

Yale University

CHER-Ob

A User's Guide

This guide was last updated August 17, 2016 and is current as of CHER-Ob version 1.0.0

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1. Introduction

1.1. Scope and Purpose

CHER-Ob was developed to meet the needs of the experts and researchers in the cultural heritage related fields. Those needs can be listed as Management of Large Scale of Data and Project, Analysis and Evaluation Tools, Documentation and Sharing.

CHER-Ob provides a unified platform for heterogeneous documents of historical materials for a variety of users. In this platform users can view, interpret, comment and add new information collected as a result of different studies.

The main conceptual features of the software are the Cultural Heritage Entity (CHE) and the Project. CHEs are user defined set of data and Projects are different types of studies focused on answering specific research questions about a single or plural CHE(s). Although simultaneous analysis of different types of digital images (2D, 3D, RTI and CT images- see section ‘3.2 Compatible data types’, p.32) is possible in CHER-Ob, all the attributions are given to each image along with the classified information related to the CHE(s).The classification scheme is a simplified version of Getty Classification of Works of Art, that facilitates sharing of diverse nature of the documents by a variety of experts from different disciplines. The description of each class can be found in section ‘2.1.4 Tools’ (p.15) of this manual.

CHE(s) are the main sources of data to be studied in CHER-Ob. CHE(s) files are collection of available information introduced to the software by the user, including image files and classified information. The study of the CHE(s) is done by defining a project and collecting all the necessary data under the Project File. These data may belong to one or more CHE(s), depending on the needs of the user who creates the project in CHER-Ob. The user then views, annotates and shares the files/images collected under the Project File. Annotations and Notes are searchable and the evolution of the projects can be tracked by the navigation tool. The customizable automatic reports generation feature helps to distribute the results of the project.

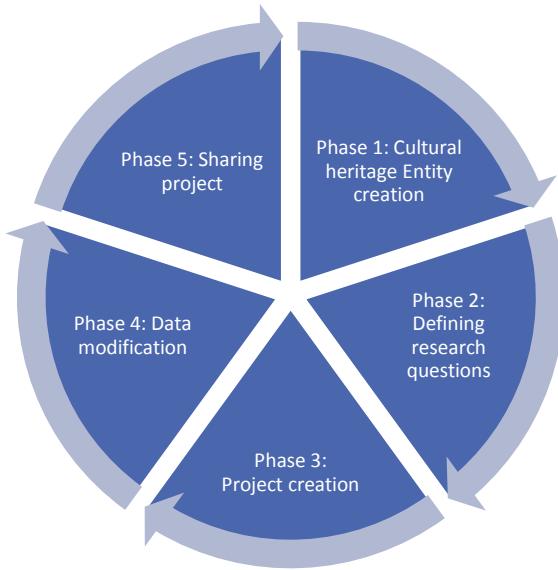


Figure 1. CHER-Ob. Process Overview. In Phase 1, the user creates a CHE, providing the already existing information followed by Phase 2, where the research questions are defined, leading to a creation of a project in Phase 3. During the development of the project, in Phase 4, the data are modified, new information is added until its completion in Phase 5, where the project is shared.

The main objectives of this manual are to provide an initial orientation for working with CHER-Ob and present its most important features. The manual begins with an overview of the CHER-Ob's user interface in section 2 (p. 5) and demonstrates typical methods for working with the various file types supported by CHER-Ob in section 3 (p. 32). Via exploring the sample CHER-Ob projects in section 4 (p. 40) the user can familiarize with the main concepts of the software.

1.2. Installation

For installation instructions please visit <https://github.com/WeiqiJust/CHER-Ob>.

2. Interface

When you open CHER-Ob for the first time, you will be greeted by an interface similar to the one in Figure 2, if you are running the software on Windows 7. If your screen resolution is too small, the right toolboxes will be merged with separate tabs (Figure 3).

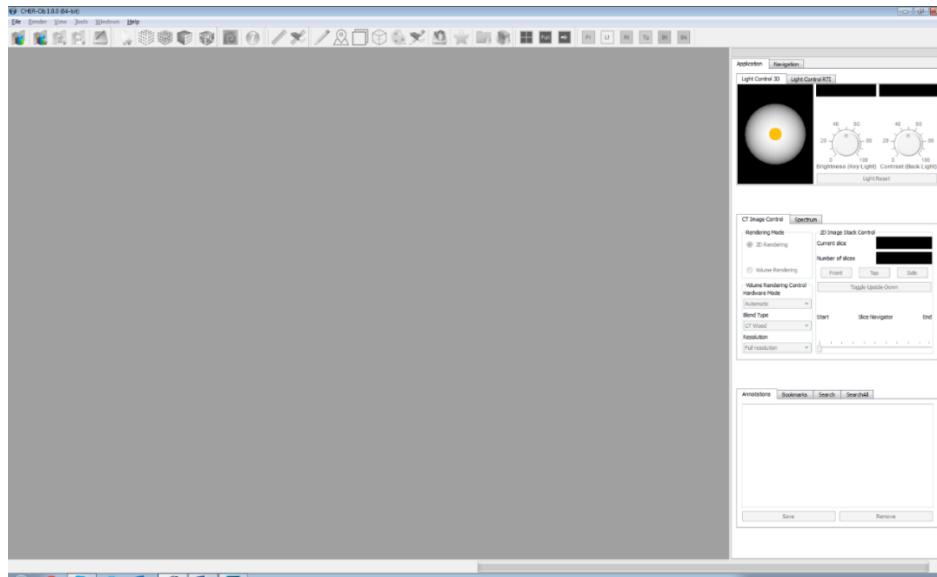


Figure 2. The initial appearance of CHER-Ob on Windows 7 at startup.

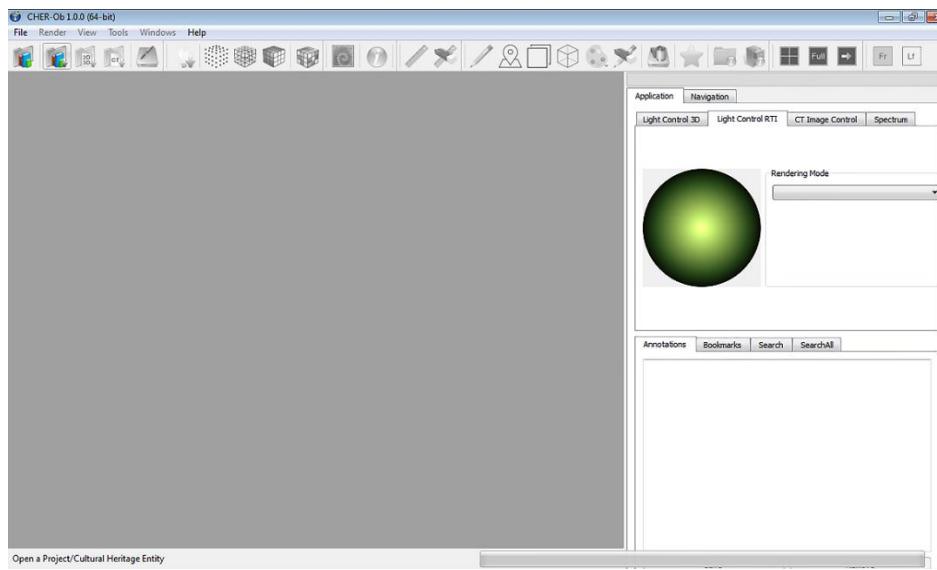


Figure 3. The initial appearance of CHER-Ob on Windows 7 at lower resolution.

When CHER-Ob works in Cultural Heritage Entity mode the acronym CHE appears on the title line just before the Cultural Heritage Entity's name. In case of Project mode, the label Project

appears just before the project's name (Figure 4). The tabs on the right hand of the screen are slightly differentiated. The textual information is represented by the Cultural Heritage Entity Tab in Cultural Heritage Entities and by the Classified Info tab in Projects (Figure 5). The Project Info icon is deactivated in Cultural Heritage Entity mode (Figure 6).



Figure 4. Label CHE just before Cultural Heritage Entity's name "YBC7289" (left) and label Project just before the project's name "3D Printing QR..." (right).

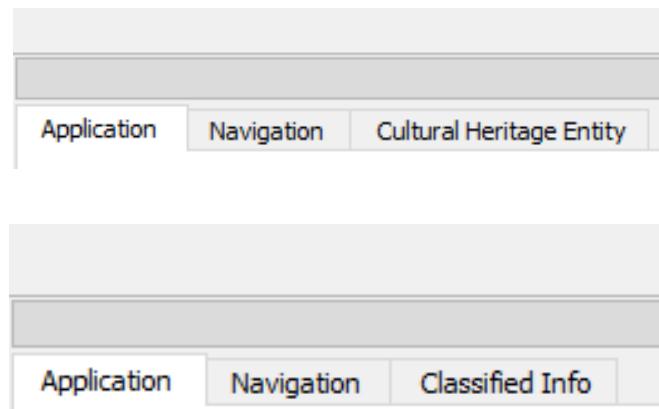


Figure 5. The textual information is represented by the Cultural Heritage Entity Tab in Cultural Heritage Entities (above) and by the Classified Info tab in Projects (below).



Figure 6. File Info (left) and Project info (right) icons.

2.1. Menu

An easy way to access all of the features of CHER-Ob is the menu bar (Figure 7).

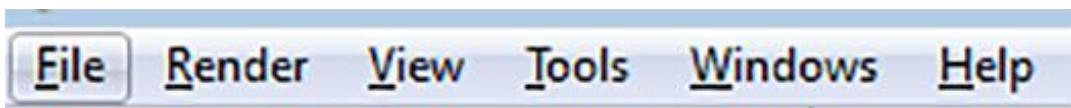


Figure 7. The menu bar.

2.1.1. File

- File>New
 - New > Project...: Creates a new CHER-Ob Project
 - New > Cultural Heritage Entity...: Creates a new CHER-Ob Cultural Heritage Entity

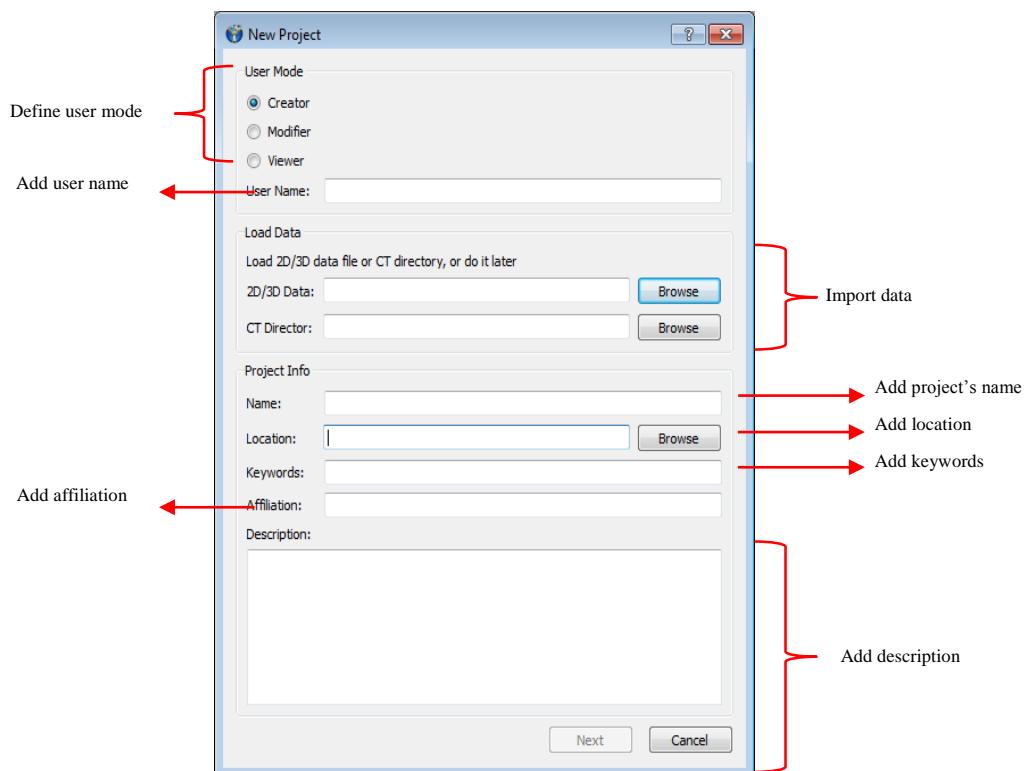


Figure 8. Create "New Project" dialog box.

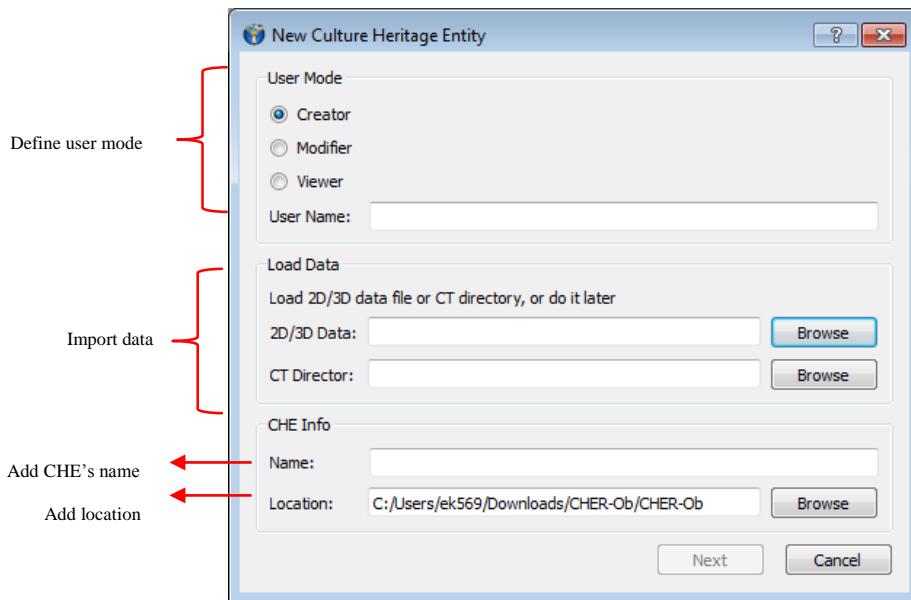


Figure 9. Create “New Cultural Heritage Entity” dialog box.

