

## D5.1: Report on 3D Publication Formats Suitable for Europeana

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## D5.1 Report on 3D publication formats suitable for Europeana

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### 1 Executive Summary

This deliverable, 3D Publication Formats Suitable for Europeana, examines the many requirements for 3D formats, analyses the current technologies and likely future landscape and proposes a set of suitable publication formats that will cater for the wide range of type of 3D models being made available by the 3D-ICONS project whilst meeting as many of the identified requirements as possible.

The requirements include the basic set of rules defined by Europeana such as the ability to view 3D models on all platforms without installation of plug-ins or additional software and the need for standard file formats and sustainability. Some examples of 3D models are already available through Europeana and these are reviewed with respect to the current requirements. However, the technical landscape has moved on considerably since many of these models were published (up to 3 years ago). The range of devices and operating systems has increased enormously with the increasing uptake of mobile devices (phones, tablets, etc.) while it isn't yet clear how people are currently using 3D models in Europeana.

A detailed overview of the available publication technologies forms a major part of this report and aims to select a small set of technologies to deliver 3D content in a maximum number of browsers on a maximum number of digital platforms which include mobile. The technologies covered are:

- 3D PDF
- HTML5/WebGL
- 3D Streaming
- Unity3D and Unreal
- Game solutions used in social media (Unity3D, SketchFab, WordPress)
- Pseudo3D
- Remote rendering

These are examined with respect to their availability within current operating systems and platforms and their suitability for different types of 3D models. The issue of IPR is also discussed along with the security aspects of key technologies.

The report concludes with an evaluation of suitable technologies with specific examples of 3D models being supplied by 3D-ICONS and proposes a selection of formats:

- 3D PDF for visualisations of object that do not have special material properties and that are not too big or complex.
- WebGL as this covers a wide range of visualisation modes from point cloud visualisation over object visualisation to interactive walkthrough and predefined guided tours. Special attention should be given to the Nexus format that will allow visualisation of complex 3D objects without simplification as it uses a streaming approach that results in a quick and refining visualisation of the visible parts while the remaining parts of the 3D model are streamed after that.
- Unity3D (and also Unreal Engine) for 3D models requiring complex behaviour such as interaction with the site, building and objects (for example opening a door), walking behaviours on complex terrain (including stairs) and collision detection.
- HTML5-based pseudo-3D visualisation for visualisation of 3D that cannot be rendered in real time, because of size, complexity, very high visual quality or special properties (for example: glass objects). Pseudo-3D is well suited for visualisation of interiors and it also allows visualisation in 4D (evolution of sites).

Further testing of tools and the resulting 3D models will be viewed on a variety of platforms and browsers in order to provide comprehensive guidelines as the project progresses. Training will be provided during the project and the finalised guidelines made available for the process pipeline in Deliverable 5.2 Report on Publication.

## 2 Introduction

The scope of the 3D-ICONS project is twofold:

- Making available 3D content for Europeana;
- Developing a metadata schema able to capture all the semantic information present in the digitisation process (provenance) and in understanding and interpretation of data objects (paradata).

As a best practice network, 3D-ICONS is developing a complete process pipeline which addresses data capture (digitisation) and processing, post-processing and publication to Europeana. The project is also developing an IPR schema which is integral to the complete process and which is based upon the Creative Commons licensing scheme.

The 3D data that is provided by the project has an unseen richness and complexity, and focuses on World Heritage and masterpieces of European cultural heritage.

This report focuses on the publication formats, which are the forms in which this rich and complex 3D data can be visualised for the Europeana user, which can be any person in the world interested in European culture, just as an interested layman or as a person with a specific goal, be it study of cultural heritage subjects or preparing a tourist trip to a European destination, or a high school student preparing a presentation.

In other words, the visualisation of 3D assets in Europeana needs to serve a very wide variety of needs and users, and needs to be focused on accessibility, ease of use and engagement, independent of any knowledge or technical environment to visualise 3D. Consequently, this report focuses on maximising the 3D experience of the Europeana user who is not prepared or equipped for 3D visualisation. In other words, the resource exploration of 3D assets needs to be an experience as easy and natural as for any other asset on Europeana.

This report does not focus on the creation and structure of the metadata of these objects, as this is a quite different topic from both a technical and conceptual point of view. This report focuses on optimising the visualisation of 3D assets provided through Europeana for a maximum of users, and doing this in a sustainable and feasible way. This report also provides guidelines for the cultural heritage organisation that is looking for the most optimal way to display 3D assets online.

### 3 Europeana and 3D content

#### 3.1 Europeana requirements

When discussing (in the context of the CARARE project) the use of 3D with the Europeana team, the following requirements were defined:

- 3D assets need to be visualised on all major platforms (which means all platforms that have a certain market share),
- visualising 3D assets needs to avoid installing additional software,
- visualising 3D assets needs to be intuitive and easy,
- visualising 3D assets needs to support the concept of resource exploration (for example by having URLs integrated),
- 3D assets need to have open and standard file formats that can be sustained in the long term.

This means we need to take care about the current and projected market share of operating systems and browsers, as browsers are the publication channel with different capabilities on the various desktop and mobile platforms, so that we can maximise the availability of the 3D assets for the Europeana user by selecting the most appropriate 3D visualisation technologies.

The requirement for open and standard file formats is not only a question of digital preservation but also a question of sustainability of the data for the longer term. Although most institutions that provide data to Europeana are stable and long-standing organisations, the teams that make and provide the data can be much more volatile. Using some high-end, complex or custom-made 3D visualisation technology can yield appealing and spectacular 3D visualisations but when the team that has made these visualisations fades away, it becomes difficult to support or even sustain them, even if the involved technology is still supported and used.

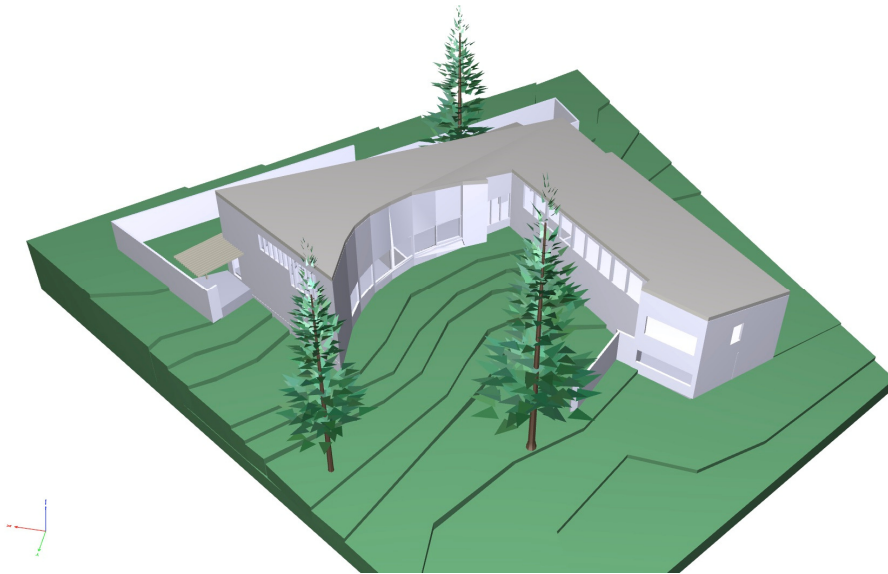
The same holds for technologies that are at the end of their life cycle. A lot of the 3D visualisation technology of the past decade will go out of use quickly because the new WebGL/HTML5 solutions will replace them and support for these older technologies will quickly disappear, even if they are still used and available today.

So the choice of the most suited technologies for 3D-ICONS does not only have technological aspects, but certainly also sustainability, usability and marketing aspects. Publishing 3D for the layman is a far from trivial task, and we need to do that with a long-term perspective.

### 3.2 Providers of 3D content in Europeana

Currently, there are 5 content providers that have 3D content on display in Europeana.

**LinkedHeritage**<sup>1</sup> is by far the largest provider with 13.353 3D objects. These objects are architectural elements and buildings made in CAD.



*3D model of the Alvar Aalto Studio on Europeana provided by LinkedHeritage*

**CARARE**<sup>2</sup> is the second largest provider, currently with 286 3D objects. However, many more 3D objects are still in the waiting list as they have been provided in EDM (CARARE was the first project to provide metadata in EDM) and technical issues have blocked the publishing of these objects until now.



*Inside and outside of Ayios Vasilios church in Kefala, Greece, on Europeana by CETI (CARARE)*

<sup>1</sup> <http://www.linkedheritage.eu/>

<sup>2</sup> <http://carare.eu/>

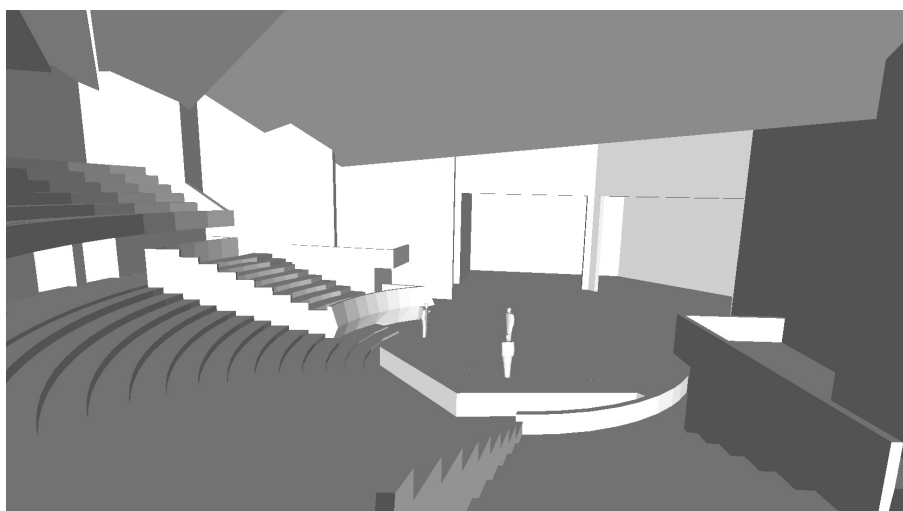


**3D-COFORM**<sup>3</sup> has 48 3D objects published. These objects come from a variety of sources, such as museums, public monuments and a private collection. The quality of the 3D models is high.



