Real Time web player and downloaded for high resolution desktop viewing (mpeg 4 file format).

g. Augmented Reality

Virtual graphics data will be overlaid onto real world objects.

Example Paphos XML records in CARARE format

The metadata described below is the resource discovery metadata attached to the 3D PDF file which will enable the users to find the object via Europeana and refers to the 3D object.

Collection Information

<collectionInformation>
<title>**The Paphos Theatre 3D collection**</title>
<rights>**STARC - The Cyprus_Institute, Department of Antiquities of Cyprus, University of Sydney**
</rights>
<source>**STARC – The Cyprus Institute**</source>
<language>**en**</language>
<creation>
<createdOn>**July 2011**</createdOn>
</creation>
</collectionInformation>

Heritage Asset

<heritageAssetIdentification>
<recordInformation>
<id>**STARC_072011-1**</id>
<source> **STARC – The Cyprus Institute** </source>
<country>**Cyprus**</country>
<creation>
<date>**2011-08-02**</date>
<actor>
<name>**STARC – The Cyprus Institute**</name>
<actorType>**organisation**</actorType>
<contacts>**p.ronzino@cyi.ac.cy**</contacts>
</actor>
</creation>
<language>**en**</language>
<keywords lang=”en”>**theatre**</keywords>
</recordInformation>

<appellation>
<name lang=”en” preferred=”true”>**Paphos Theatre**</name>
<id> **STARC_072011-1**<id/>
</appellation>

<description lang=”en”>**description text of the theatre**</description>

```xml
	<characters>
		<heritageAssetType>Theatre</heritageAssetType>
		<temporal>
			<timeSpan>
				<startDate>300 BC</startDate>
				<endDate>365 AD</endDate>
			<periodName lang="en">Hellenistic</periodName>
			<displayDate lang="en">300 BC</displayDate>
			<periodName lang="en">Roman</periodName>
			<displayDate lang="en">365 AD</displayDate>
		</temporal>
	</characters>

	<spatial>
		<locationSet>
			<namedLocation lang="en">Paphos</namedLocation>
		</locationSet>

		<spatialReferenceSystem>wgs84</spatialReferenceSystem>

		<geometry>
			<quickpoint>
				<x>34.76023</x>
				<y>32.40726</y>
			</quickpoint>
		</geometry>
	</spatial>


<relations>
		<sourceOfRelation> STARC_072011-1</sourceOfRelation>
		<typeOfRelation>hasPart</typeOfRelation>
		<targetOfRelation> STARC_072011-2</targetOfRelation>
	</relations>
</heritageAssetIdentification>
```

In the Relations part above, it is defined that the theatre (id = **STARC_072011-1**) is related to a record for another heritage asset which describes the cavea (id = **STARC_072011-2**), as outlined in the previous section.

Digital resources and related activities

The *Digital Resource* metadata describes the 3D PDF file that embeds the 3D models of the Paphos theatre and its structural components and architectonic elements. The creation process is connected to the 3D models using relations. This section defines crucial information for the publication process in Europeana through the definition of where the 3D PDF file (<link>) and its thumbnail image (<object>) are located and what the landing page is (<IsShownAt>).

```
<digitalResource>
	<recordInformation>
		<id>3DPDF_id</id>
		<source>STARC – The Cyprus Institute</source>
		<country>Cyprus</country>

		<creation>
			<date>2011-04-02</date>
			<actor>
				<name>STARC – The Cyprus Institute</name>
				<actorType>organisation</actorType>
				<contacts>p.ronzino@cyi.ac.cy</contacts>
			</actor>
		</creation>

		<update>
			<date>2011-05-07</date>
			<actor>
				<name>STARC – The Cyprus Institute</name>
				<actorType>organisation</actorType>
				<contacts>p.ronzino@cyi.ac.cy</contacts>
			</actor>
		</update>

		<language lang="en"/>
	</recordInformation>

	<appellation>
		<name lang="en">Interactive 3D model of Paphos Theatre</name>
		<id> STARC_072011-92</id>
	</appellation>

	<actors>
		<name>STARC – The Cyprus Institute, Nicosia, Cyprus</name>
		<roles>author </roles>
	</actors>
```