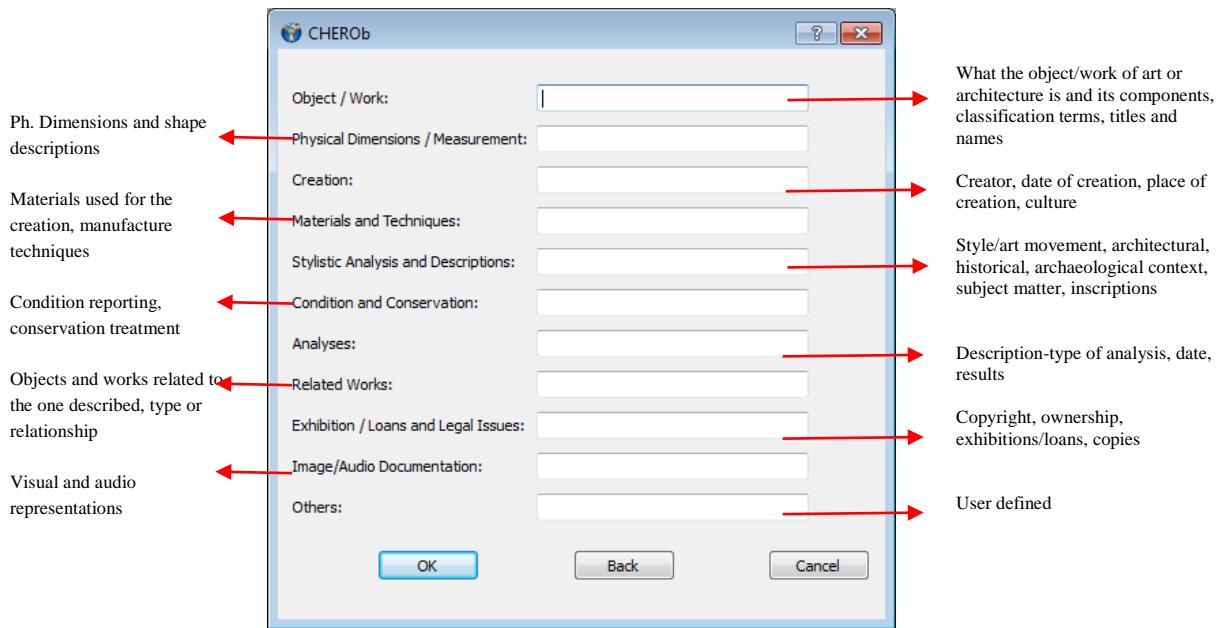


Figure 10. After creating a “New Cultural Heritage Entity” the user can add information organized in 11 categories.

- Open
 - Open > Project...: Opens a dialog box to select and open an already existing CHER-Ob Project

- Open > Cultural Heritage Entity...: Opens a dialog box to select and open an already existing CHER-Ob Cultural Heritage Entity
- Save: Saves the currently active CHER-Ob Project or Cultural Heritage Entity
- Save as
 - Save Cultural Heritage Entity as...: Opens a dialog box to save the Cultural Heritage Entity with a different name, and/or at a different location, and/or under different user name (Figure 11)
 - Save Project as...: Opens a dialog box to save the Project with a different name, and/or at a different location, and/or under different user name (Figure 12).

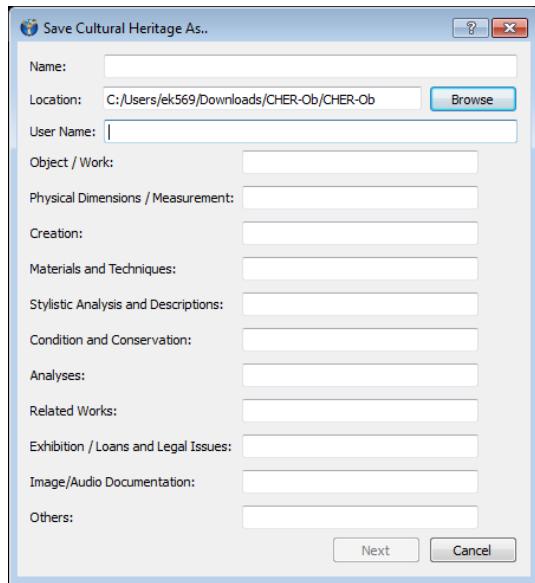


Figure 11. "Save Cultural Heritage Entity as" dialog box.

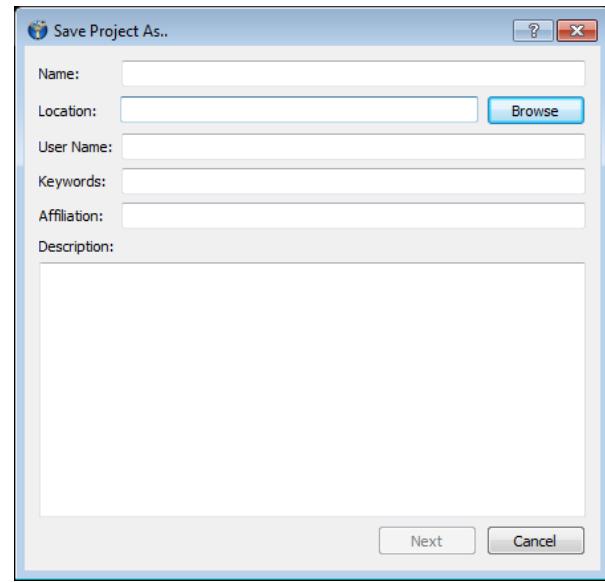


Figure 12. "Save Project as" dialog box

- Close: Closes the currently active CHER-Ob Project or Cultural Heritage Entity
- Import
 - Object...: Opens a dialog box to select 3D, 2D and RTI imaging data

- CT Directory...: Opens a dialog box to open CT data and images. Instead of opening a specific file, you must navigate to the directory that contains the desired image(s), then press “Select Folder.”
- Project...: Opens a dialog box to select a project
- Cultural Heritage Entity...: Opens a dialog box to select a Cultural Heritage Entity
- Merge Objects to Cultural Heritage Entity...: Opens a dialog box to select files to be merged to a Cultural Heritage Entity (Figure 13, Figure 14)

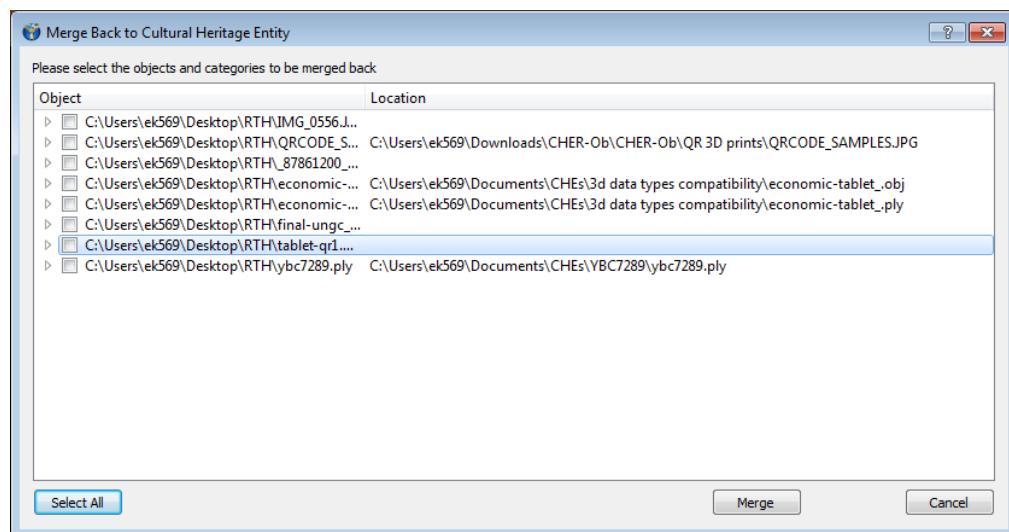


Figure 13. “Merge Objects to Cultural Heritage Entity” dialog box.

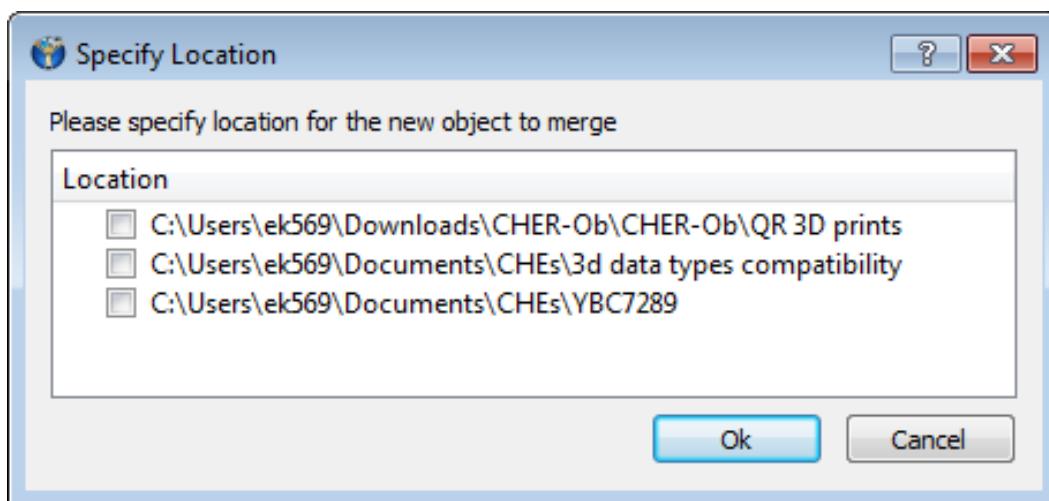


Figure 14. After selecting the objects to be merged a dialog box asks users to specify Cultural Heritage Entities.

- Remove: Opens a dialog box to select files to remove (Figure 15, Figure 16)

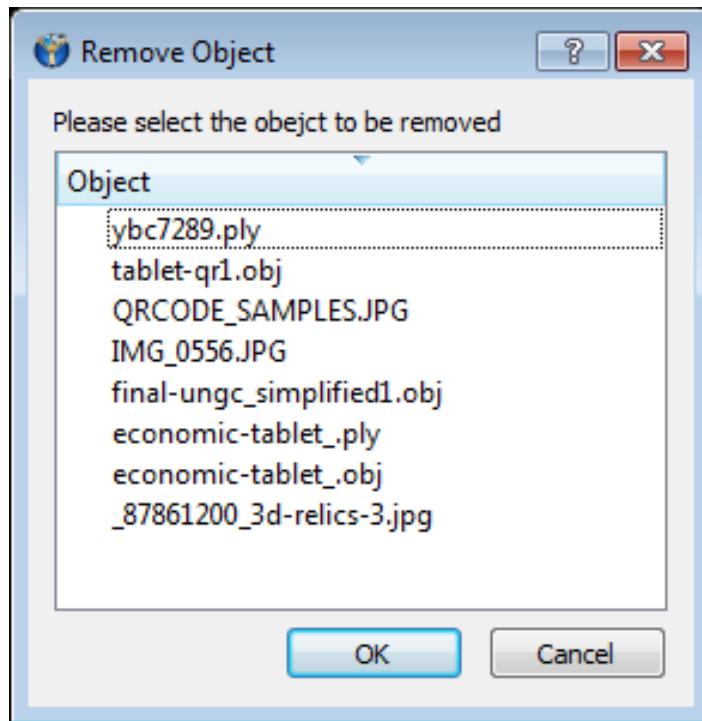


Figure 15. "Remove Object" dialog box.

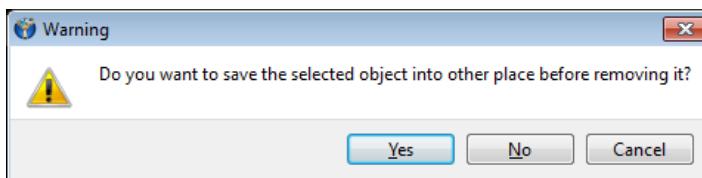


Figure 16. After selecting the object to be removed a dialog box asks whether the selected object should be saved in another location.

- Recent
 - Projects: Hover over this option and you can select and open any of the 8 most recent CHER-Ob projects.
 - Cultural Heritage Entity: Hover over this option and you can select and open any of the 8 most recent CHER-Ob Cultural Heritage Entities.
 - Recent Files: Hover over this option and you can select and open any of the 8 most recent files that CHER-Ob has displayed.
- Exit: Closes the program.

The options Import Object and Import Project and Merge Objects to Cultural Heritage Entity are available only in Projects (Figure 17).

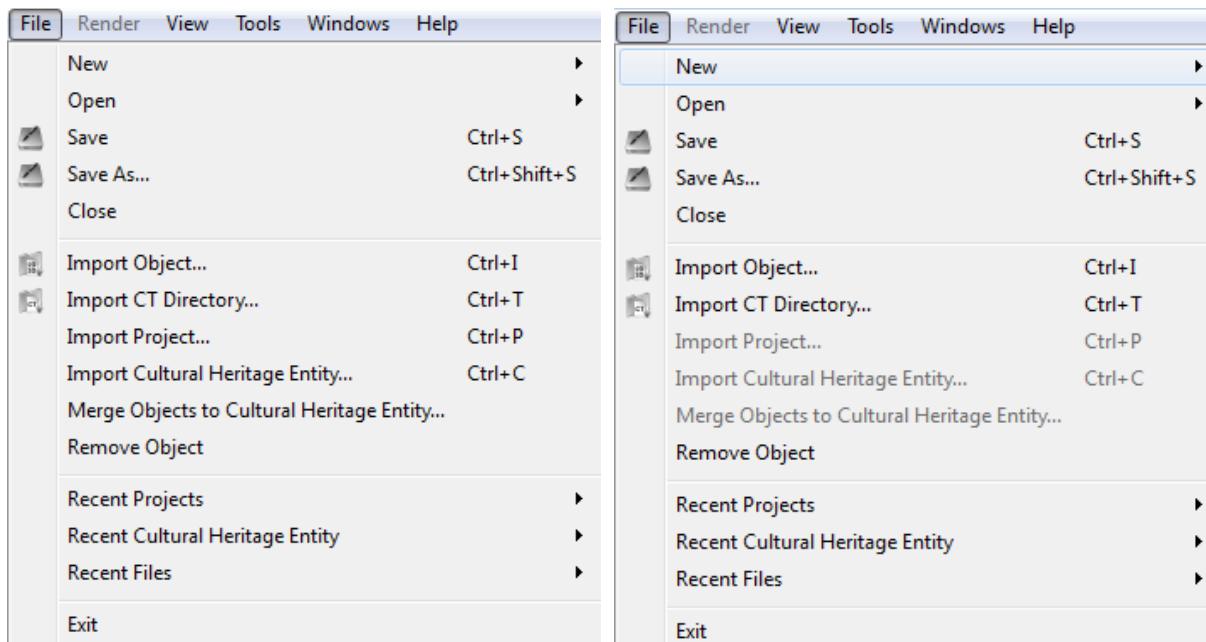


Figure 17. The file menu for Projects (left) and Cultural Heritage Entities (right).