*Objects from the Victoria and Albert museum on Europeana by 3D-COFORM*

**ECLAP**<sup>4</sup>, the European e-library for performing arts, has 10 3D objects, which show 3D models of theatres. These models are very elementary.



*Olivier National Theatre on Europeana provided by ECLAP*

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<sup>3</sup> <http://www.3dcoform.eu/>

<sup>4</sup> <http://www.eclap.eu/>

The **Cyprus University of Technology** has provided 2 3D models of Byzantine churches in the context of the EU presidency of Cyprus. These models are technology demonstrators and are not part of a larger digitisation effort or project.



*Timiou Stavrou church (Cyprus) on Europeana by the Cyprus University of Technology*

### 3.3 Analysis of current 3D content in Europeana

The LinkedHeritage 3D data is available in a variety of 3D file formats, but the visualisation is done consistently through images and 3D PDF. The 3D models are downloadable for further use.

Most of the CARARE 3D assets are visualised through 3D PDF. In general this has worked quite well, the most serious issue that occurred was that some 3D files are still too large to work properly on all computers (3D PDF files can contain quite large 3D models but the long load time and slow interactivity on low end computers can be a problem). This shows that content providers not always can or want to provide highly optimised 3D models, so that a publishing methodology that can deal with large, highly detailed 3D models is necessary.

The 3D-COFORM 3D assets are visualised through WebGL, based upon the developments of Fraunhofer IGD. All 3D assets are museum objects and are visualised in an object way. The visualisation works successfully on all platforms except iOS based devices. This 3D visualisation effort is certainly one of the good examples that have served as inspiration for the choices made in this report.

The ECLAP 3D data consists of VRML models that are being visualised through the FreeWRL plugin<sup>5</sup>, which is available for most platforms but unfortunately not for

<sup>5</sup> <http://freewrl.sourceforge.net/>

MacOS X or iOS. This example shows again that the use of plugins is difficult to maintain for the large number of operating systems that are currently in use. It is a pity that the choice for a VRML plugin to publish these simple 3D models results in a part of the users not being able to see those models, and does not guarantee a long term use of the data (as VRML and VRML plugins will disappear soon).

The 3D data of the Cyprus University of Technology are very large in size (files are 60 and 70 MB) and shows again the need for the simplification and optimisation of 3D models of full buildings, including not only the 3D shape data but certainly also the high-resolution textures (wall paintings) that are contained in the 3D model. Using the compression feature of 3D PDF (that performs JPEG compression on the texture files) would have reduced the file size significantly. This example illustrates that the publication of 3D data for non-specialised users is far from trivial and requires in-depth knowledge of the publication process and its features (in this case 3D PDF).

## 4 Challenges of complex 3D data

### 4.1 Web access

The 3D assets, that 3D-ICONS is making available through Europeana, are quite detailed and complex. Publishing them online for non-dedicated users is already quite a challenge. But 3D-ICONS wants to blend the 3D visualisation of Europeana assets smoothly into searching and using of other Europeana assets, without hassle or complexity. Therefore we need to rely on new developments in this domain, which have been going through a quite dramatic change during the last few years.

When the CARARE project had to make its choice about 3D visualisation in 2010, the web access of 3D data was situated in a quite different context than today. Online browsing happened through Firefox or Internet Explorer, with about 10 % of the users relying on the new Chrome browser. Online browsing on mobile devices was a hot topic, but only a small minority (2 % of the online users) was really using their mobile phones and tablets to search for information on the internet. The bulk of the online activity took place on a Windows or Mac desktop computer.

Today, we have a much wider variety of browsers that are actively used, but we also have more operating systems than ever before. We still have Mac and Windows desktop computers (with Windows being a colourful bunch of different flavours, from Windows XP that still has a dedicated group of users to Windows 8.1, that tries to ease the commotion of the radical changes of Windows 8). Linux desktops are owned only by a marginally small group of users. But the mobile devices have spawned a new set of operating systems, such as Android (in many versions and flavours), iOS, Windows Mobile, Blackberry, Firefox OS, ...

The normal approach of releasing software for all these platforms and flavours would be too much of a burden for a small and short project such as 3D-ICONS. Therefore, we



focus on using standards such as PDF and HTML5/WebGL to publish our data, trying to achieve as much platform coverage as possible.

#### 4.2 Use of 3D assets

The number of 3D assets available through Europeana is still too small to investigate how people are using these 3D assets. However, we have some ideas how people would like to use these 3D assets.

First of all, 3D is a more engaging way of showing an object, building or site. However, 3D should have added value over photos or video. If we investigate for example the visualisation of the virtual reconstructions of the palace of Versailles<sup>6</sup>, this is positioned by the creators as interactive film, not 3D. The visualisation provides the possibility to walk around in the gardens and rooms of Versailles (on a predefined path) and look around at any point, as you would do during a real walk on the real terrain. Being limited to the predefined path provides, on the other hand, a kind of guided tour, and also simplifies the task of the 3D designer in what parts of the 3D scene are visible or need high resolution detail or not, and elegantly solves the problem to 'fence off' areas where the visitor should not go because the 3D model has to stop somewhere or is provided in an elementary way. In other words, the 3D visualisation gives a much better experience of the space while the build-in limitations yield some guidance for the visitor and some relief for the 3D modeller and interaction designer.

Visualising objects in 3D provides also another experience, which is being able to see museum objects or building elements of historical buildings from all sides and in high detail. The psychological impact of this is mostly overlooked: it gives the user the impression having the object in hand and creating a feeling of owning the object. In this way, 3D helps a lot in creating the feeling that the general public owns the objects (which in fact they do).

The other aspect of making buildings, sites and objects available in 3D is the use for research. Research requires a full study of the object and sometimes, the back or the bottom of the object is more interesting for a researcher than the nice front view. 3D tools can be useful in showing information that is useful for research, such as cross sections (in 3D PDF) or building structure. Virtual reconstructions for example are a synthesis of a lot of knowledge and show how objects or archaeological remains fit together. Link with sources and context information here is essential.

For research, higher resolution or direct access to the 3D model (instead of only visualisation) can be useful but this should be organised outside Europeana, as this requires other IPR (and technology).

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<sup>6</sup> <http://www.chaostoperfection.com/scenes.html?lang=en>

## 5 Available technologies

The goal of this text is to select a small set of technologies to deliver 3D content in a maximum number of browsers on a maximum number of digital platforms.

The range of 3D technologies that are available is huge. We limit ourselves to technologies that can deliver 3D assets through the Internet, that are currently multiplatform and that have already a certain track record (or obvious potential for new technologies) in easy use and take up by a wide range of users. Technologies that target a specific group of users or that have too stringent requirements towards hardware or software are not considered.

In any case, most 3D visualisation technology is quite new, so it is important to recognize that 3D visualisation could encourage users to upgrade their software and/or hardware, which they could also refuse to do. In other words, the availability of web-based 3D visualization is a complex 4-dimensional parameter space that is constantly in evolution, and that could look less optimal in practice than heralded by the latest developments. We expand on this in paragraph 5.9.

### 5.1 3D PDF

3D PDF has been selected by CARARE<sup>7</sup> as the major format for delivering 3D content to Europeana. The major reasons for this choice are the ease of use and the available functionality, the fact that 90% of the users have a 3D enabled PDF reader installed and the fact that 3D PDF files can be used on a wide range of platforms both in online and stand-alone mode.

However, recent developments have troubled this elegant solution. Due to a major security issue when visualising PDF files in a browser, and due to the slow and inadequate reaction of Adobe, the PDF visualisation plugin has been declared unsafe and most recent versions of browsers have been swiftly equipped with internal PDF visualisation that unfortunately lacks all high-end functionality, including 3D. As most people have the automatic update of their browser(s) enabled, the switch to this new functionality went unnoticed, also for those people that preferred to open PDF file directly in their PDF reader. Opening a 3D PDF file now results in different behaviours, depending on the browser.

In Firefox for example (we have tested version 22 on MacOS 10.8), a message is given that the PDF content cannot be displayed properly. This can be solved simply by clicking the button “*open with different viewer*” to open the file in the standard PDF reader (mostly Acrobat Reader) but this requires some user guidance, as it is not obvious for non-technical people that there is nothing wrong with the file, but that the issue is due to the limited PDF visualisation in their browser. This situation is not likely to change soon.

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<sup>7</sup> <http://www.carare.eu/eng/Media/Files/D5.1-Req-Spec-for-preparing-3D-VR-for-Europeana>

The PDF visualisation of *Google Chrome* (we have tested version 28 on MacOS 10.8) does not support 3D PDF and the direct possibility to open the PDF in Acrobat Reader is not given. No error message is produced when 3D content cannot be displayed.

The PDF visualisation of *Safari* (we have tested version 6 on MacOS 10.8) is much more elaborated and does visualise 3D PDF files properly.