<actors>
<name>**CNR-ITABC, Rome, Italy, STARC-The Cyprus Institute, C.I.S.A.-University of Naples, Italy**</name>
<roles>**author** </roles>
</actors>

<format>**PDF**</format>
<type>**3D**</type>
<description lang="en">**This 3D reconstruction model… of the monument**</description>
<created>**2011**</created>
<link>**http://www.3dtheater.teletronltd.com/PDF/theatre.pdf**</link>
<object>**http://www.3dtheater.teletronltd.com/PDF/theatre.jpg**</object>
<isShownAt>**http://www.3dtheater.teletronltd.com/pages/theatre.html**</isShownAt>

<relations>
<sourceOfRelation>**3DPDF_id**</sourceOfRelation>
<typeOfRelation>**isRepresentationOf**</typeOfRelation>
<targetOfRelation> **STARC_072011-1**</targetOfRelation>
</relations>

<relations>
<sourceOfRelation>**3DPDF_id**</sourceOfRelation>
<typeOfRelation>**isDerivativeOf**</typeOfRelation>
<targetOfRelation>**3D model_id**</targetOfRelation>
</relations>

<rights>
<copyright>
<rightsHolder>STARC-The Cyprus Institute**Department of Antiquities of Cyprus**</rightsHolder>
<creditLine>**© Department of Antiquities of Cyprus**</creditLine>
</copyright>
</rights>
</digitalResource>

The 3DPDF(id= 3DPDF_id), as described in the relation above, **is derivative of** 3D model (id=3D model). Another set of information in Digital Resources will describe the 3D model which will be linked to the 3DPDF and the theatre (id=theatre_id) using relations.

The 3D model is defined through an Activity such as aerial photogrammetry that yields the 3D model. Here the creators of the 3D model and the equipment used for the digital acquisition are defined.

```
<activity>
	<recordInformation>
		<id>survey_id</id>
		<source>STARC – Paphos Theatre</source>
		<country>Cyprus</country>

		<creation>
			<date>2009-04-15</date>
			<actor>
				<name>STARC – The Cyprus Institute</name>
				<actorType>organisation</actorType>
				<contacts>p.ronzino@cyi.ac.cy</contacts>
			</actor>
		</creation>

	<appellation>
		<name lang="en">Survey and 3D model of Paphos theatre</name>
		<id>survey_id</id>
	</appellation>

	<description> text describing the activity </description>

	<actors>
		<name>CNR-ITABC, Rome, Italy</name>
		<roles>survey and creator of the 3D model</roles>
	</actors>
	<actors>
		<name>STARC- The Cyprus Institute</name>
		<roles>survey and creator of the 3D model</roles>
	</actors>

	<eventType>Survey</eventType>
	<eventType>3D modelling</eventType>

	<temporal>
		<displayDate>2009</displayDate>
	</temporal>

	<spatial>
```

```
            <locationSet>
                        <namedLocation lang="en">Paphos</namedLocation>
            </locationSet>

            <spatialReferenceSystem>wgs84</spatialReferenceSystem>

            <geometry>
                        <quickpoint>
                                    <x>34.76023</x>
                                    <y>32.40726</y>
                        </quickpoint>
            </geometry>
  </spatial>

  <eventMethod lang="en">Aerial photogrammetry</eventMethod>
  <materialsAndTechniques>Data capture device: Fly Scan</materialsAndTechniques>

  <relations>
            <sourceOfRelation>survey_id</sourceOfRelation>
            <typeOfRelation>isRelatedTo</typeOfRelation>
            <targetOfRelation>theatre_id</targetOfRelation>
  </relations>

</activity>
```