2.1.2. Render

This menu is only selectable when working with 3D meshes.

- Rendering Mode (Figure 18)
 - Points: Displays the object as a mass of individual points or vertices.
 - Wireframe: Displays the object as a series of vertices connected by edges, giving the appearance of a collection of transparent polygons.
 - Surface: Displays the object as a series of connected polygons with smooth, flat faces in grayscale.
 - Texture: When selected, displays the overlying texture on the points, frame, or mesh (depending on which rendering mode you have chosen). When not selected, the object is displayed in gray-scale. If the file has no texture associated with it, toggling this option does nothing.
- Lighting > Directional Light On/Off: Toggles the directional light. Turning this option off will bathe the object in constant illumination from all directions and give it a flat

appearance. Turning it on will project light only from the direction indicated by the sphere in the Light Control toolbox (Figure 19).

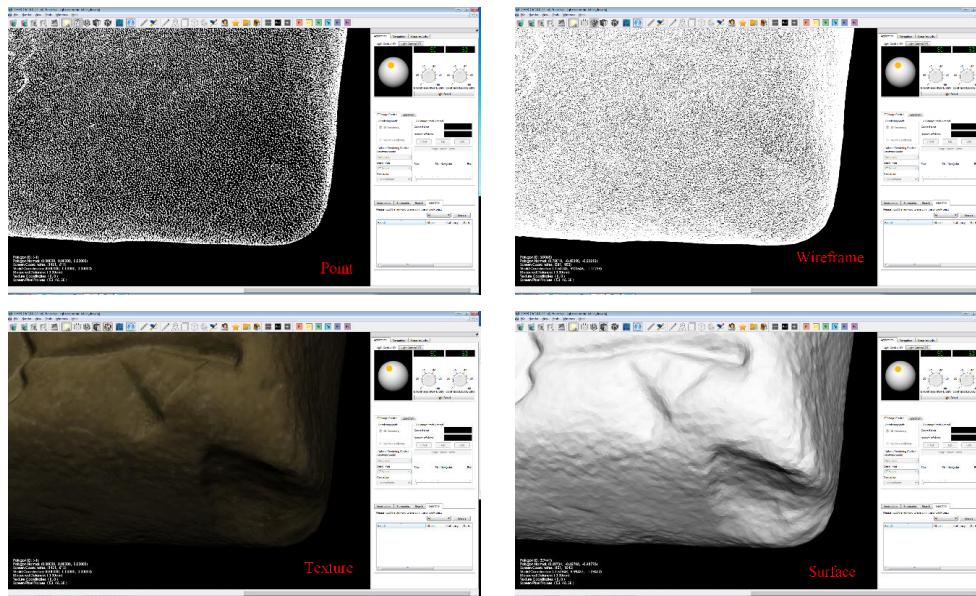


Figure 18. Detail of a clay tablet from the Yale Babylonian Collection displayed in points, wireframe, texture and surface rendering modes.

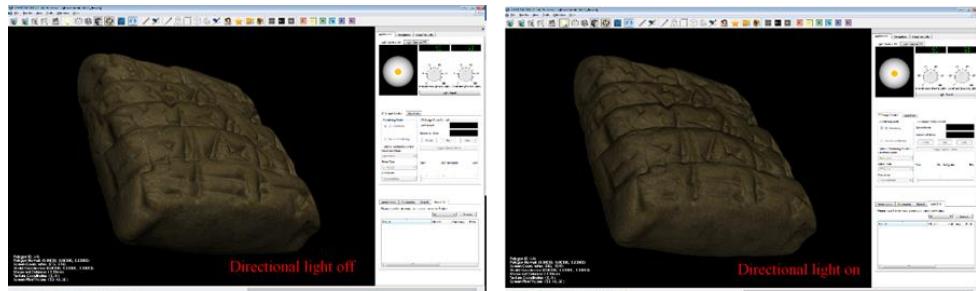


Figure 19. Clay tablet from the Yale Babylonian Collection displayed with directional light off (left) and on (right).

2.1.3. View

- Information: Toggles the display of information about the file and your viewing perspective in the bottom-left corner of the image panel.
- Interpolation: Toggles whether the object texture or picture is displayed as a series of discrete pixels or whether it is smoothly interpolated, causing the image to appear soft and blurry. This option is set off by default and not available for 2D medical images.
- Reset View: Centers the picture or object and displays it at its original size.

- Zoom In: Changes the image panel to present a more close-up view of the picture or object. Zoom Out: Changes the image panel to present a more distant view of the picture or object.
- View From: Hover over this option—only accessible when working with 3D meshes—and you can change your viewing perspective to one of six predetermined positions around the object: front, left, right, top, bottom, and back. Note that selecting one of these positions will zoom the image panel in or out to present the object at its original field of view (Figure 20).

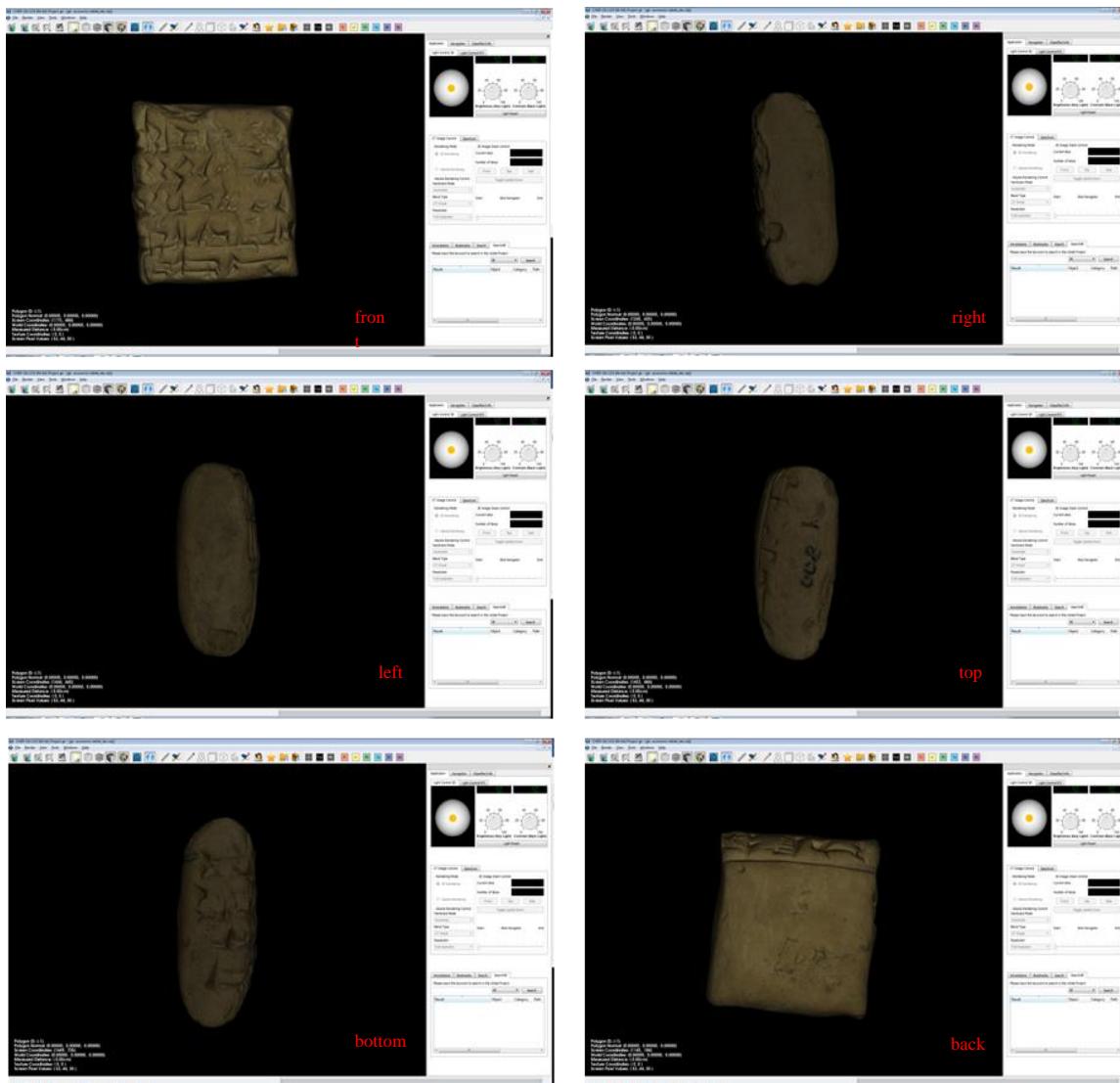


Figure 20. Different views of a clay tablet 3D model from the Yale Babylonian Collection as presented in CHER-Ob.

2.1.4. Tools

This menu includes the following functions (Figure 21):

- Generate report: exports the context of Projects and Cultural Heritage Entities in .pdf or .html format.
- Show Polygon Indicator: Displays red lines to indicate the edges of the polygon currently under your cursor.
- Measuring Tool: Displays the length between two points that you select, represented in the image panel as a straight orange line. The line drawn must begin at some point on the mesh. If you click outside the mesh to begin the line, the program will refuse and will draw the line beginning from the starting point of the last successful line that you drew, or from an arbitrary point on or near the mesh if this is the first line for this mesh (Figure 22).
- Clear Measuring Tool: Clears the line drawn by the measuring tool and the distance displayed next to it. If View > Information is toggled on, the distance measured remains in the bottom-left corner of the image panel under the “Measured Distance” field.

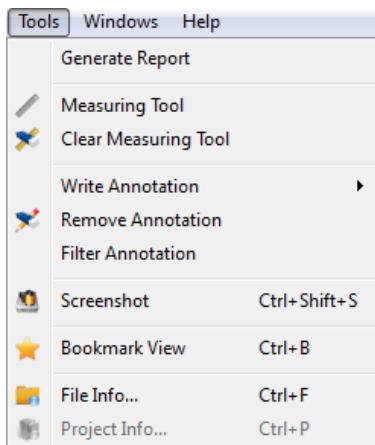


Figure 21. The tools menu

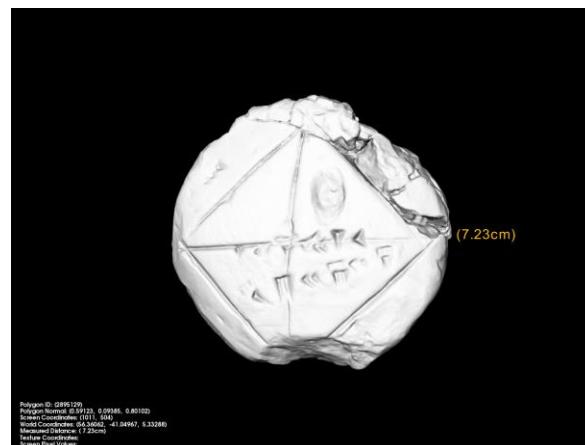


Figure 22. Measuring the diameter of a clay tablet from the Yale Babylonian Collection.

- Write annotation (Figure 23-Figure 25, Table 1)
 - Point note: Addition of annotation connected to a point
 - Surface note: Addition of annotation connected to a surface.

- Frustum note: Addition of annotation connected to a segment
- Color: Attributes each annotation to a particular color category.

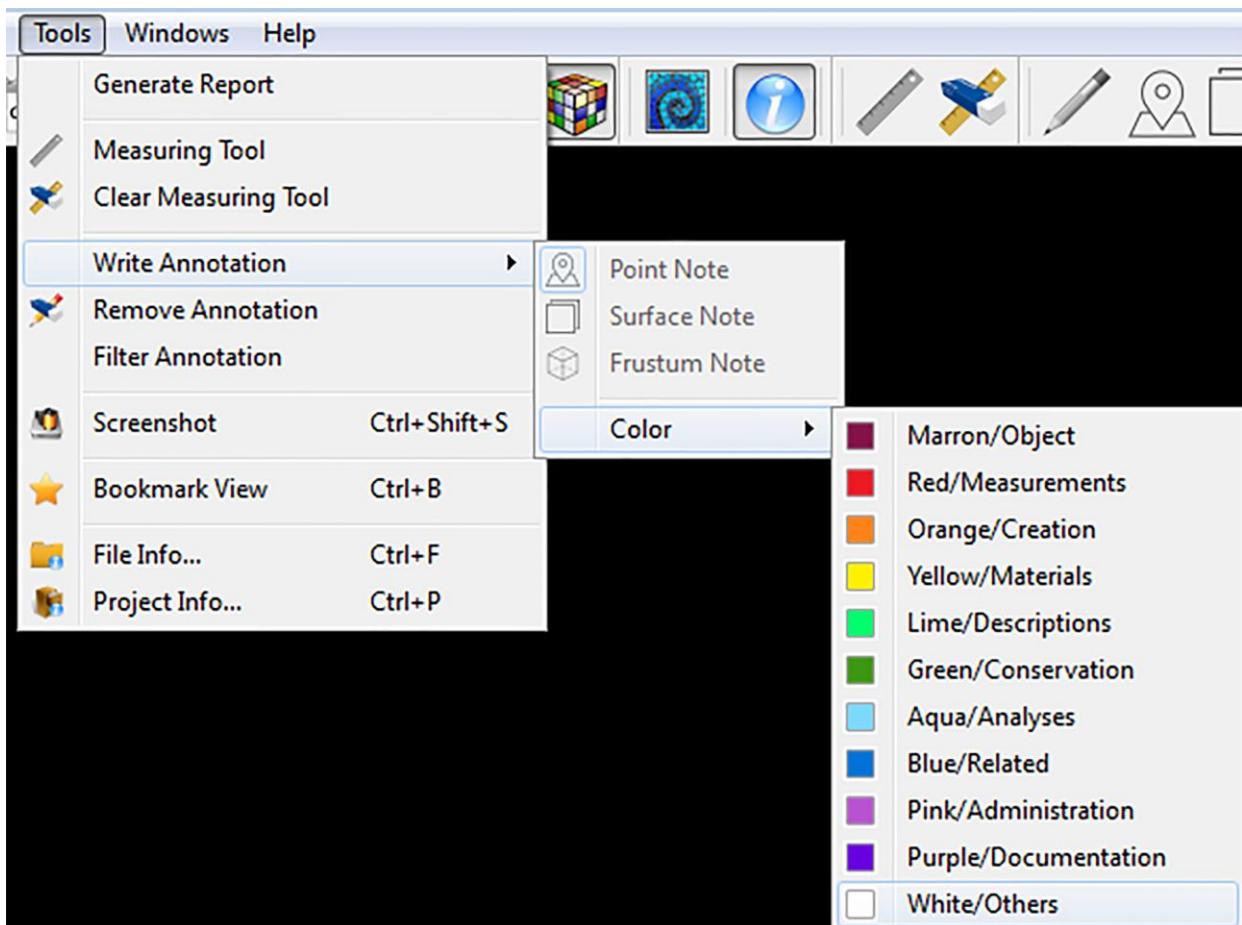


Figure 23. "Write annotation" menu.