On iOS devices, the standard Acrobat reader is available, accompanied by an app called *3D PDF Reader*<sup>8</sup> from Tech Soft 3D (costs 4.5 euro). When 3D content is available in a PDF file, one gets a button to open this 3D content in the 3D PDF app. Most of the tested 3D PDF files could be visualised properly, but a lot of the functionality that is available in the Acrobat PDF reader is missing. There is no visualisation of predefined views, most visualisation options are missing (including walking) and links in the text to activate 3D views are not working. Visualising 3D objects works fine, visualising buildings and sites or linking context to the 3D object does not work in this iOS solution.

On Android mobile devices and on other mobile operating systems, there is currently no 3D PDF solution.

In other words, the direct visualisation of 3D PDF on desktop computers with Acrobat Reader is still working fine, but the delivery and visualisation of PDF files in a browser has some issues for Firefox and Chrome and has become confusing. The visualisation on mobile devices is only partial and limited, and is currently not for free.

Nevertheless, the authoring of 3D PDF through Acrobat has advanced in quality and functionality and now includes animation. As proper visualisation of the high-end features of 3D-PDF on mobile platforms is still lacking, this evolution does add little to the importance that 3D PDF can have in this project, or for visualising 3D digital heritage in general.

As expected, online visualisation of 3D (see next paragraph) is providing the same functionality as 3D PDF and evolves more quickly than the 3D PDF functionality.

## 5.2 HTML5 based solutions

The visualisation of 3D in a web browser without installing software or plugins is preferably done by WebGL in a HTML5 context. This solution has already been adopted widely by the 3D community and 3D repositories are being implemented in WebGL/HTML5<sup>9,10</sup>.

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<sup>8</sup> <http://www.techsoft3d.com/our-products/3d-pdf-reader>

<sup>9</sup> <http://sketchfab.com/>

<sup>10</sup> <http://xts.uchicago.edu/>

WebGL<sup>11</sup> is currently considered to be part of the HTML5<sup>12</sup> standard, as WebGL uses HTML5 elements (such as the *canvas* element). WebGL, however, is provided by the Khronos Group<sup>13</sup> (a non-profit industry consortium), not by the W3C, the organisation that provides the standardisation of HTML with HTML version 5 being the latest standard.

WebGL uses in a transparent way the available hardware acceleration that is available on each individual computer. This is very important for this project, as we publish 3D data for a wide range of users, basically without minimum requirements, so the 3D visualisation should adapt itself in the most optimal way for a given hardware platform. This is especially true for mobile devices where graphical performance is only one requirement, next to battery life, weight, size, ...

Recently, WebGL has gained major support in the different browsers and platforms<sup>14</sup>.

The *Chrome browser*<sup>15</sup> is available on Windows, MacOS X, Linux, iOS (for mobile Apple devices) and Android (for mobile devices) and fully supports WebGL. Since March 2013, the *Chrome for Android* browser supports WebGL, although one needs to enable the WebGL capabilities still manually<sup>16</sup>. The *Chrome for iOS* browser however does not support WebGL because of platform restrictions.

The *Firefox browser*<sup>17</sup> is available on Windows, MacOS X, and Linux supports fully WebGL. For mobile devices, the *Firefox for Android* browser supports WebGL. There is no Firefox browser for iOS.

*Android* has WebGL support in the newest available browsers (like Chrome, Firefox, ...) but is fragmented with a slow upgrade cycle, mainly driven by the replacement through new systems, not by the updating of existing systems. For example, Chrome for Android requires at least a 4.0 version of the operating system to have operational WebGL functionality, while 36 % of the current Android systems still have a lower version. The standard *Android browser* does not support WebGL, except the improved versions on Sony Ericsson Xperia and Samsung devices.

The *Safari browser* both for MacOS and Windows does support WebGL, although it still requires the user to enable it manually. Apple still earmarks WebGL as an *experimental feature* in Safari for desktop computers. WebGL is in fact also available on Safari on its

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<sup>11</sup> <http://en.wikipedia.org/wiki/WebGL>

<sup>12</sup> <http://en.wikipedia.org/wiki/HTML5>

<sup>13</sup> <http://www.khronos.org/webgl/>

<sup>14</sup> <http://caniuse.com/webgl>

<sup>15</sup> [http://en.wikipedia.org/wiki/Google\\_Chrome](http://en.wikipedia.org/wiki/Google_Chrome)

<sup>16</sup> <http://blog.laptopmag.com/how-to-enable-webgl-support-on-chrome-for-android>

<sup>17</sup> [http://en.wikipedia.org/wiki/Firefox\\_browser](http://en.wikipedia.org/wiki/Firefox_browser)

mobile devices but it is disabled. It can be made active on *jailbroken* devices, but this is something that a normal user is not supposed to do. In reality, however, Apple does not allow WebGL on its mobile devices for commercial reasons. Currently, 3D applications on iPad and iPod only can be provided through the AppStore, with 30 % of all sales income going to Apple. Providing WebGL on its mobile devices would allow 3D applications that do not need distribution through the AppStore, depriving Apple of a substantial amount of income. Although some experts expected Apple to make WebGL available in Safari for iOS7, no WebGL is available in this new version<sup>18</sup>.

The *Opera browser*, which is only having a small market share, does support WebGL, both for desktop computers and mobile devices. The same holds for the *Blackberry browser*, on the Blackberry mobiles.

Most adversaries of WebGL have surrendered by now. Microsoft, for example, makes WebGL available in its new version (version 11) of *Internet Explorer* for which the beta-testing is currently on-going. Before version 11, there was already a plugin (Google Chrome Frame) that provided HTML5/WebGL functionality. So, all major browsers on desktop computers currently have native support of HTML5/WebGL.

The other competing technology for displaying 3D is Flash, owned by Adobe. But in 2012, Adobe has stopped all development of Flash on mobile devices<sup>19</sup> and focuses on HTML5 for browser content.

All major applications that use Flash are switching to HTML5. One of the most known is YouTube for which a HTML5 version already exists<sup>20</sup>. A lot of other Flash-based authoring platforms are making the step towards HTML5.

One of the major players in the 3D domain to drop Flash is Unity. This company that produces one of the most successful open game authoring platforms had focused on Flash for delivery of games on a wide range of platforms, but has stopped its Flash development<sup>21</sup> in favour of its own WebPlayer. Unity does provide HTML5 interfacing, but considers the optimisation of HTML5 still to be insufficient for high end games<sup>22</sup>. Nevertheless, they confirm they are working on a new initiative that most probably will be HTML5 based<sup>23</sup>.

We can summarise that for most browsers and most platforms, HTML5 and WebGL are supported, except for the Apple mobile devices (on which only HTML5 is supported<sup>24</sup>,

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<sup>18</sup> <http://www.mobilexweb.com/blog/safari-ios7-html5-problems-apis-review>

<sup>19</sup> [http://en.wikipedia.org/wiki/Adobe\\_Flash](http://en.wikipedia.org/wiki/Adobe_Flash)

<sup>20</sup> <http://www.youtube.com/html5>

<sup>21</sup> <http://www.develop-online.net/news/43963/Unity-ditching-Flash-support>

<sup>22</sup> <http://www.develop-online.net/news/39242/Unity-Well-support-HTML5>

<sup>23</sup> <http://blogs.unity3d.com/2013/04/23/sunsetting-flash/>

<sup>24</sup> <http://www.apple.com/html5/>



not WebGL). This is a strange development of the story, as it was the denial of Apple to support Flash on its mobile devices that has unlocked the development of HTML5 from its stalemate position, in which it found itself a few years ago due to the political games between the major software providers. It is finally Apple that has locked itself as only major player into the uneasy position of deliberately not supporting WebGL on its mobile platforms. Because WebGL is present and working on all iOS mobile devices but unavailable to the normal user (the feature is blocked), Apple is under pressure to make WebGL available. Nevertheless, there is no WebGL in the current iOS 7 version, so chances are low WebGL on iOS will become available soon.

We need to see this in its context however. The most recent numbers (IDC Worldwide Mobile Phone Tracker<sup>25</sup>) show that in smartphones, Android has a market share of 80% while Apple has a 13% share. Although the Apple mobile platforms get a lot of visibility, they are outnumbered significantly by the Android based mobile devices.

### 5.3 3D streaming

The display of 3D in an online context still needs to mature. We can compare this evolution with the advent of video and large images some years ago, where compression, multi-resolution and video streaming have improved the use of these assets significantly. The same holds for 3D, where on top of visualisation mechanisms such as HTML5 and WebGL, we need to have compression and streaming of 3D content to make the use of 3D easy and elegant.

CNR-ISTI, that has been in the forefront of visualising large 3D data for many years, has developed the Nexus format<sup>26</sup> that allows to stream large 3D models online<sup>27</sup>. Nexus is based upon WebGL and uses the SpiderGL library written by CNR-ISTI. It is for example used in the Cenobium project<sup>28</sup>.