Figure 24. Point annotation (pink cross) and surface annotations (lime rectangles) on a 2D image.

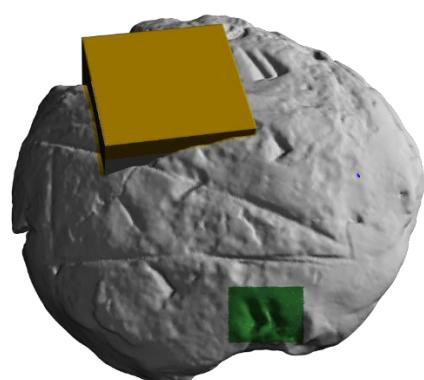


Figure 25. Point (blue spot), surface (green rectangle) and volume (yellow) annotation on a 3D model.

Table 1. Color coding for annotations

Color	Category name	Description
Maroon	OBJECT	What the object/work of art or architecture is and its components, classification terms, titles and names
Red	MEASUREMENTS	Physical dimensions (type, value, unit) and shape descriptions
Orange	CREATION	Creator, date of creation, place of creation, culture
Yellow	MATERIALS	Materials used for the creation, manufacture techniques
Lime	DESCRIPTIONS	Style/art movement, architectural, historical, archaeological context, subject matter, inscriptions
Green	CONSERVATION	Condition reporting, conservation treatment
Aqua	ANALYSES	Description-type of analysis, date, results
Blue	RELATED	Objects and works related to the one described, type or relationship
Pink	ADMINISTRATION	Copyright, ownership, exhibitions/loans, copies
Purple	DOCUMENTATION	Visual and audio representations
White	USER DEFINED	

- Remove annotation: Deletes annotations
- Filter annotation: Opens a dialog box to filter annotations according to user name
(Figure 26)

- Screenshot: Saves a screenshot of the currently selected object.
- Bookmark: Saves views of interest. Opens a dialog box for naming the bookmark (Figure 27)



Figure 26. "Filter annotations" dialog box

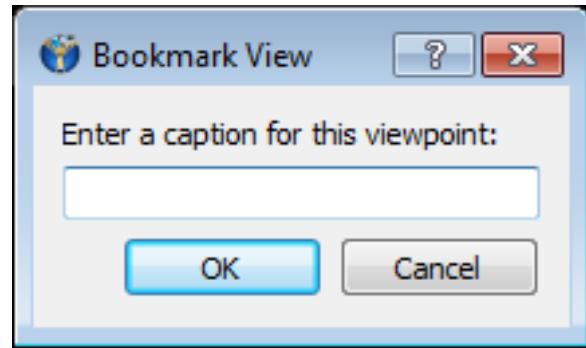


Figure 27. "Bookmark" dialog box.

- File Info: Displays the basic file information (Figure 28).

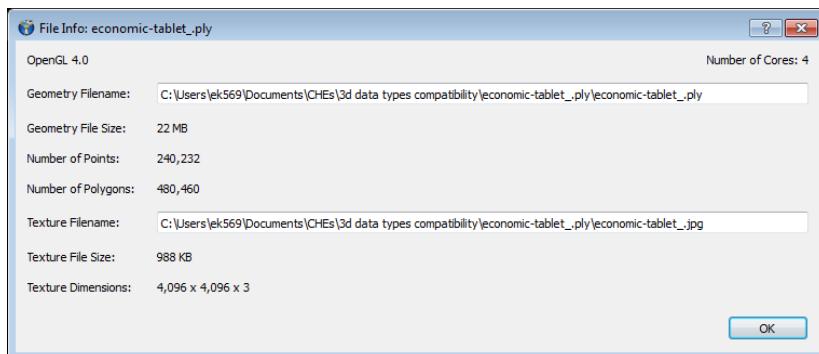


Figure 28. File Info.

- Project info: Displays the basic project information (Figure 29).

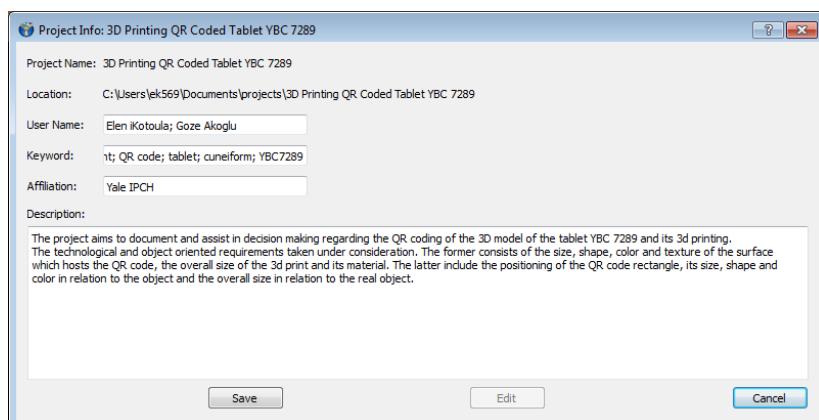


Figure 29. Project Info.

2.1.5. Windows

- Close all windows: closes all currently open windows.
- Close current window: closes current window.
- Open closed window: opens a dialog box for the selection of the object (Figure 31).
- Tile: If more than one file is open, displays all of the open files in windowed mode inside the image panel.
- Maximize: Displays only the active file at maximum size inside the image panel.
- Next: If more than one file is open, displays the next file inside the image panel if you're in maximized mode, or switches to the next file if you're in windowed mode

Below the “Next” menu option, there is a list of all files open in CHER-Ob. You can quickly switch to any given file by clicking on its title.

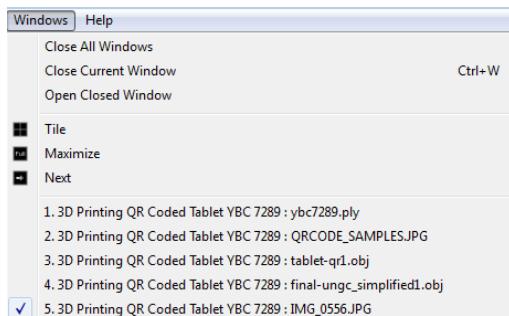


Figure 30. The Windows menu.

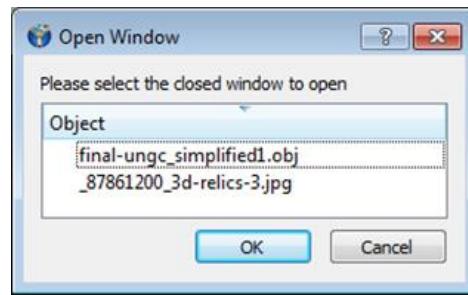


Figure 31. “Open closed window” dialog box.

2.1.6. Help

Help: Presents the user with CHER-Ob’s help files, which are identical to this manual.

About: Displays a small box containing information about the program.

When you are viewing an image in maximized mode, the menu bar also contains three icons to the far right that allow you to alter the image display.

- Minimize: Shrinks the image and displays the title bar at the bottom of the screen.
- Restore Down: Displays the image panel in a small window and displays the other open files in windowed mode.

- Close: Closes the file.

2.2. Icons

The icons (Figure 32) shown between the drop-down menus and the image panel replicate most of the menus' functionalities and commands.



Figure 32. The icons bar in CHER-Ob.

2.2.1. Project

The two leftmost icons allow creating and opening a project . The icon allows saving a project.

2.2.2. Open

The two icons allow easy access to the dialog box for opening files. The first opens 2D and 3D images, and the second opens CT imaging data.

2.2.3. Render

The following five icons are only usable when working with 3D meshes.

- Lightbulb: Toggles the directional light.
- Points: Displays the mesh as a series of points or vertices.
- Wireframe: Displays the mesh in wireframe mode.
- Surface: Displays the surface polygons on the mesh.
- Texture: Toggles the texture display.

2.2.4. View

These two icons alter what you see in the image panel when displaying an image.

- Spiral: Toggles the use of interpolation on the picture or texture (Figure 33).
- Info: Toggles the display of computer, image, and perspective information in the top-left and bottom-left corners of the panel.

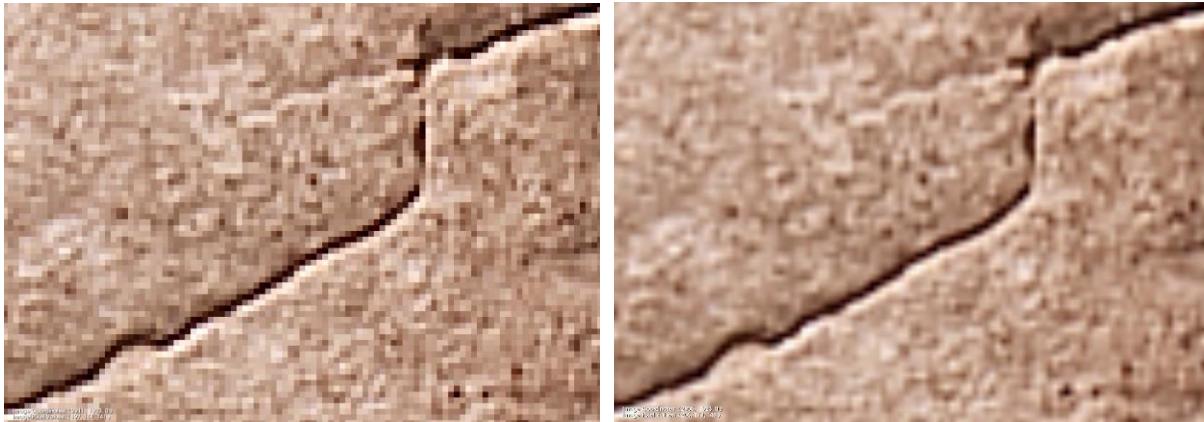


Figure 33. Close-up of a crack showing the difference between the pixelated image (left) and the smoothly interpolated image (right).

2.2.5. Tools

The measuring tools are for use with 3D meshes only.

- Ruler: When selected, measures the length between two points that you select, at least one of which must be on the mesh.
- Ruler/Eraser: Removes the line drawn by the measuring tool and the text indicating the line's length from the image panel.

2.2.6. Annotation and Screenshot

The next icons allow creating , color coding , and deleting annotations , either point , surface , or frustum .

You can use the icon to take and save a screenshot.

2.2.7. Bookmark View

The icon allows you to create a list of bookmarks for views of interest. The bookmark list created will appear under the “Bookmarks” tab at the bottom left corner.

2.2.8. File and Project Info

By clicking the icon , you will see the basic file information, which varies depending on the type of file, e.g., 2D or 3D. By contrast, clicking the icon will bring you the basic information of the project.

2.2.9. Windows

You can use the next three icons to navigate among multiple open files.

- Tile: Displays all open files as tiles inside the image panel.
- Maximize: Displays only the active file at maximum size inside the image panel (Figure 34).
- Next: Displays the next picture or object in the image panel if in maximized mode, or makes the next picture or object the active project if in tile mode.

2.2.10. Perspective

The final six colored square icons are only usable when working with 3D meshes. They allow you to select a pre-determined position from which to view the mesh:

- Front: “Fr” - red
- Left: “Lf” - yellow
- Right: “Rt” - green
- Top: “Tp” - blue
- Bottom: “Bt” - indigo
- Back: “Bk” - violet

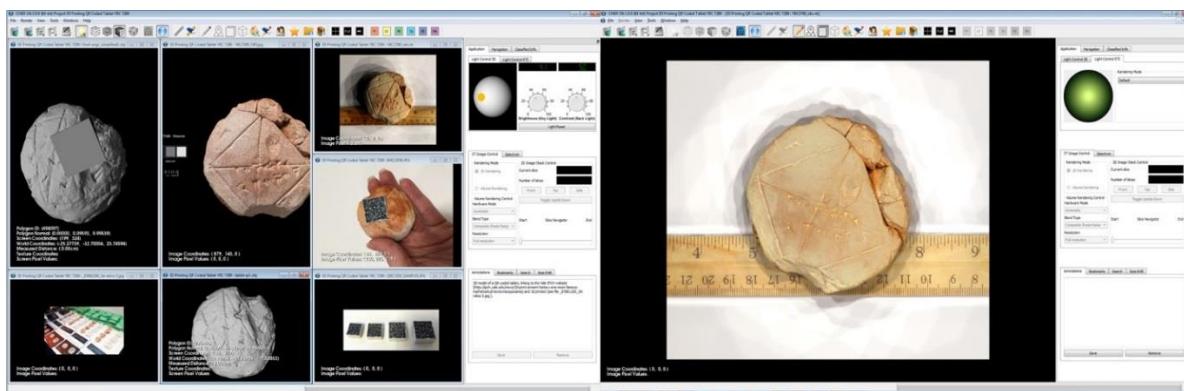


Figure 34. Images displayed in tiled mode (left) and RTI image displayed in maximized mode (right).

2.3. Tabs

2.3.1. Image Panel

The image panel is where the picture or object that you select will be rendered. When a file is loaded, the panel consists of a black background upon which the open picture or object is displayed, as well as accompanying information about the file and your system.

The bottom-left corner of the panel contains data about the open image and your viewing perspective.

2.3.2. Navigation Tab

The navigation tab (Figure 35) is structured in a hierarchical mode and provides information about the:

- Project name
- Cultural Heritage Entities from which Objects are retrieved
- A list of the Objects imported to Cultural Heritage Entities or Projects
- A list of annotations attached to each Object
- A list of Bookmarks

The Navigation Tab in Cultural Heritage is exactly the same as the one in Projects, apart from the Project Name, and the list of Cultural Heritage Entities, which is limited to one. Removed notes appear faded in the navigation tab. Right click on the faded note in the Navigation tab provides the option to undo the remove (Figure 36).

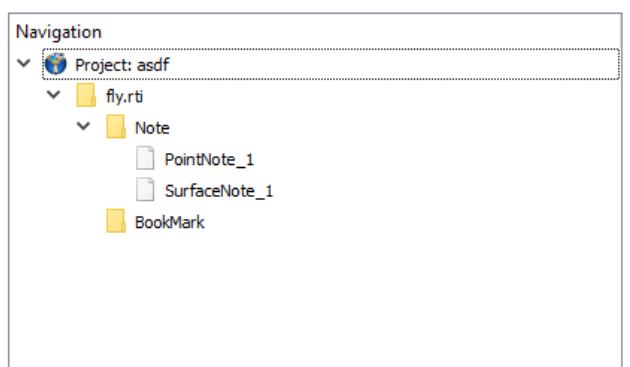


Figure 35. The Navigation Tab of a Project.

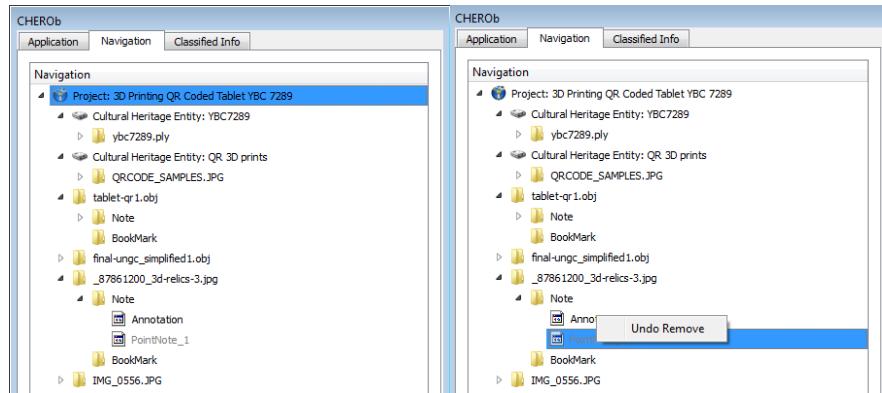


Figure 36. Removed notes appear faded in the Navigation tab (left). Right click on the faded note in the Navigation tab provides the option to undo the remove (right).

2.3.3. Cultural Heritage Entity and Classified Info Tab

The Cultural Heritage Entity (Figure 37) and Classified Info Tabs (Figure 38) provide access to textual information about the Cultural Heritage Entities classified in 10 categories (for a description of the categories please see Table 1). The Cultural Heritage Entity Tab applies when CHER-Ob works in Cultural Heritage Entity mode. It is a dropdown list of the predefined categories associated to each Cultural Heritage Entity. The user can edit the text and export the context from a Cultural Heritage Entity to a Project. The Classified Info tab is the equivalent for Projects. The user can select from a dropdown list the Cultural Heritage Entity and the category and access the relevant information. Edit option is available for Classified Info tab.

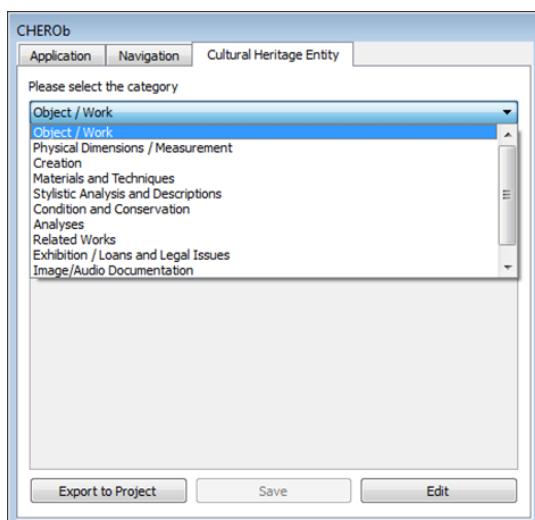


Figure 37. The Cultural Heritage Entity Tab.

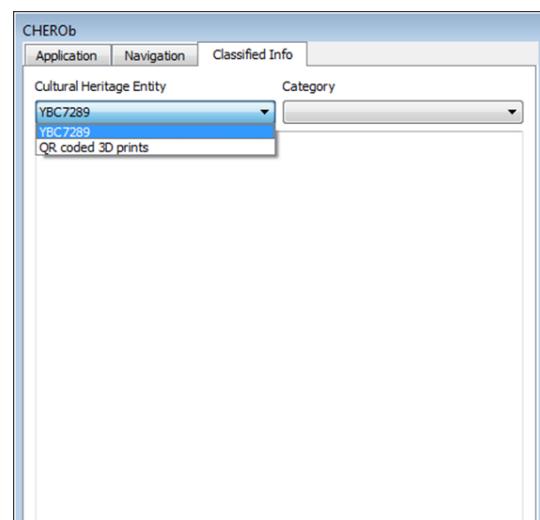
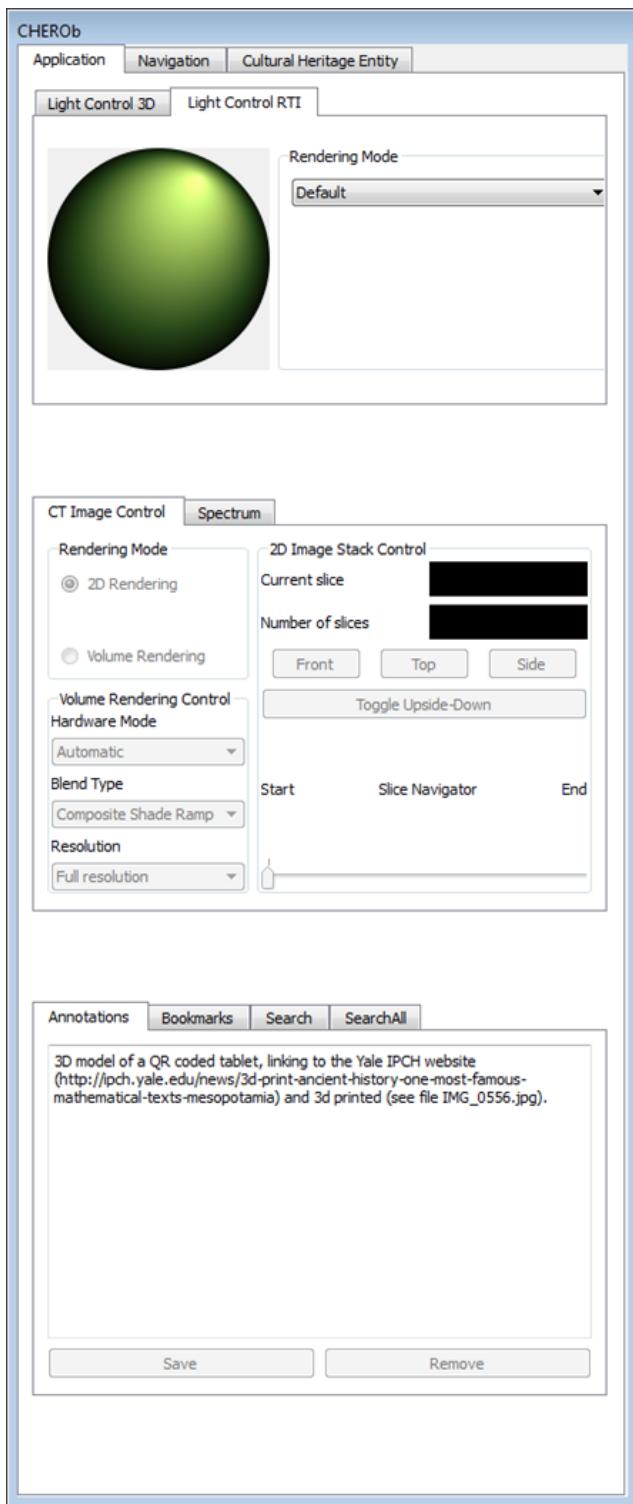


Figure 38. The Classified Info Tab.



2.3.4. Application Tab

The application tab contains the following (Figure 39):

- Light control 3D and RTI
- CT Image control
- Spectrum
- Annotation
- Bookmarks
- Search

Figure 39. Application Tab

2.3.4.1. Light Control

The Light Control toolbox (Figure 40) is ordinarily at the right side of the application. Only some options, or none at all, may be available in this window depending on the type of active image. Please note that changing these settings will affect all open 3D images, not simply the active one. You can adjust the direction of light striking the image or object by clicking on the sphere to the left and dragging in the direction that you want to move the light source. The position of the yellow circle indicates the direction at which the light strikes the object and the point at which the illumination is greatest. The light direction can also be moved behind the sphere, providing a backlight effect to the object (Figure 41). To return to the toolbox's default values, click the "Light Reset" button. This places the light direction at the front center of the sphere and sets the brightness and contrast to the median value of 50.

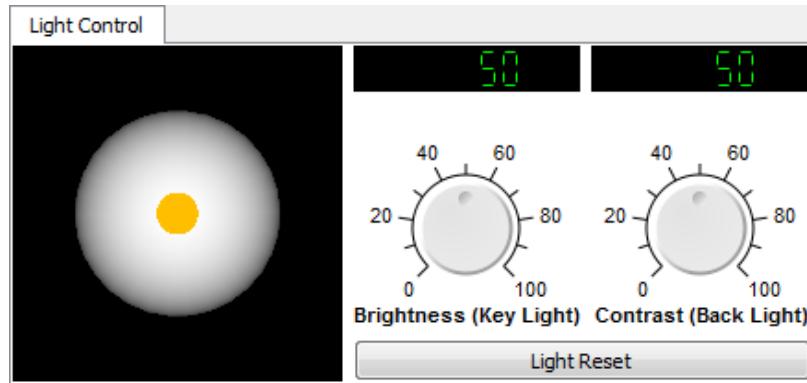


Figure 40. Light Control toolbox. Default settings.



Figure 41. Examples of different light settings available in CHER-Ob. Default settings (right), directional light (middle) and enhanced brightness and lowered contrast (left).

2.3.4.2. *Light control RTI*

The light RTI control toolbox provides the basic viewing features, such as the light controller, rendering modes (default, specular and normal map) and navigation options (zoom and pan) (Figure 42)

2.3.4.3. *CT Image Control*

This toolbox is only active when working with CT scanning data. You can use it to navigate through a series of 2D image slices or to select display options when working with 3D models. These options are only accessible when the “2D Rendering” mode is selected. From here, you can see the current slice that is displayed in the image panel, as well as the total number of slices available to scroll through. You can also change the view in the image panel to a front, side, or top perspective and flip the image upside down. Perhaps most importantly, you can navigate through the full range of slices by dragging the slider at the bottom from beginning to end and back again. If your image has many slices and the slider is not precise enough to navigate to your desired slice, you can also move more slowly through the slices with the left and right arrow keys. When you select the Volume Render radio button, the “2D Image Stack Control” options on the right side of the toolbox are deactivated and the “Vol. Rendering Control” options are activated. The second box allows you to change the blend type. Unless you want to work with a specific blend type (e.g. modes to better visualize CT scans of skin, bone, and muscle), you should likely leave this setting alone. Finally, you can change the resolution at which the object is displayed. If the image is rendering very slowly, selecting “Half resolution” or “Quarter resolution” may provide better performance for your machine (Figure 42).

2.3.4.4. *Spectrum*

The Spectrum toolbox (Figure 43), in case of standard RGB images, contains three meaningful data points; red, green and blue reflectance values. It is most useful when working with hyperspectral images and textures. The ultraviolet spectrum consists of those wavelengths to the left of the violet line on the graph, while the infrared spectrum appears to the right of the red line. It has no effect when working with 3D meshes with no texture or data in grayscale.

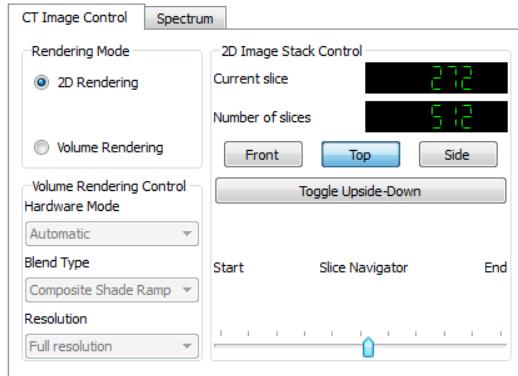
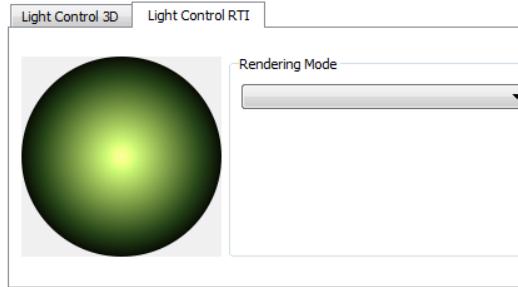


Figure 42. The Light RTI and CT control toolbox.

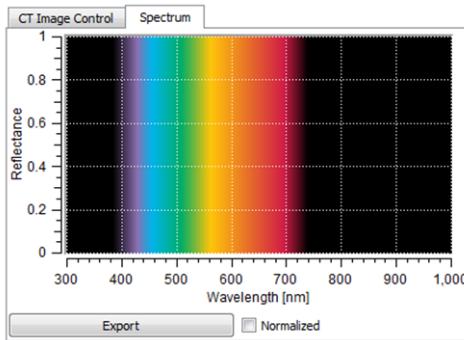


Figure 43. The “Spectrum” toolbox

To use the Spectrum toolbox, simply right-click on a given pixel or cell to display a graph of the available wave-lengths plotted against the reflectance values normalized into $[0, 1]$. By clicking the tick box **Normalized** just under the graph, you can re-normalize the reflectance values so that the length of the vector that is composed of these original normalized reflectance values becomes 1 (Figure 44).