*Capital from Monreale abbey (Cenobium project) after 1, 3 and 7 seconds of loading*

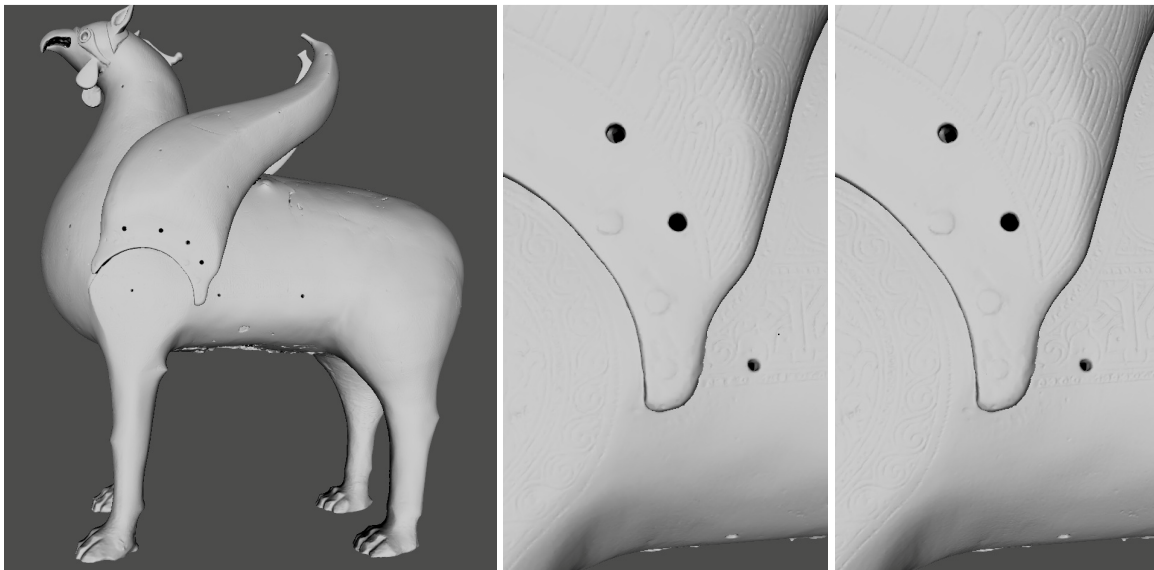
<sup>25</sup> <http://www.idc.com/getdoc.jsp?containerId=prUS24257413>

<sup>26</sup> <http://vcg.isti.cnr.it/nexus/>

<sup>27</sup> <http://vcg.isti.cnr.it/presenter/grifo/index.html>

<sup>28</sup> <http://cenobium.isti.cnr.it/>

The visualisation of objects in Nexus format allows to interact immediately with a coarser version of the 3D model, that refines gradually while the 3D data of the finer details are coming in. The refinement takes place first in the areas that are visible while for example the back of the object is loaded later than the front. The visualisation also takes the zoom level into account and loads more data when zooming in (see below). In this way, large and complex 3D models with millions of polygons can be viewed without the penalty of waiting for the data to come in.



*Comparison of a Nexus 3D model (left) after three seconds (middle) and 30 sec (right), by CNR-ISTI*

In the coming months, the European Network of Excellence V-MusT will make the *Community Presenter*<sup>29</sup> available as a web service. This web service will allow automatic conversion of 3D models into streaming online visualisations based upon the Nexus format and a graphical template that designs the web page. To display these 3D models in streaming mode, nothing more is needed than a WebGL enabled browser. The software (Java scripts) that is needed to visualise the refining 3D model while streaming the 3D data is referenced in the 3D model and comes over the internet without the need for installing.

#### 5.4 Serious games solutions

Another way to deliver 3D online is the use of 3D serious games technology that has evolved significantly in the last five years. In cultural heritage, the most used platform is Unity3D<sup>30</sup>. Unity can be developed platform independently and has publication towards specific platforms in the final stage, supported by specific tools. Unity3D supports all major desktop platforms (Windows, MacOS, Linux) and all major mobile platforms (Android, iOS, Windows Phone, Blackberry). Although the file format of the

<sup>29</sup> <http://vcg.isti.cnr.it/presenter/>

<sup>30</sup> <http://unity3d.com/>

application is not open, the advantages and appeal of such applications compensate for that.

The major advantage of Unity3D (or other serious games platforms) is the interaction with the space and the 3D models. These applications have the notion of a ground floor and stairs (on which you can walk), of walls (with which you can collide), of doors and other objects (with which you can interact). Sound can give you feedback on the space you are in, procedural animation can simulate wind blowing or water running.

Exploring a 3D model through such an application creates a much better feeling for the building or site, for its complexity, functions and content, and can be combined with non-linear storytelling, with goal based exploration or game functionality.

Publishing 3D content online uses the Unity Web Player, a highly optimised visualisation tool for the major browsers and computer platforms. Unity is confirming it is working on “a new web publishing initiative” which is most probably a HTML5/WebGL based development that is expected to be unveiled soon.

Unity online applications using the Web Player can be made in such a way that they install themselves, as the Web Player is a plugin to your browser(s), so the software is easy to use for non-technical users. A good example of architectural walkthrough can be found here<sup>31</sup>. An online walkthrough of the Acropolis of Athens can be found here<sup>32</sup>. A good example of an online cultural heritage serious game, showing the virtual reconstruction of a city centre, based upon archaeological research, can be seen here<sup>33</sup>.

The Unreal games engine<sup>34</sup> is also available for most computer platforms<sup>35</sup> and has been integrated into development kits that allow its use as a visualisation engine of complex 3D data (such as used by some 3D-ICONS partners). The installation of a resulting visualisation is a bit more technical than with Unity3D.

There are other serious game platforms such as Blender<sup>36</sup> and Virtools (3DVia<sup>37</sup>) that also could provide the kind of 3D visualisation that 3D-ICONS needs, but none of these applications allow publication on all the computer platforms in the way that Unity does. Unity3D is also the de facto standard for cultural heritage, and provides the best opportunities for re-use of the 3D assets.

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<sup>31</sup> <http://www.tetravol.com/citilab/>

<sup>32</sup> [http://www.mindscape3d.com/m3d/demo\\_akropolis.html](http://www.mindscape3d.com/m3d/demo_akropolis.html)

<sup>33</sup> <http://www.deynse1783.be/>

<sup>34</sup> [http://en.wikipedia.org/wiki/Unreal\\_Engine](http://en.wikipedia.org/wiki/Unreal_Engine)

<sup>35</sup> <http://www.unrealengine.com/en/platforms/>

<sup>36</sup> [http://en.wikipedia.org/wiki/Blender\\_Game\\_Engine](http://en.wikipedia.org/wiki/Blender_Game_Engine)

<sup>37</sup> <http://www.3ds.com/products-services/3dvia/>



## 5.5 Game solutions in social media

In its recent version (currently 4.2), *Unity3D for Facebook*<sup>38</sup> has integrated functionality for interaction with Facebook from within the game. For example, you can post screenshots on Facebook or invite friends without leaving the game. These Unity3D Facebook applications are based upon the highly successful Unity Web Player (200 million installs). The 3D model resides on your own server.

Another example of this kind of integration is *SketchFab*. This software allows to integrate 3D models (from 27 different file formats<sup>39</sup>) into your Facebook page<sup>40</sup> or any other page by embedding some HTML code. The 3D model resides on the SketchFab server.

Also in *WordPress*, the 3D capabilities of SketchFab can be integrated<sup>41</sup> like in these examples<sup>42,43</sup>. And there are other 3D plugins<sup>44</sup> in WordPress.

Integrating interactive 3D in a social media context can be an innovative approach to publishing cultural heritage content, and a trial could be carried out during the project. This kind of integration of 3D digital heritage content into social media has not been done before, but has the potential to spread appealing Europeana content through other channels that especially appeal to younger users.

## 5.6 Pseudo3D solutions

Pseudo3D visualises no 3D but in fact a set of images in an interactive way. It can be organised in such a way that it mimics real 3D visualisation, although it relies only on images. Pseudo3D solutions are to be used for all 3D that cannot be rendered in real-time, for reasons of complexity, high-end rendering requirements or special visualisation issues. For example, the image below contains 30 billions polygons and has a render time of about one hour on a normal quad core processor. The image is part of an ObjectVR based application where every historical period is visualised through 72 rendered images in a circle around the centre of the abbey.

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<sup>38</sup> <http://blogs.unity3d.com/2013/03/26/unity-and-facebook-are-now-in-a-relationship-and-its-awesome/>

<sup>39</sup> <http://sketchfab.com/faq>

<sup>40</sup> [https://www.facebook.com/SketchFab/app\\_190322544333196](https://www.facebook.com/SketchFab/app_190322544333196)

<sup>41</sup> <http://wordpress.org/plugins/sketchfab-viewer/>

<sup>42</sup> <http://www.klaasnienhuis.nl/2012/06/sketchfab-obj-fileformat-supported-features/>

<sup>43</sup> <http://michaeljclarke.wordpress.com/tag/sketchfab/>

<sup>44</sup> <http://wordpress.org/plugins/3d-viewer-configurator/>



*Example of complex scene (virtual reconstruction of the Ename abbey, Belgium in 1065, by VisDim)*

Pseudo3D also can be used as a visualisation tool of images of the object, avoiding any digitisation but still using an interactive 3D-looking paradigm to visualise them. For example, a UAV can photograph a building from a large number of positions on a circle around the centre of the building and this set of images can be visualised interactively in an ObjectVR way.

Although the capabilities of the current high-end graphics cards could deal with complex scenes and/or sophisticated rendering, the delivery of 3D in Europeana cannot rely on such high-end solutions, as we want to reach a maximum number of users, also those users that have hardware with limited graphical capabilities. The performance of pseudo-3D assets relies on performing 2D image drawing, which is available on even low-end platforms.

Although most ObjectVR solutions were Flash based (Object2VR<sup>45</sup>, Flashificator<sup>46</sup>, KRpano<sup>47</sup>), all of them currently are available in HTML5 mode. These solutions allows typically a combination of panoramic and ObjectVR visualisations and allow easily for additional context information to be integrated. This type of ObjectVR visualisation can be used to obtain a similar basic functionality as other object based visualisation methods (see above) but can also be configured to provide a much more elaborated functionality. For example, the image below shows an image from a walkthrough of the

<sup>45</sup> <http://gardengnomesoftware.com/object2vr.php>

<sup>46</sup> <http://flashificator.com/>

<sup>47</sup> <http://krpano.com/>

Gallo-Roman villa of Plassac in France, which combines videos and panoramas to create an interactive exploration of the villa (KRPano software). Note the high quality of the rendering, which is very difficult to obtain in any real-time 3D visualisation.