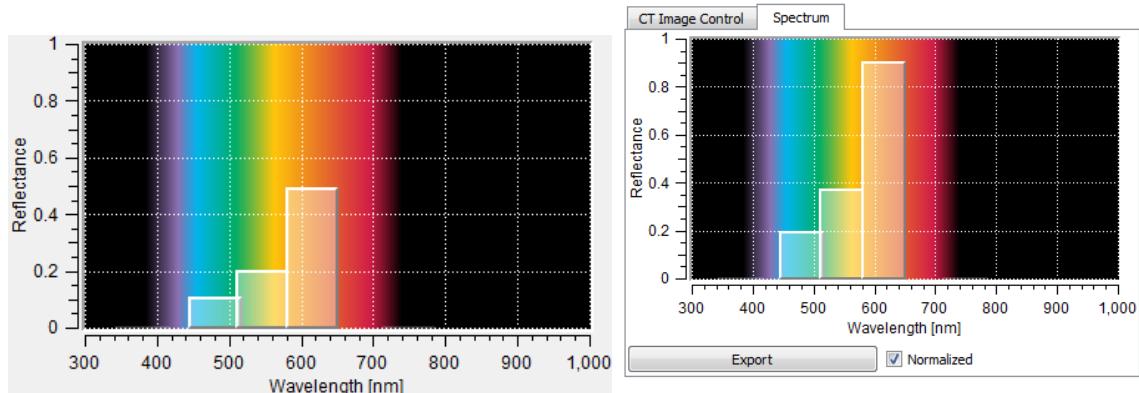


Figure 44. Reflectance graph of a point with adhesive residue before (left) and after normalization (right).

By clicking the button just left to the tick box Normalized , you can export some useful information associated with the point clicked. You will see a dialog immediately after clicking the “export” button, where comments can be added and will be exported (Figure 45).

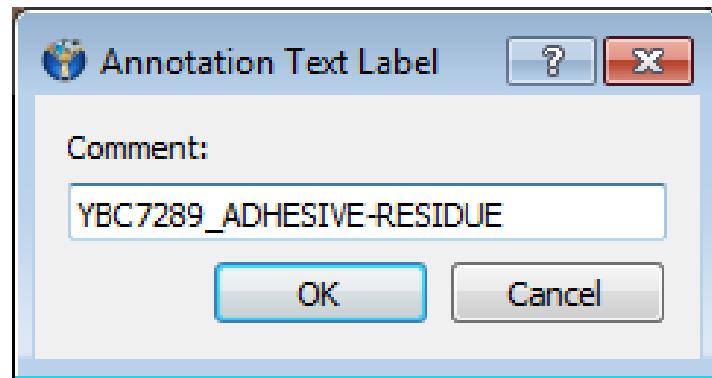
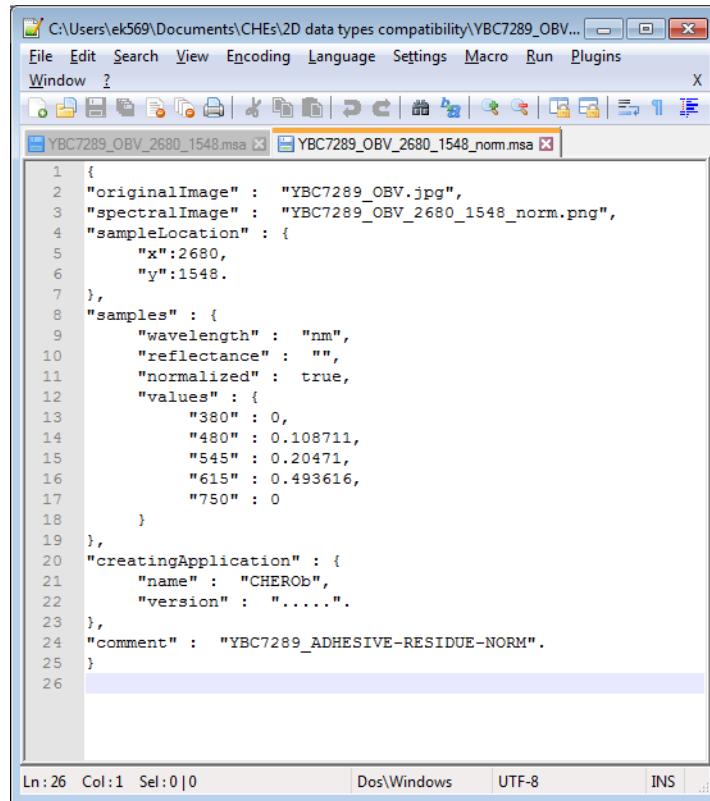


Figure 45. The dialog box that enables to add a label to the exported reflectance data.

After exporting, two files (.png and .msa) will be generated into the same folder where the file exists. The PNG image shows the reflectance values against the wave-length (for example Figure 44 left), while the MSA file is actually a text file with a structure as shown in Figure 46.



The screenshot shows a text editor window with two tabs: "YBC7289_OBV_2680_1548.msa" and "YBC7289_OBV_2680_1548_norm.msa". The content of the "norm.msa" tab is a JSON object representing spectral data. It includes fields for original and spectral images, sample location coordinates (x: 2680, y: 1548), wavelength values (nm) at various wavelengths (380, 480, 545, 615, 750), and application details (name: CHEROb, version:). A comment field indicates the data is for YBC7289_ADHESIVE-RESIDUE-NORM.

```
1 {
2   "originalImage" : "YBC7289_OBV.jpg",
3   "spectralImage" : "YBC7289_OBV_2680_1548_norm.png",
4   "sampleLocation" : {
5     "x":2680,
6     "y":1548.
7   },
8   "samples" : {
9     "wavelength" : "nm",
10    "reflectance" : "",
11    "normalized" : true,
12    "values" : {
13      "380" : 0,
14      "480" : 0.108711,
15      "545" : 0.20471,
16      "615" : 0.493616,
17      "750" : 0
18    }
19  },
20  "creatingApplication" : {
21    "name" : "CHEROb",
22    "version" : ".....".
23  },
24  "comment" : "YBC7289_ADHESIVE-RESIDUE-NORM".
25 }
26
```

Figure 46. Text file exported using the “Spectrum” toolbox.

2.3.4.5. Annotations

The ‘Annotation tab’ provides a general annotation that does not refer to a particular point, surface or volume but to the whole visualization. The tab displays the annotation for the currently active window (Figure 47).

2.3.4.6. Bookmarks

The ‘bookmarks tab’ provides a list of views of interest, assigned by the user. The tab displays the bookmarks for the currently active window (Figure 48).

2.3.4.7. Search and Search all

The ‘search and ‘search all tabs’ provide the option to search for a term either in the currently active window or the whole Cultural Heritage Entity or Project. Search results can be sorted and filtered based on the category (Figure 49).

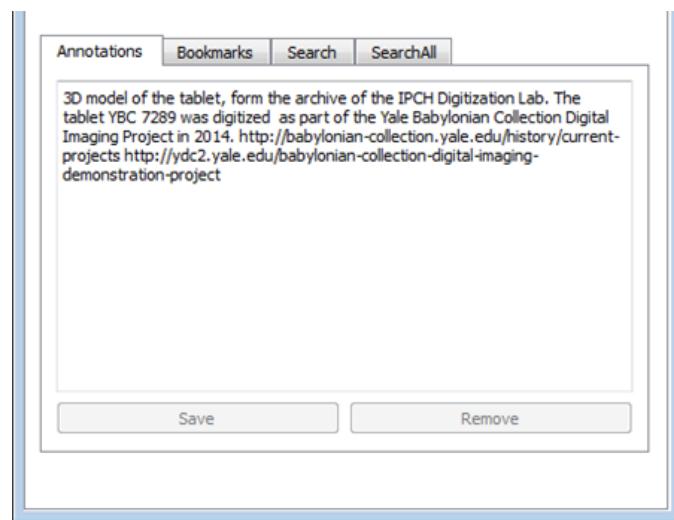


Figure 47. The Annotation tab.

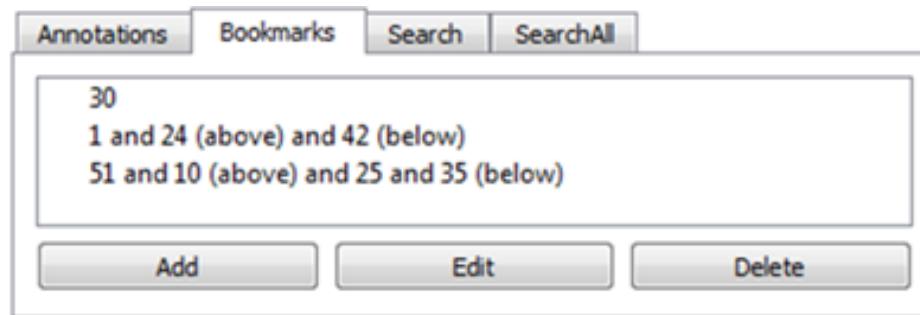


Figure 48. The Bookmarks tab.

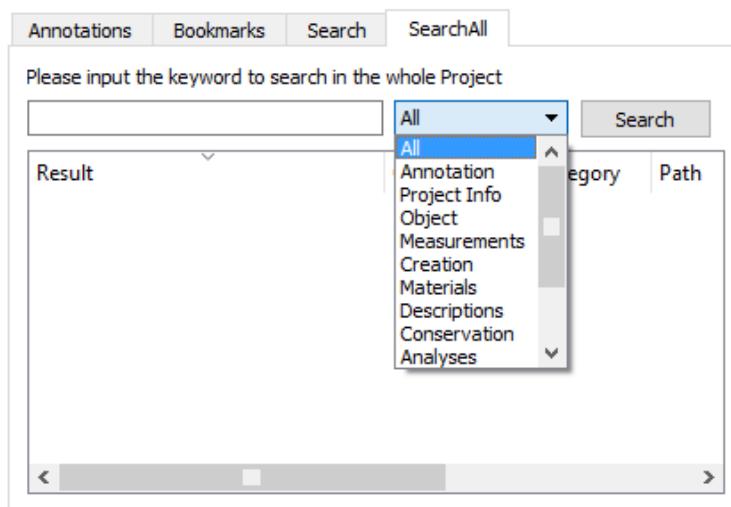


Figure 49. The search tab.

3. Using CHER-Ob

3.1. Navigation

Image navigation within CHER-Ob is simple and intuitive:

- To move the picture around the image panel, hold the Shift key down and drag the image with the left mouse button, or push down on the mouse scroll wheel and drag.
- To zoom in, move the scroll wheel up, press Ctrl-Plus (+) on Windows or select View > Zoom In from the menu.
- To zoom out, move the scroll wheel down, press Ctrl-Minus (-) on Windows or select View > Zoom Out from the menu.
- To center the picture or object and display it at its original size, press Ctrl-0 on Windows or select View > Reset View from the menu.
- To view the spectral information for the current pixel, click the right mouse button. This functionality is available for 2D images and 3D meshes with associated textures.
- To rotate a 3D mesh, hold down the left mouse button and drag the mesh in the desired direction. This functionality is not available for 2D images.

3.2. Compatible data types

CHER-Ob can open 3D models in .obj, .wrl and .ply file format, 2D images in .png, .tif, .tiff, .bmp, .jpg, .jpeg, .exr and .bmp file format, RTI images in .ptm and .rti file format. and CT data. For the information displayed in the file info and the image panel info see Table 2.

3.3. Working with different file types

3.3.1. RTIs

CHER-Ob allows users to load and examine RTI visualizations. It has basic RTI viewer features, such as the light controller, rendering modes, navigation options (zoom and pan), screenshot (snapshots) and bookmarks, but also simultaneously multiple RTI visualization both in .rti and .ptm file format. The annotation options for RTIs are point, area and general file annotations. The notes are searchable, and sortable, and can be attributed to one category for the descriptions of work of art. Certain RTI views can be revisited using bookmarks (Figure 50).

- For placing a point note right click the point on the image.
- For placing a surface note select area.

3.3.2. 2D Images

The CHER-Ob screenshot shown in Figure 51 presents in tiled mode four different 2D images. On the upper left image panel, a photograph retrieved online from the web page of 2015 WEF in Davos showing the Pythagorean Tablet from the Yale Babylonian Collection and a Palmyran statue from the Smithsonian Institution. The general annotation provides information for the image such as context, location, date. The point annotation provides information for the online retrieval of the 3D model of the statue. On the lower right image panel, a group of surface annotations explain the cuneiform writings with attached images. Individual details of the image have been bookmarked and screenshots have been created.

- For placing a point note right click the point on the image.
- For placing a surface note select area.

3.3.3. 3D Models

CHER-Ob can load more than one 3D models, that can be viewed in different rendering modes, annotated, bookmarked and related to a categorized textual information, either simultaneously at tiled mode or separately in full screen mode. Measurements and searches can be performed (Figure 52).

- For placing a point note right click the point on the image.
- For placing a surface note press ‘R’ and then select area.
- For placing a frustum note press ‘R’ and then select volume.

3.3.4. CT data

CHER-Ob allows users to load and examine CT data. It has basic viewer features in 2D stack and volume rendering modes, navigation options (zoom and pan), screenshot (snapshots) and bookmarks, but also simultaneously multiple CT images examination. The annotation options for CT are points, area and general file annotations. The notes are searchable, and sortable, and

can be attributed to one category for the descriptions of work of art. More functions for exploring CT data are coming soon.

Table 2. Info displayed in file info and image panel info

FILE TYPE	FILE INFO	IMAGE PANEL INFO
2D	Filename, File type, File size, Image dimensions, Number of codes	Image coordinates and pixel values
3D	Polygon ID: This field updates when the cursor moves to a new polygon. If the cursor is not currently over a polygon, this value is -1. Polygon Normal: The normalized x-, y-, and z-coordinates of the vector normal to the surface of the currently selected polygon. This field updates when the cursor moves to a new polygon. If the cursor is not currently over a polygon, this value is all zeros. Screen Coordinates: The physical pixel coordinates of the cursor's current location, based on the resolution of the image panel. This field updates when the cursor moves to a new pixel. World Coordinates: The x-, y-, and z-coordinates of the base primitive system for the overall 3D model that is the frame of reference for all other model coordinates. If the cursor is not currently over the mesh, this value is all zeros. Measured Distance: The length of the last line drawn by the measuring tool. If you have not used the measuring tool with the current object, this value is 0 cm. Texture Coordinates: The pixel coordinates of the current texel (texture element) in the original 2D texture image. If the mesh has no texture, this value is blank. Screen Pixel Values: The RGB values of the pixel currently under the cursor. If the mesh has no texture, this value is blank.	Geometry Filename: The name of the open file, without the file type extension. Texture Filename: The name of the 2D texture associated with the 3D mesh. If the mesh has no texture, this value is blank. Number of points. Number of polygons. Texture File Resolution: The first two values describe the width and height of the texture associated with the mesh; the third value is the number of channels in the image (e.g. 3 for RGB images). Model Info: The total number of points and polygons contained in the mesh.

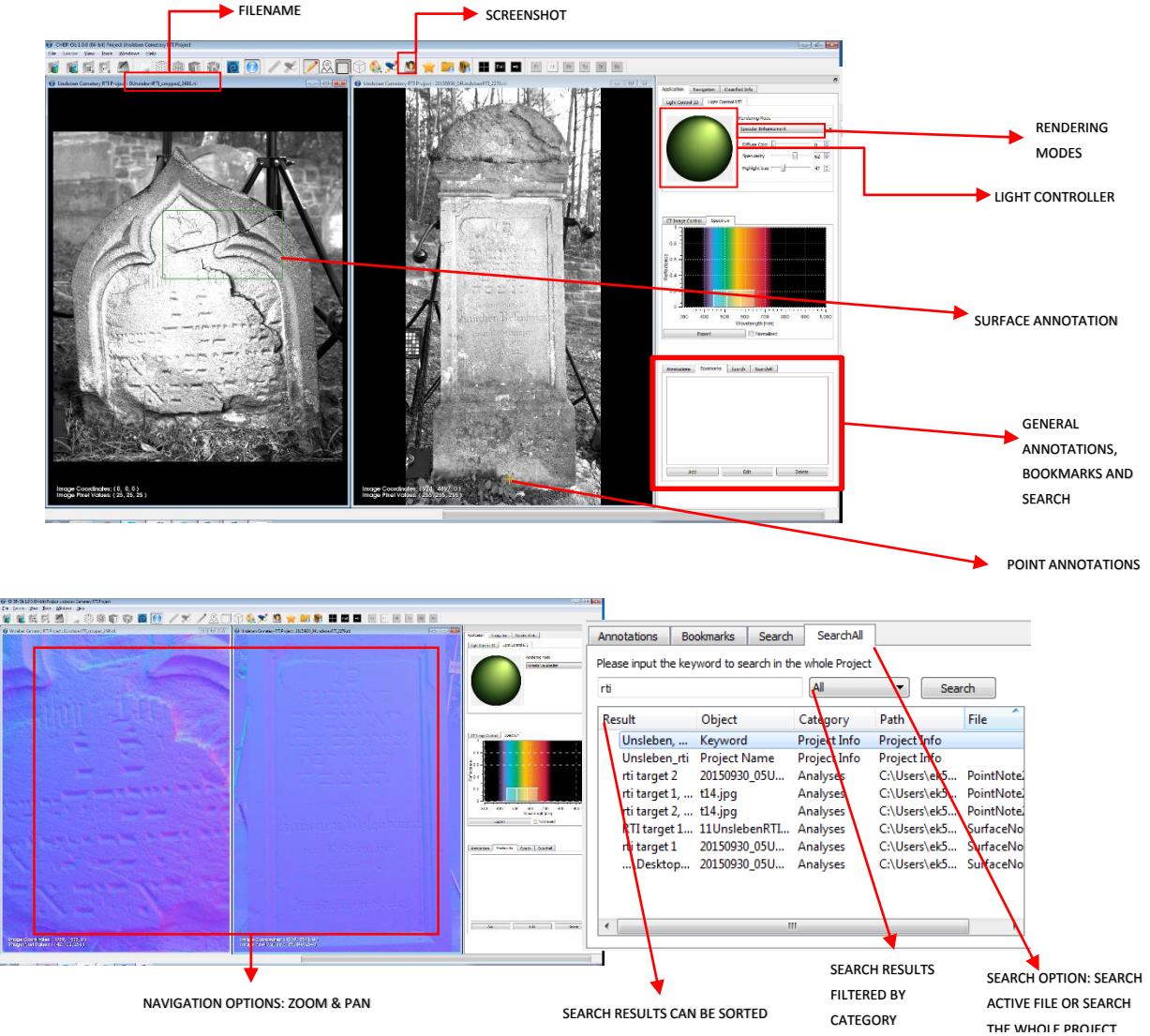


Figure 50. Overview of features relevant to RTI visualizations.

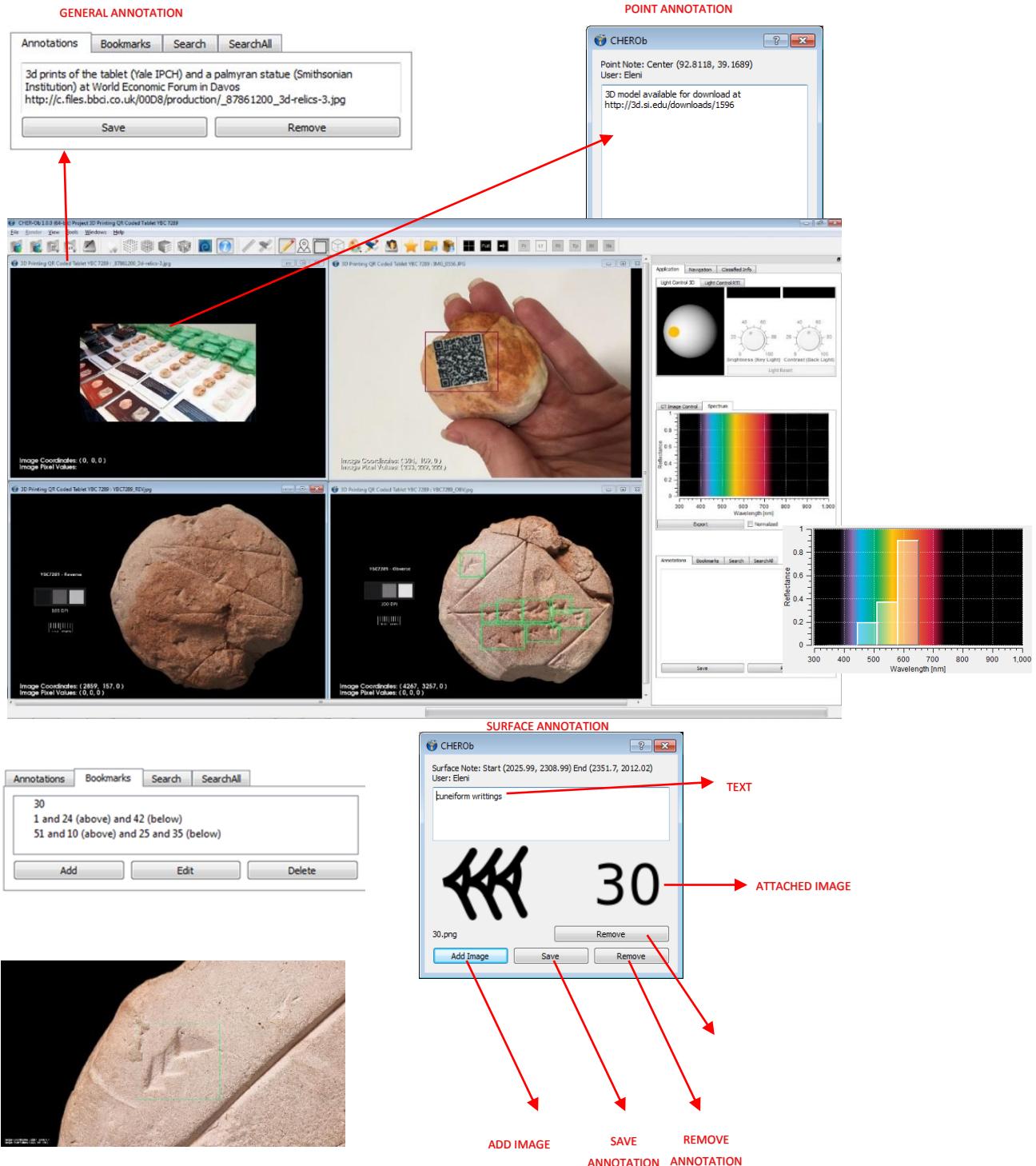


Figure 51. Overview of features relevant to 2D images.

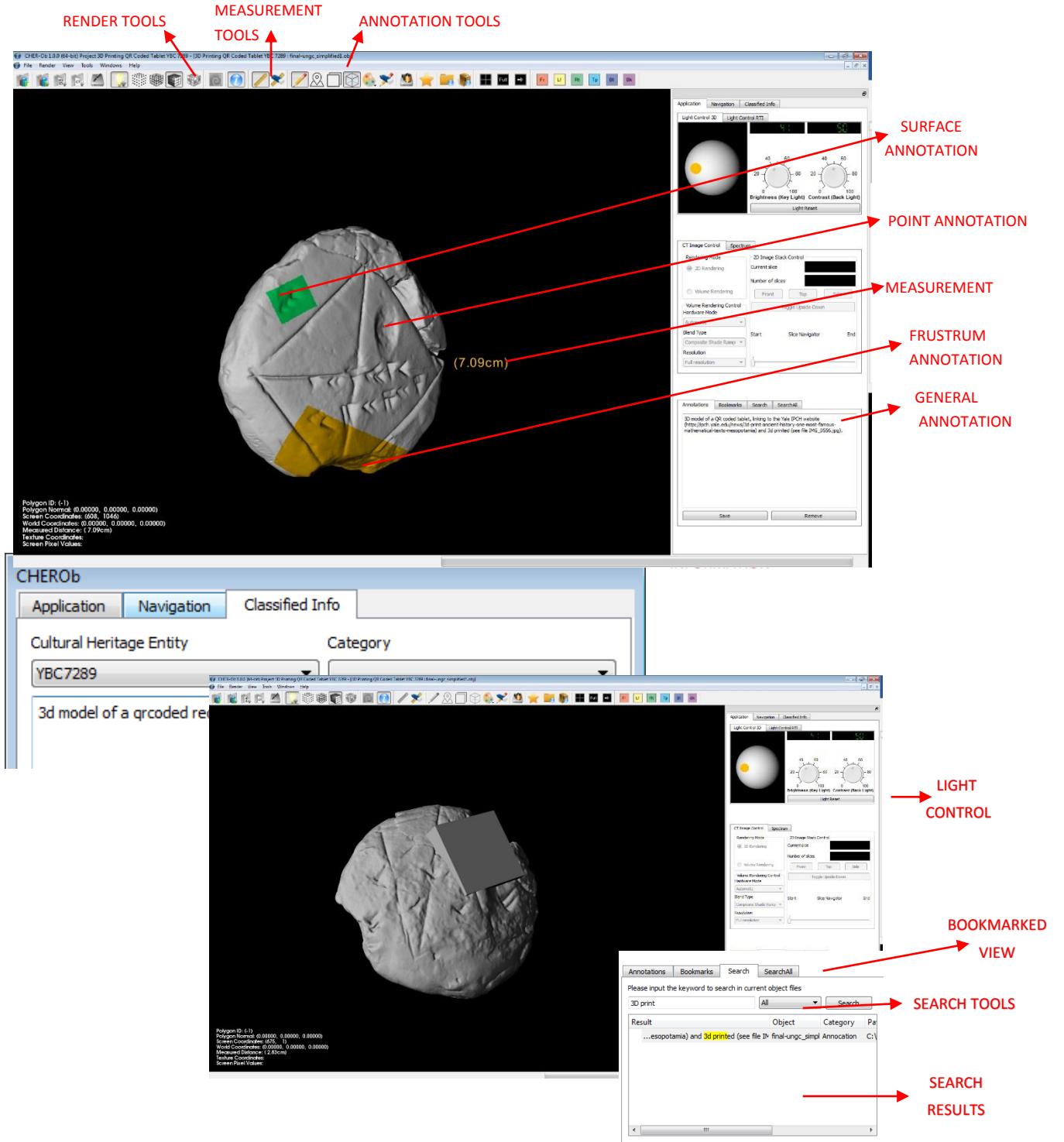


Figure 52. Overview of features relevant to 3D models.

3.4. Working with CHEs

The main functions for working with CHEs are:

- Create a CHE (File > New > Cultural Heritage Entity or Ctrl+Shift+N)
- Fill the New Cultural Heritage Entity Dialog Box
 - Add user mode (creator, modifier, viewer)
 - Add user name (necessary field)
 - Browse objects
 - Add CHE name (necessary field)
 - Add location (necessary field)
 - Fill the 10 categories with already existing information about your Cultural Heritage Entity

To modify the information, go to File > Save as... or Ctrl+Shift+S.

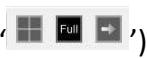
To modify the textual information go to the Cultural Heritage Entity Tab.

To add an object, go to File > Import object or Ctrl+I.

To remove an object go to File > Remove object.

To modify the image panel go to Windows menu.

To modify the information added to the 10 categories go to the Cultural Heritage Entity Tab.

- Explore rendering options in the Application Tab and/or Zoom/Pan.
- Create annotations (Tools> Write annotation...).
- Create bookmark (Tools> Bookmark view or '').
- Create screenshots (Tools> Screenshot or '').
- Navigate to the Cultural Heritage Entity (go to the Navigation Tab or the Windows menu or the '').
- Generate Report (Tools > Generate report...).
- Search and/or Filter and/or Sort information (Application, Search/Search all tab).
- Export to project (Cultural Heritage Entity Tab).

3.5. Developing CHER-Ob Projects

The main functions for working with Projects are:

- Create new project (File > New > Project or Ctrl+ N)
- Fill the New Project Dialog Box
- Add user mode (creator, modifier, viewer)
- Add user name*
- Browse objects
- Add Project name*
- Add location*
- Add keywords
- Add affiliation
- Add project description

The * indicates necessary fields.