*Gallo-Roman villa in Plassac by ArcheoTransfer*

## 5.7 Remote rendering

Interactive remote rendering uses the combination of an interactive low resolution 3D model (visualised through WebGL) with rendering the corresponding high resolution 3D model on a remote server and sending just the rendered image to replace the low resolution WebGL visualisation. One software application that implements this methodology is Venus<sup>48</sup> that is available for all WebGL enabled browsers. On mobile devices, the viewer is available as an app on iOS and Android devices (hence does not need a browser).

The major advantage is that the 3D model does not need to reside on the computer of the user, or be transferred over the internet (complex 3D models are typically 100 times more heavy than the JPEG image which is rendered on the remote server). Another advantage, which is important for this project, is that the performance of the software is nearly independent of the complexity of the 3D model.

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<sup>48</sup> <http://www.ccrmlabs.com/>





*Interactive (left) and remotely rendered (right) visualisation of Venus figurine*

The major disadvantage, however, is that such central hosting and rendering does come at a certain cost, which is yearly recurring. There is also the aspect of IPR, as making such 3D models available in this special format could imply rights upon the visualised model. An additional drawback is that the company that made this software, is not active anymore and that other similar solutions, adapted to cultural heritage, are not available yet.

### 5.8 Other Technologies (Flash, plugins, ...)

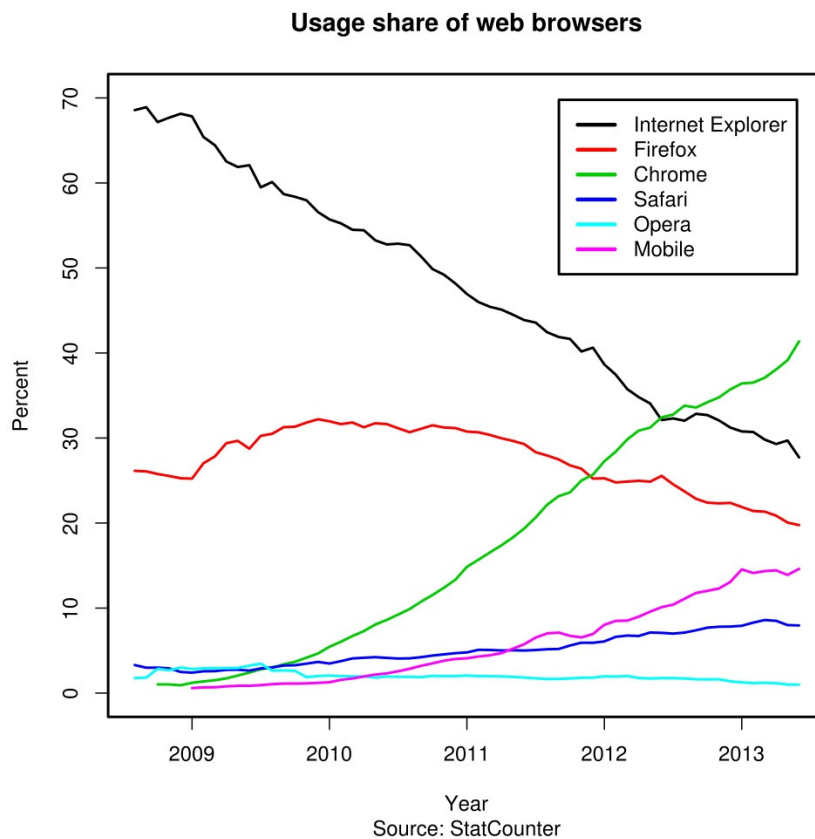
Although most of the 3D visualisation was – and partially still is – relying on custom software, plugins and Flash technology, the current evolution towards HTML5 and WebGL looks very obvious and permanent. Selecting a software context in which 3D data can be published for a non-specialised audience and making this very simple, easy-to-use and multi-platform no longer needs any of those former solutions. In addition, those previous-generation solutions have explicit dependencies on the operating system and on the browser used, and require in most cases explicit and complex installation procedures.

In some cases however, Flash and browser plugins can be a fall-back option for older operating systems and browsers.

### 5.9 Notes on current trends

The graph below shows the evolution of the market share of the different major browsers during the last 5 years. This information is a key element in the decision process how to deliver online 3D assets to the European user.

We see that major shifts are taking place concerning the use of browsers, which can be summarised in a steady decline of Internet Explorer, a steady rise of Chrome, a slow decline of Firefox and the steady rise of browsers on mobile devices.



*Evolution of the usage of the major browsers through the last 5 years*

In 2010, when the decision had to be taken in the CARARE project which publishing mechanism to use for 3D assets, the importance of mobile devices was still marginal.

For the moment, the online activity of a significant number of people is shifting from desktop platforms (Windows, MacOS, Linux, ...) to mobile platforms (iOS, Android, Firefox OS, ...). The graph below shows that currently 15 % of the browsing activity happens on mobile devices, and is likely to further grow in the coming years. This means concretely that we need to take mobile platforms into account when deciding upon the publication mechanism of 3D assets in 3D-ICONS.

In June 2013, Gartner<sup>49</sup> stated: *“Android will take increasing share across the device landscape, driven by the penetration into the phone market. Tablets meanwhile will grow to surpass combined shipments of desktop and notebook PCs by 2017. Microsoft Windows and Apple (iOS and MacOS) will grow slowly and by 2017, the number of devices with Android operating systems will outnumber the total number of devices with all other OS.”*

We need to also note that mobile devices are complementary to desktop systems, so that a growing number of people have both, work on both and access the internet on both types of devices. This means that it is important that we provide similar functionality on both desktop computers and on mobile devices, as people switch frequently from desktop to mobile platforms and vice versa. It also will be perceived as a failure if 3D assets in Europeana can be visualised on desktop computers and not on mobile devices (or vice versa).

The current shift to mobile platforms and the fast changes that the current digital communications sector is experiencing creates the aspect of *fragmentation* that is important when discussing the potential uptake of 3D visualisation technologies. Fragmentation is the number of different versions of a platform on the different hardware platforms that are actively used. Fragmentation is, for example, high on Android, where about 1400 different “versions” (combinations of different hardware platforms times the different versions of Android) are actively used.

An important aspect of fragmentation is the speed of upgrading of the OS, which is low on Android (and which is a commercial choice). Fragmentation on Apple platforms is low because there are only a limited number of different hardware devices in the field, while Apple stimulates very much the upgrading of its systems to the latest version of the iOS operating system.

In other words, although Android is becoming one of the dominating platforms, the take up of new 3D visualisation techniques on Android is slowed down because of this high fragmentation. Most Android users only get a new version of the Android OS when they buy a new device. Currently, Android versions 2.3, 4.0 and 4.1 are the most used platforms on Android based mobile devices<sup>50</sup>. WebGL enabled browsers are only available from Android 4.0 onwards. In earlier versions, WebGL<sup>51</sup> is supported on Sony Ericsson Xperia<sup>52</sup> smartphones and on Samsung devices through the Android browser.

One operating system that has the potential to make a significant rise is Firefox OS. This operating system is offered on cheap mobile systems in some European countries since July 2013. The key element for our purpose here is its full dedication to HTML5 and

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<sup>49</sup> <http://www.gartner.com/newsroom/id/2408515>

<sup>50</sup> <http://developer.android.com/about/dashboards/index.html>

<sup>51</sup> <http://developer.sonymobile.com/2011/02/24/webgl-support-in-the-android-web-browser/>

<sup>52</sup> <http://www.sonymobile.com/>

WebGL, so we can expect that this operating system will certainly support all the features that have been mentioned previously for HTML5/WebGL.

Operating systems such as Windows Mobile or Blackberry, although they serve dedicated communities, remain nevertheless marginal in absolute terms. The new version of the Blackberry OS does support WebGL, while the most recent information says that Windows Mobile also will have browsers that support WebGL. A detailed analysis of the availability of browser features in the form of tables for different operating systems and browsers can be found here<sup>53</sup>, with the specific overview for WebGL here<sup>54</sup>.

The same holds for Linux, which is also marginal for the moment and does not support the new evolutions of the last years. For example, 3D PDF is no longer supported on Linux as it was in Adobe Acrobat version 9.

#### 5.10 Comparison and conclusions

We propose to use four different technologies in 3D-ICONS: 3D PDF, HTML5/WebGL, Unity3D/UnReal and pseudo-3D. The choice depends on the type of the 3D asset, the geometrical and visual complexity of the asset, the intended functionality and the intended longevity of the resulting webpage.

When creating interactive 3D assets that can be published online, we need to realise that most 3D models as they exist today in the databases of the 3D-ICONS content providers are not suited for web publication. In most cases, a range of technical file formats are used and the files are too large for both online delivery and web display. In other words, the 3D models need to go at least through a file format conversion and an optimisation procedure. In addition, some 3D models require some interaction design and some additional information to be added to be useful as 3D online asset. For each class of objects, we need to evaluate which is the most optimal approach, taking into account the possible file format conversions and optimisation procedures.

A second aspect is the availability of technology on the platforms that are in use, currently and in the near future (see next chapter). As a summary, we can say that *3D PDF* is well supported on desktop platforms (but with some issues as mentioned above) but not so well on mobile platforms. *HTML5/WebGL* is well supported on all platforms except on mobile devices from Apple (but this is only true for recent versions of browsers and operating systems). *HTML5/WebGL* is definitely the best choice on the longer run and if Apple would change its policy concerning WebGL, the coverage would be nearly complete. *Unity3D* does have a nearly complete coverage of all occurring platforms and provides great tools to create an appealing exploration of the 3D model. The recent versions of *pseudo-3D* applications are based upon HTML5 (hence supported on nearly all platforms and browsers) with a graceful fall-back to Flash where needed.

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<sup>53</sup> <http://caniuse.com/>

<sup>54</sup> <http://caniuse.com/webgl>

A third aspect is the required functionality when interacting with the 3D model. This depends not only on the type of 3D asset but also on the additional work that can be spent on each of the assets to create that functionality and added value.

If we have 3D assets that are *objects* (i.e. 3D models that consist more or less of one element that can be visualised from all sides externally and that does not need detailed context information about certain parts), then we could use a simple visualisation of the object in being able to look at the object from all sides, zoom in and pan. In the case of objects, there is little need to provide additional context information within the 3D visualisation.



*Examples of objects in 3D-ICONS (POLIMI)*

For objects we could use the following technologies:

- 3D PDF (without extensive context information or links)
- HTML5/WebGL/Nexus (through the Community Presenter)
- Pseudo-3D (through ObjectVR visualisation, especially for complex models)



*Buildings that could be visualised as objects (left to right: POLIMI, CETI, MAP)*

For single buildings, we could also decide to use the same approach, although it is recommended that at least views are included that visualise the building from a human



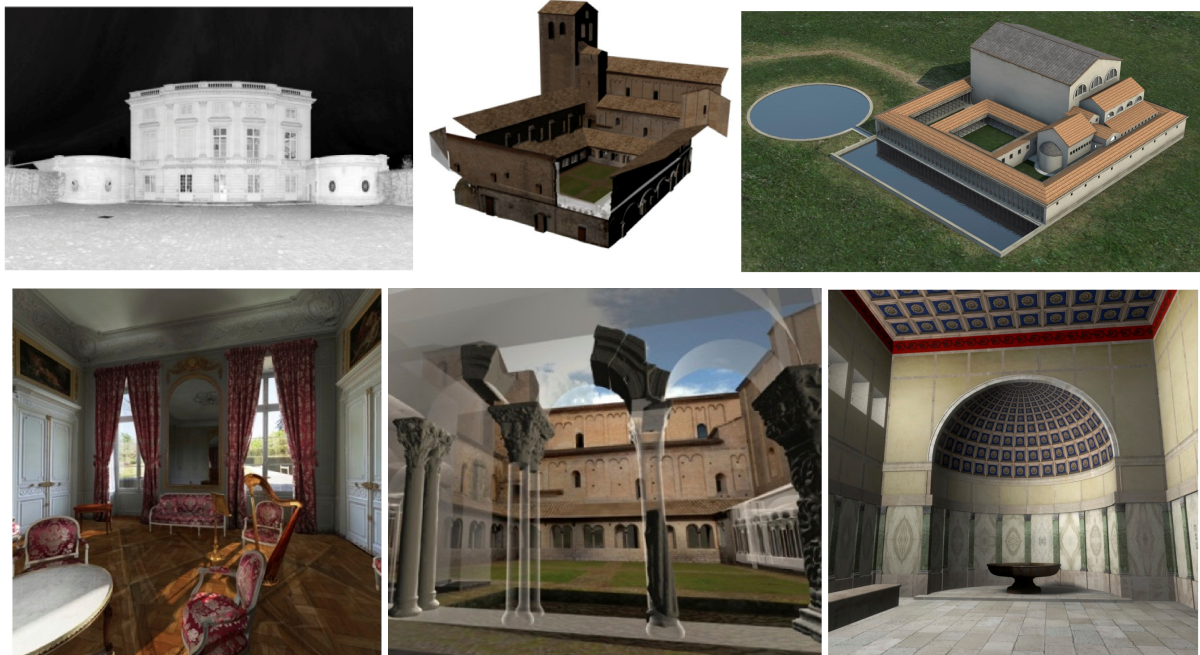
perspective on ground level. This can be done, for example, by integrating such views in the 3D PDF file or by setting a default view at ground level in other software.

About 15 % of the main entities in 3D-ICONS are objects, while the majority of the details are also objects. So more than half of the files to be published are objects.

If we have 3D assets that are *complex buildings and sites*, we want to make the user experience the building or site, explore its structure, appreciate its beauty and understand its function or evolution. This functionality requires at least navigation capabilities, but also the addition of some context information that is useful to understand the building or site.

We propose to visualise these buildings and sites through the following technologies:

- HTML5/WebGL (interactive walkthrough or point cloud visualisation)
- Unity3D (as interactive walkthrough)
- Pseudo-3D (through panoramic walkthrough, see Plassac example in Section 5.6)



*Examples of buildings with the outside (top row) and resp. inside (bottom row) by MAP and CNR-ITABC*

The simple way to deal with these buildings is to use pseudo-3D with a combination of ObjectVR (for outside) and panoramic (for inside) visualisation in HTML5.

Sites, on the other hand, could benefit from the interaction with the complex space and could be implemented in a serious games environment such as Unity3D (two of the three examples below are already in Unity3D format). Some form of context information (for example a short description when clicking a certain part of the

building) or storytelling (for example a voice over that provides information when entering a certain area) could be added.



Examples of sites (medieval Bologna and Regolini-Galassi tomb by CNR-ITABC, Enne 1300 by VisDim)

If we have 3D assets that *cannot be rendered in real-time*, we can rely on HTML5 based pseudo-3D applications using ObjectVR and panorama visualisation to show the site in an interactive but pre-rendered way. The example below shows 2 of the 72 images of a 360 degrees visualisation of the virtual reconstruction of the abbey of Enne in 1665. Each of the images (average render time 1 hour) has the buildings and features of the site marked by a clickable symbol, that shows information about that building or feature.



Two images from an ObjectVR visualisation of the abbey of Enne in 1665 (by VisDim)



Information panel providing information about one clickable zone (by VisDim)



The Ename site, in 8 different periods, will be published in pseudo-3D, including a 4D visualisation (3D and time) of the site through its evolution.

Concerning IPR issues, there are three aspects. The first aspect is whether the 3D data resides on the servers of the content provider or not. The second aspect is if visualisation through a specific technique implies additional rights for the hosting organisation. The third aspect is if the 3D model can be extracted from the 3D visualisation and (ab)used for other purposes.

For the first aspect, we observe that most new HTML5/WebGL solutions use a cloud solution, in which the 3D models are residing on servers of the company providing the visualisation software. As the visualisation software in many cases comes for free, it is clear that this central server model is part of the business model and will not change. This is a major drawback for using most commercial WebGL based 3D visualisation software, limiting the available options.

Concerning the aspect of interference of the hosting organisation in the IPR, we see that some companies claim a number of rights including changes to the 3D models<sup>55</sup>. This is a major drawback and difficult to integrate in the IPR scheme of 3D-ICONS.

Concerning the possible abuse of the 3D models that are being visualised, we need to make several remarks.

First of all, this is not a black and white story as it requires certain skills and resources to extract the 3D model from the visualisation process. For example, a 3D PDF file can be password protected so that the included 3D file (in U3D or PRC format) cannot be read (but without a safe form of encryption). But the PDF format is an open and documented format, and open source libraries are available to read the data from the PDF file and set the parameters. So, if somebody makes a software programme to unlock such protected 3D PDF files, the 3D data can be extracted. The same holds, for example, for the Nexus format where it is probably not impossible to re-engineer a normal 3D model from the Nexus-data, but at the expense of a substantial amount of work.

Secondly, we doubt that the pressure to “steal” the 3D models from the visualisation would be high. Suppose that a games company takes the 3D model of a well-known building that 3D-ICONS provides to integrate it in a game. Nearly always, a lot of processing is still required to turn this 3D model into a resource that can be used in a game. As most of the 3D-ICONS models come from governmental or academic resources, the cost for obtaining a licence to use the 3D model would not be high while the risk for negative publicity would be high as the 3D model of the building would be clearly visible in the game. Nevertheless, we will analyse in the next chapter the vulnerability of each of the solutions with regard to extraction of the 3D model.

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<sup>55</sup> <http://sketchfab.com/terms#intellectual-property>

### 5.11 Decision table

The following decision table summarises the recommended choice(s) of technology according to the subject matter and complexity of the 3D model to be presented to the end user.

3D model	Objects		Complex buildings		Sites	
	Low	High	Low	High	Low	High
3D PDF	X					
HTML5/WebGL	X	Nexus/ point cloud		Point cloud		Point cloud
Unity3D/UnReal			X	LOD optimisation	X	LOD optimisation
Pseudo-3D	Special cases (glass, ...)	X		X		X

\*LOD – Level of Detail

## 6 Evaluation of authoring systems and viewers

This chapter reviews the most useful authoring systems and viewers concerning their potential for use in the 3D-ICONS project, which is using a wide range of formats and degrees of processing of the scanned or created 3D data. This means we need a variety of tools and visualisation techniques to cover the different types of data and goals of the project.

An important new development<sup>56</sup> that will play a crucial role in the project is WebGL in combination with HTML5, for which a wide range of new visualisation paradigms<sup>57</sup> and implementations<sup>58</sup> are used.

Other visualisation tools and approaches are also evaluated and a selection of them will be tested in detail to be proposed as the preferred tools that 3D-ICONS will use.

### 6.1 3D PDF authoring systems

The CARARE project has used 3D PDF as the recommended 3D format to create 3D assets for Europeana. In the related deliverables<sup>59,60</sup>, a number of authoring systems are listed and evaluated.

The main authoring platform is Acrobat Pro, that, in combination with the 3D PDF Converter plugin<sup>61</sup> (only on Windows) and additional software allows to import 3D models in a large number of file formats, to create 3D visualisation, even in interactive combination with text and images (see example below), and to create animations. 3D PDF is excellent for the visualisation and contextualisation of objects, and can be used to a certain extent for buildings and scenes, but without collision detection. Tests will be made to improve the rendering of material properties and the use of predefined paths to explore buildings and scenes.

3D PDF files can be created in Acrobat Pro without the Tetra4D Converter plugin if one is capable of translating the 3D models into U3D file format (for example through MeshLab), this workflow is available on both Mac and Windows.

Automatic creation of 3D PDF files can be obtained through available libraries that are integrated in repository systems. This potential will be verified and tested.

3D PDF files have also the advantage of stand-alone use, they can be stored in repositories and don't need an internet connection to be used.

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<sup>56</sup> <http://learningwebgl.com/blog/>

<sup>57</sup> <http://www.chromeexperiments.com/webgl/>

<sup>58</sup> <http://spidergl.org/>

<sup>59</sup> <http://carare.eu/eng/Media/Files/D5.1-Req-Spec-for-preparing-3D-VR-for-Europeana>

<sup>60</sup> <http://carare.eu/eng/Media/Files/3D-Training-Materials>

<sup>61</sup> <http://www.tetra4d.com/>

## Basilica

### General Description

The Basilica of Pompeii is considered one of the most magnificent buildings of the Civil Forum. Placed at the South-West corner of the Forum, it is oriented perpendicularly to the major axis of the square, on which it opens its main entrance. It is bounded on the North by *Via Marina*, the street leading to the harbor, on which a secondary entrance is opened. Another secondary entrance opens on the *Vicolo di Championnet* on the South.

The Basilica consists of a vestibule, commonly called *chalcidicum*, and a main, elongated hall; this is adorned with a continuous line of columns on four sides, which separates a central space from a corridor running all around, and a raised, columned *tribunal* in the short side opposite to the main entrance, flanked by two lateral rooms.

The vestibule is accessible from the portico of the Forum through five entrances, that could be closed by shutters: traces of their slots are visible within the pillars made of tufa *opus quadratum*, that framed the entrances and shaped the façade of the building. On the opposite side of

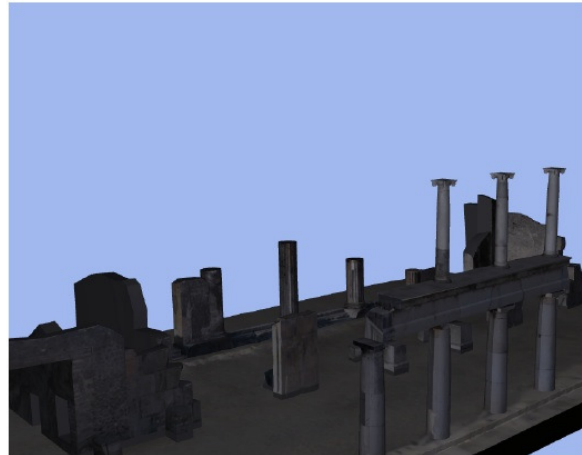
the vestibule, five more openings, aligned with the previous ones but framed by columns in addition to pillars, give way to the main hall.

### Interpretation

The Basilica was already known in 1806, but it was excavated only in 1813, when the area located at the intersection of the roads leading to the necropolis of Porta Ercolano and to the district of the theatres began to be explored.

The function of the building was immediately identified: it is named "Basilica" in the excavation reports transcribed by Giuseppe Fiorelli since its first mention in 1806 (FIORELLI 1860-64, I, p. 176).

In the second volume of the opera edited by Fiorelli we can read about the circumstances that led to the identification of the building: in 1820 the Superintendent of the excavations refers about an inscription engraved on one of its walls containing the word "*bassilica*" and points out the similarity between the building found in Pompeii and the description of the basilica building type given by Vitruvius.



Indeed, Vitruvius wrote that a basilica is an elongated building, whose width is half or one third of its length; it consists of a *medium spatium*, the central space, a lateral *porticus*, and perhaps of a *chalcidicum*; the width of the portico should be one third of that of the central space, equal to the height of columns separating the

central space and the portico itself (Vitruvius, *De Architectura* V, 1,4-1,10).

Being identified with a Basilica, this building is believed to have commercial, administrative and judicial function (GROS 1996). At least during the Roman period, inside this

1/5

pompei.sns.it

Example of 3D PDF (CARARE – SNS) with interaction between text and 3D window

## 6.2 WebGL-based object viewers

With the advent of HTML5 and WebGL, a range of applications have become available for WebGL-based object visualisation, such as p3D<sup>62</sup>, Sunglass<sup>63</sup>, 3Dsom<sup>64</sup> and SketchFab<sup>65</sup>. These applications typically store the visualised 3D models in the Cloud (i.e. on their dedicated servers) and provide a kind of visualisation, where the object can be inspected from all sides by spinning it around its centre of gravity and where you can zoom in on interesting details. There is no walking around or other animation. These applications also come with a limited free space and a monthly fee for more substantial storage and support.

<sup>62</sup> <http://p3d.in/>

<sup>63</sup> <https://sunglass.io/>

<sup>64</sup> <http://www.3dsom.com/webGL/index.html>

<sup>65</sup> <http://sketchfab.com/>



*Visualisation of SketchFab test object*

Some applications only import .obj files (such as p3D), some others come with a wide range of different formats (27 file formats for SketchFab) which is an interesting feature as the 3D-ICONS data is provided in a wide range of file formats. Most of these tools use a very standard visualisation of polygon-based meshes. SketchFab, for example, has not only the standard diffuse, specular and shininess parameters, but also light maps, normal maps and environment reflection.

P3D is limited to 50 MB .obj models (which is about 650,000 polygons), but SketchFab and 3Dsom support large meshes, the latter even uses optimisation and compression techniques.

### 6.3 WebGL-based point cloud viewers

However, not all 3D models have gone through a full processing of the data by merging, simplification and texture mapping. A lot of laser scan data (especially when alignment targets are used) just consists of aligned sets of raw scan data with colour per vertex texture information. This kind of scan data, however, can be visualised nicely and interactively through WebGL-based point splatting techniques (where each data point is visualised from back to front by a small dot with the digitised colour).

Good software for point cloud rendering (used by MAP) is provided by EcoSynth<sup>66</sup>, based upon the TeraPoints<sup>67</sup> research at the university of Vienna. The software is suitable for buildings and sites and allows free exploration of the digitised space.

<sup>66</sup> <http://potree.org/wp/>

<sup>67</sup> <https://www.cg.tuwien.ac.at/research/projects/TERAPOINTS/>





3D Viewer: [Potree](#) / [TeraPoints](#)  
 This is in a freeflight mode viewer. To move your point of view: click & drag  
 To move the model: alt + click & drag  
 Use the arrow keys to "fly"  
 To move faster, move your mouse wheel up, move it down to slow down.



*Tholos in Delphi (MAP) in WebGL point cloud visualisation*

#### 6.4 WebGL-based scene viewers

More complex scenes and buildings require walkthrough visualisation in which the user can interact with the building or site (collision detection, walking on uneven terrain, climbing stairs, ...). Good WebGL-based authoring systems such as CopperCube<sup>68</sup> have started to emerge that not only visualise 3D scenes but also allow definition of behaviours to explore those scenes and interact with them.

CopperCube has a comprehensive set of features such as collision detection, terrain following, possibility to create guided tours (by following a path<sup>69</sup>), normal maps and a wide range (22) of input formats<sup>70</sup> including .ply. CopperCube creates not only HTML5/WebGL webpages but also iOS and Android apps (for Apple mobile devices and earlier Android platforms) and Windows .exe files (for earlier Windows platforms). CopperCube costs 99 euro.

An excellent example of an interactive WebGL-based walkthrough along a predefined path, both for outdoors and indoors, can be found in this very nice reconstruction<sup>71</sup> of the palace of Versailles at the end of the 17<sup>th</sup> century. Note that a predefined path not only provides a kind of guided tour through the site or building, but that it also

<sup>68</sup> <http://www.ambiera.com/coppercube/>

<sup>69</sup> <http://www.ambiera.com/coppercube/demo.php?demo=backyard&mode=webgl>

<sup>70</sup> <http://www.ambiera.com/coppercube/features.html>

<sup>71</sup> <http://www.chaostoperfection.com/scenes.html?lang=en>



simplifies significantly the task of the 3D modeller and interaction designer, and that it takes away the processing for terrain following and collision detection.



*Interactive exploration of the virtual reconstruction of the palace and gardens of Versailles (Google)*

WebGL is expected to be used extensively in cultural heritage in the near future. The 3D-COFORM project has demonstrated the visualisation of museum objects through WebGL<sup>72</sup> through X3DOM<sup>73</sup> and research at the University of Bonn aims to visualise the complex material properties of museum objects<sup>74</sup> much more precisely. Tutorials show how museums can integrate 3D models in their web pages<sup>75</sup>.

## 6.5 Nexus

The Nexus 3D file format combines several features that are very important for the 3D-ICONS project: levels of detail (to visualise a 3D model in a refining way), 3D streaming (to deliver the 3D data in the most optimal way, depending on the view upon the object) and WebGL visualisation (to allow the most optimal 3D visualisation that a certain computer is capable of, without installing software).

A major part of the 3D models that are made available in 3D-ICONS are quite detailed and have large file sizes, so visualisation through this Nexus format (and the Community Presenter) could be very useful to create an interactive visualisation of the large 3D

<sup>72</sup> <http://www.3dcoform.eu/x3domCatalogue/>

<sup>73</sup> <http://www.x3dom.org/>

<sup>74</sup> <http://btf.cs.uni-bonn.de/viewer/>

<sup>75</sup> <http://www.digitalepigraphy.org/museum/embed.html>

data, especially for the platforms that are less powerful. Nexus also supports point cloud visualisation.

A major advantage is that dense 3D models, that typically would go through a simplification (less vertices) and optimisation (geometrical detail turned into normal mapping) process, can be shown as they are, providing all detail where this detail is being visualised (at the cost of transporting the data over the internet). This saves a lot of post-processing for such models and makes such detailed models easy to handle and visualise.

The other advantage is that Nexus is made by one of the 3D-ICONS partners and that the Community Presenter is made in the related V-MusT project, so certain adaptations and optimisations can be made easily for the 3D-ICONS project.



*Capital in Nexus format from the Cefalu cloister in Sicily, Italy (Cenobium project)*

The disadvantage is that Nexus is limited to *colour per vertex* data, which is typical for digitised data coming from laser scanning and 3D from images. Data coming from CAD processes, 3D models with texture mapping and highly optimised 3D models (containing for example normal mapping) are not suited for display through this streaming format. This is not a major problem, however. Most data that comes from digitisation processes has a colour per vertex structure. In the rare case that densely digitised 3D models would rely on texture mapping instead of colour per vertex, it is easy to convert such models in a colour per vertex structure without jeopardising the visual quality of the model.

In other words, the Nexus format only provides a solution for dense 3D models with colour per vertex data.

## 6.6 Unity3D and Unreal Engine

Unity3D has four major advantages for the 3D-ICONS project. First of all, this serious game authoring software can publish a virtual world on 10 different software platforms, without major effort and supported by a set of specialised tools. For the purpose of this project, we only need web publishing for the different platforms.

Secondly, the web publishing comes for free, while the Unity Web Player is a very stable, highly optimised and self-installing software with integrated functionality for Facebook. In other words, while the content for the web player comes from the server of the content provider, promotional content for the project could be put on its Facebook page.

Thirdly, it has a large community that produces additional tools and plugins for optimal creation of specific aspects, such as vegetation, terrain or weather. For example, the vegetation, terrain and weather system in the 2 by 2 km area of the Ename abbey in Belgium (reconstructed in 1300, see below) has been implemented by the TerrainComposer<sup>76</sup> plugin (90 euro).



*Unity3D test on the 3D virtual reconstruction of the Ename abbey in 1300 (VisDim)*

<sup>76</sup> <http://www.terraincomposer.com/>



Finally, Unity3D has efficient tools to establish collision detection, terrain walking and interaction with the site and the buildings (for example, to open a door). These functionalities provide an excellent experience while exploring the site.

The same holds for the Unreal Engine which also allows authoring of easily interactive scenes and to publish on multiple platforms.

So we propose that Unity3D and Unreal Engine are used for a limited number of high-end applications that demonstrate the potential of this technology. Unity3D is expected to announce a HTML5/WebGL initiative soon, making its publishing process standard and open.

## 6.7 Pseudo3D solutions

Pseudo3D solutions are quite effective ways of visualising 3D content in an interactive way, without relying on local 3D visualisation of the 3D models, but by providing interactive panoramas and sets of interactive renderings of the 3D models, simulating interaction with the 3D models.

This solution is quite elegant as the technical and software requirements on the side of the user are quite low, while sufficient interaction is provided. On the side of the content provider, there are three major advantages. First of all, this approach is an excellent solution when the 3D model is too complex or when the rendering effects are not feasible or expensive to create in real-time visualisation. Secondly, it takes the burden away to optimise the 3D model for real-time interactive display. Thirdly, the 3D model does not need to be sent to the user side, preventing any unauthorised use.



*Virtual reconstruction of Versailles in 1624 as panorama (Versailles 3D by the Google Cultural Institute)*

The combination of panoramas (where the camera looks around from a fixed point) with an ObjectVR kind of visualisation (where the camera moves around a fixed point)

provides an elegant way to explore a site or building, both for outdoors and indoors visualisation.

An excellent example of the pseudo3D approach is the visualisation of the evolution of the palace of Versailles in 3D<sup>77</sup>.

Creating content for such tools requires rendering of panoramas (available in nearly all 3D modelling software) and ObjectVR sets of images (for example by rotating the rendering camera around a fixed point and rendering 72 images). As the amount of rendering is quite limited compared to making animations, rendering can produce the most sophisticated effects that are not feasible in real-time visualisation, or require special effects that are complex to produce in a real-time environment.

ObjectVR visualisation can use multiple sets of images, creating special effects such as evolution through time. To do this, the images are organised as a matrix and each row represents another point in time. Moving the cursor horizontally makes the camera move around the fixed point, moving the cursor vertically visualises the evolution for a certain camera point of view.

Suited tools to make pseudo3D visualisations are KR pano, Object2VR and Flashificator. These tools all provide HTML5 output, but can fall back on Flash implementations for older versions of operating systems. QuickTime VR was another excellent software that in fact pioneered this form of visualisation, but has been discontinued by Apple since mid-2010. It is still used to some extent, but QuickTime VR authoring is not recommended anymore.

KR pano is available in both Flash and HTML5 implementations and provides excellent visualisation of panoramas, even in multi-resolution format (so that very high resolution images can be used). KR pano supports also single row ObjectVR visualisation.

Object2VR is software specifically for ObjectVR visualisation, both in HTML5 and Flash. It deals with multi-resolution and multiple row visualisation, and can be used for example for 4D visualisation (3D + time) where vertical movement of the cursor shows the evolution of a site in time.

Flashificator is a software that allows building of interactive applications in HTML5 and Flash based upon panoramas and ObjectVR. This software provides a kind of graphical programming and can create the more complex visualisations (for example, comparing the virtual reconstruction of a site with the current state of the site). This software is probably too advanced for the kind of visualisations that 3D-ICONS requires and is more suited for kiosk applications on fixed hardware.

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<sup>77</sup> <http://www.versailles3d.com/en/discover-the-3d-scale-models/>



## 6.8 Conclusions

The wide variety of 3D models available in 3D-ICONS, both from the content as from the technical side, requires a range of different publication tools.

3D PDF is still a valid option for visualisations of object that do not have special material properties and that are not too big or complex. 3D PDF is supported on all platforms besides Android mobiles, and is well accepted, including by the heritage community. 3D visualisations can be combined with text and images and made interactive, but good visualisation of these features is limited to the Acrobat Reader, while proper visualisation is limited to a few browsers. 3D PDF authoring comes with conversion of a wide range of possible input formats. The new animation feature in 3D PDF could probably also be used for predefined guided tours through a site or building, but again will be limited to Acrobat Reader. This feature will be tested in detail and examples will be provided. 3D PDF files have sufficient protection against extracting the 3D model.

WebGL should be the major target of 3D-ICONS. It is supported on all platforms except iOS mobile devices, and covers a wide range of visualisation modes from point cloud visualisation over object visualisation to interactive walkthrough and predefined guided tours. Special attention should be given to the Nexus format that will allow visualisation of complex 3D objects without simplification as it uses a streaming approach that results in a quick and refining visualisation of the visible parts while the remaining parts of the 3D model are streamed after that. Several tools provide conversion of a wide range of file formats. The standardisation of WebGL within HTML5 on one hand, and the optimal and transparent use of the capacities of the available graphics hardware on the other hand, are important factors for a sustainable implementation for the longer term.

Unity3D (and also Unreal Engine) provide elegant serious game implementations on all computer platforms that provide complex behaviours such as interaction with the site, building and objects (for example opening a door), walking behaviours on complex terrain (including stairs) and collision detection. The creation of such 3D visualisations are more complex and labour intensive than other solutions described above, but the resulting experience is more engaging and richer.

HTML5-based pseudo-3D visualisation allows visualisation of 3D that cannot be rendered in real time, because of size, complexity, very high visual quality or special properties (for example: glass objects). Pseudo-3D is well suited for visualisation of interiors and it also allows visualisation in 4D (evolution of sites). This visualisation is based upon pre-rendered images and panoramas that are made interactive in a HTML5 context (with Flash as fall-back option of older versions of operating systems).

In this project, the bulk of the data will be visualised with 3D PDF and WebGL, with a small number of implementations in Unity3D, Unreal and pseudo-3D to demonstrate the potential of these techniques.

## 7 Implementation roadmap

Based upon these recommendations, a number of tools will be tested and the resulting 3D assets will be visualised through a range of browsers on different computer platforms. Special attention will be given to the Community Presenter (based upon the Nexus format) that will be released in December 2013. Tests will be undertaken with the early versions of this web service, as it is being developed by one of the 3D-ICONS partners. Some testing (such as the Unity3D and pseudo3D implementations) has already started for the 3D assets from Ename (virtual reconstruction of the abbey and village in 8 different periods).

Time will be spent on investigating and implementing the (semi-) automated creation of the 3D assets and the integration with WP4. This includes methods to make the conversion happen through an application that uses software libraries for the conversion. For example, 3DPDF conversion can be done this way.

For virtual reconstructions, the focus will be on the metadata creation, as this is still a new and undefined domain. Special attention will also be given to testing the integration in social media, as this could be a major development in making the Europeana content more widely available. For both domains, the Ename assets will be used to test it out and make examples and guidelines.

The goal of this testing is to create a set of guidelines for each type of visualisation, so that the content partners can create the 3D assets in the most optimal way. These guidelines will be provided in the form of internal training and will result in the D5.2 Report on Publication deliverable at the end of the project.