- To modify the information, go to File > Save as... or Ctrl+Shift+S.
- To add an object, go to File > Import object or Ctrl+I.
- To add CHE, go to File > Import CHE
- To add an already existing Project, go to File > Import Project
- To remove an object, go to File > Remove object.
- To modify the image panel, go to Windows menu.
- Explore rendering options in the Application Tab and/or Zoom/Pan.
- Create annotations (Tools > Write annotation...).
- Create bookmark (Tools > Bookmark view or '★').
- Create screenshots Tools > Screenshot or 'Screenshot'.
- Explore textual information for CHE (Classified Info Tab).
- Navigate to the Cultural Heritage Entity (go to the Navigation Tab or the Windows menu or the 'Full View' icon).
- Generate Report (Tools > Generate report...).

- Search and/or Filter and/or Sort information (Application, search/search all tab).
- Update CHE information (File > Merge Objects to CHE).

4. Explore the sample project: The Pythagorean Tablet

4.1. CHE “YBC7289”

4.1.1. Create

- i. Click File > New > Cultural Heritage Entity.
- ii. Fill the “Cultural Heritage Entity” Dialog box
 - a. Add user mode and name
 - b. Load objects (YBC7289_rev.rti; YBC7289_obv.rti; YBC7289_OBV.jpg; YBC7289_REV.jpg; ybc7289_simplified.ply)
 - c. Specify location and name for CHE
- iii. Fill the categories with available information
 - a. Object/work: tablet; hand tablet; cuneiform; Old Babylonian Period Mathematical Text.
 - b. Physical dimensions/ measurements: max. diam. 72mm. round shape.
 - c. Creation: Old Babylonian Period (1,900-1,700 B.C.E.); Mesopotamia; written by Babylonian student.
 - d. Materials and techniques: The cuneiform writing was created by using a sharp stylus pressed into the surface of a soft clay tablet to produce wedge-like impressions representing numbers.
 - e. Stylistic analysis and descriptions: The tablet shows a square with both diagonals. A number sign on the upper left indicates that the sides of the square are each 30 units long. Along the diagonal, we find the numerals 1,24,51,10 and 42,25,35, both written, in accordance with the conventions of the Babylonian sexagesimal system, to base 60. The second of these numbers indicates the length of the diagonal. The first number, converted to a decimal, gives 1.414212963, which is very close to $\sqrt{2}$, that is, 1.414213562. Apparently, the

student, to find out the length of the diagonal of a square whose sides were each 30 units long, had calculated $30 [1;24,51,10]$, which yields $42;25,35$. The tablet proves that the Babylonians of the early second millennium BCE knew that the ratio of the side to diagonal in a square is 1 to the square root of 2. They had come to this insight long before the Greek philosopher Pythagoras, who probably lived in the sixth century BCE, established his famous theorem $a^2 + b^2 = c^2$, which is behind their solution. The tablet demonstrates, moreover, that the mathematicians of the Old Babylonian era had found a remarkably good approximation to $\sqrt{2}$: $1;24,51,10$. The student who wrote the tablet seems to have taken this number from a list of coefficients (one such list is likewise housed in the Yale Babylonian Collection). Fowler, D. and Robson, E., 1998.

Square root approximations in old Babylonian mathematics: YBC 7289 in context. Historia Mathematica, 25(4), pp.366-378.; Aaboe, A., 1997. Episodes from the early history of mathematics (Vol. 13). MAA.; Neugebauer, O., Sachs, A.J. and Gotze, A., 1945. Mathematical cuneiform texts (Vol. 29). American Oriental Society.

- f. Condition and conservation: cracks; scratches; material loss; joined- remnants of adhesive material.
- g. Exhibition/ loans and legal issues: The tablet YBC 7289 came to Yale in 1909 as part of a much larger collection of cuneiform tablets assembled by J. Pierpont Morgan.
- h. Image/audio documentation: The tablet was digitized as part of the Babylonian Collection Digital Imaging Project using the following techniques: 1. reflectance transformation imaging (RTI), see files YBC7289_rev.rti and YBC7289_obv.rti 2. 3D laser scanning, see file ybc7289.obj 3. high-resolution photography, see files YBC7289_REV.rti and YBC7289_OBV.rti Benjamin R. Foster, Holly Rushmeier (2014) Babylonian Collection Digital Imaging. Available at:
<http://digitalhumanities.yale.edu/projects/babylonian-collection-digital-imaging>

4.1.2. Develop the CHE

- i. Add general annotations to the loaded objects (Figure 53).
 - a. YBC7289_rev.rti and YBC7289_obv.rti: RTI of the tablet from the archive of the IPCH Digitization Lab. The tablet YBC 7289 was digitized as part of the Yale Babylonian Collection Digital Imaging Project in 2014. <http://babylonian-collection.yale.edu/history/current-projects> <http://ydc2.yale.edu/babylonian-collection-digital-imaging-demonstration-project>
 - b. YBC7289_REV.jpg and YBC7289_OBV.jpg: Digital image of the tablet, form the archive of the IPCH Digitization Lab. The tablet YBC 7289 was digitized as part of the Yale Babylonian Collection Digital Imaging Project in 2014. <http://babylonian-collection.yale.edu/history/current-projects> <http://ydc2.yale.edu/babylonian-collection-digital-imaging-demonstration-project>
 - c. ybc7289.ply: Simplified 3D model of the tablet. The model will be replaced by a high resolution 3D scan from the archive of the IPCH Digitization Lab, digitized as part of the Yale Babylonian Collection Digital Imaging Project in 2014.
<http://babylonian-collection.yale.edu/history/current-projects>
<http://ydc2.yale.edu/babylonian-collection-digital-imaging-demonstration-project>.
- ii. Explore RTI visualizations
 - a. Use the “Light control RTI” for adjusting the light controller and rendering modes (Figure 54).
 - b. Add surface annotations under the category “Stylistic analysis and descriptions” for the translation of cuneiform writings. Images attached to the annotations provide a clear representation of the cuneiforms (Figure 55).
 - c. Create screenshots for areas of interest (Figure 56).
- iii. Explore the 3D model.
 - a. Use the “Light control 3D” for adjusting the light direction, brightness and contrast of your display and navigate around different views of the model (Figure 57).

- b. Add a frustum annotation for the label under the category “Exhibitions/loans and legal issues” and surface annotation under the category “Stylistic analysis and descriptions” for the translation of cuneiform writings. A drawing attached to the annotations provide a clear representation of the cuneiforms (Figure 58).
- iv. Explore 2D images
 - a. Add surface annotations
 - b. Add bookmarks
 - c. Create screenshots
- v. Perform search
 - a. Search for a particular term in a single object (Figure 62).
 - b. Search for a particular term in the whole CHE (Figure 63).
 - c. Filter your results based on a particular category (Figure 64).

4.1.3. Export

- i. Create Reports
 - a. For a complete report on the CHE, click Tools < Generate report and in the dialog box click select all.
 - b. In the dialog box select the. ply file for a report on the 3D model (Figure 65)

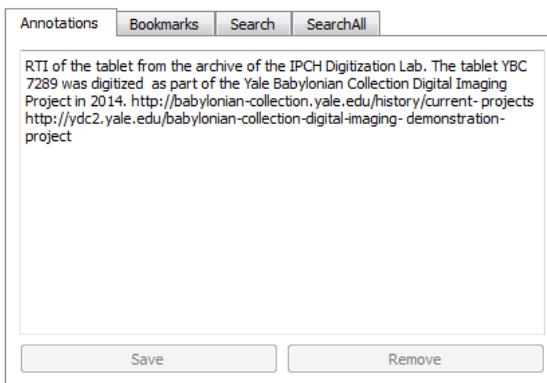


Figure 53. Application Tab. Detail showing a general annotation for the RTI visualization of the tablet YBC7289.

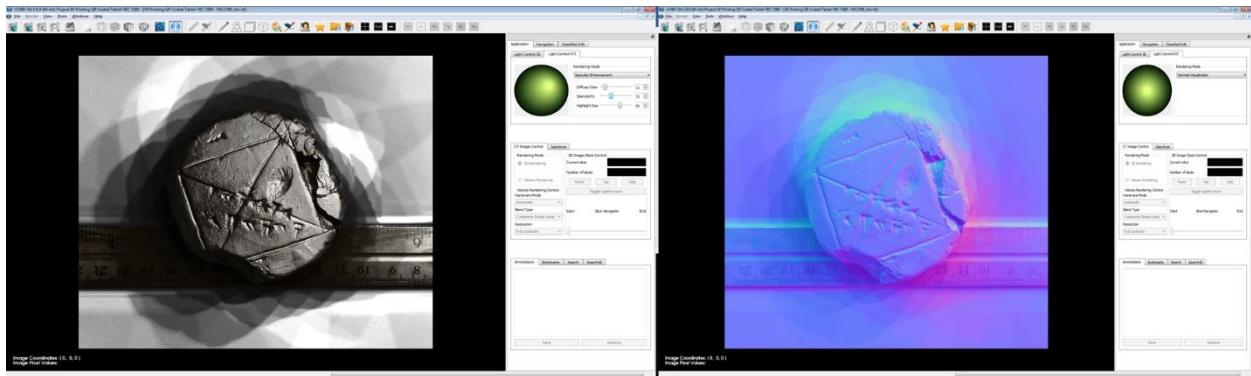


Figure 54. Exploring the RTI visualization. Different rendering modes light controller positions.

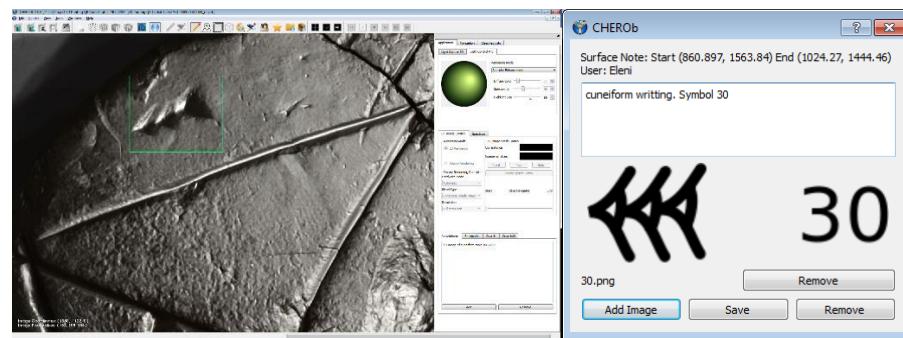


Figure 55. A zoom view of the tablet showing a surface annotation of lime color, under the category “Stylistic analysis and descriptions” (left) and the annotation window showing the comment and the attached image (right).

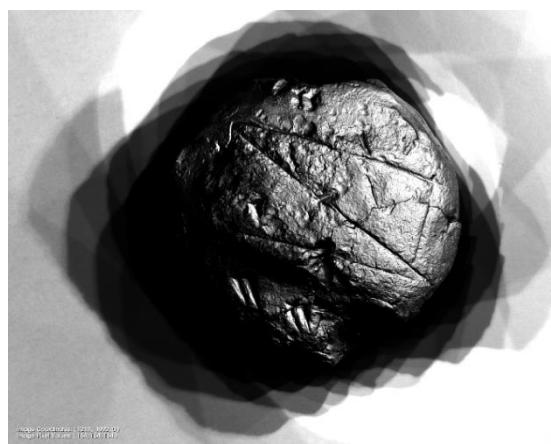


Figure 56. Screenshot of back side of tablet in specular enhancement rendering mode.

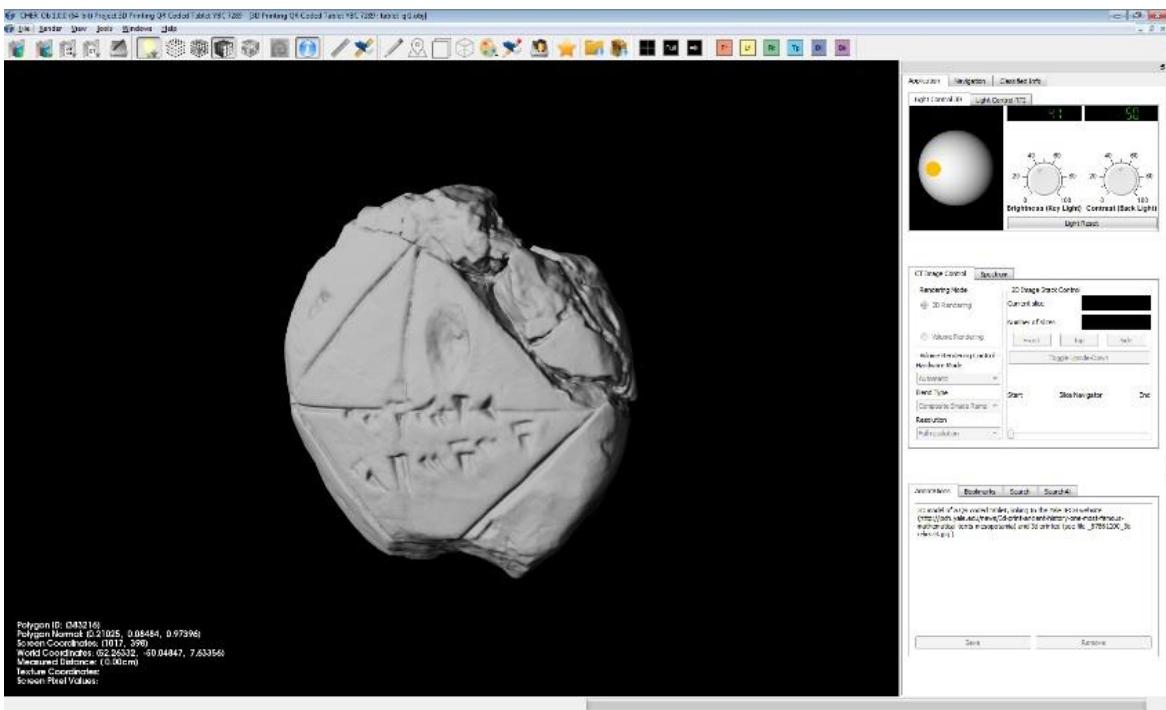


Figure 57. Exploring the 3D model.

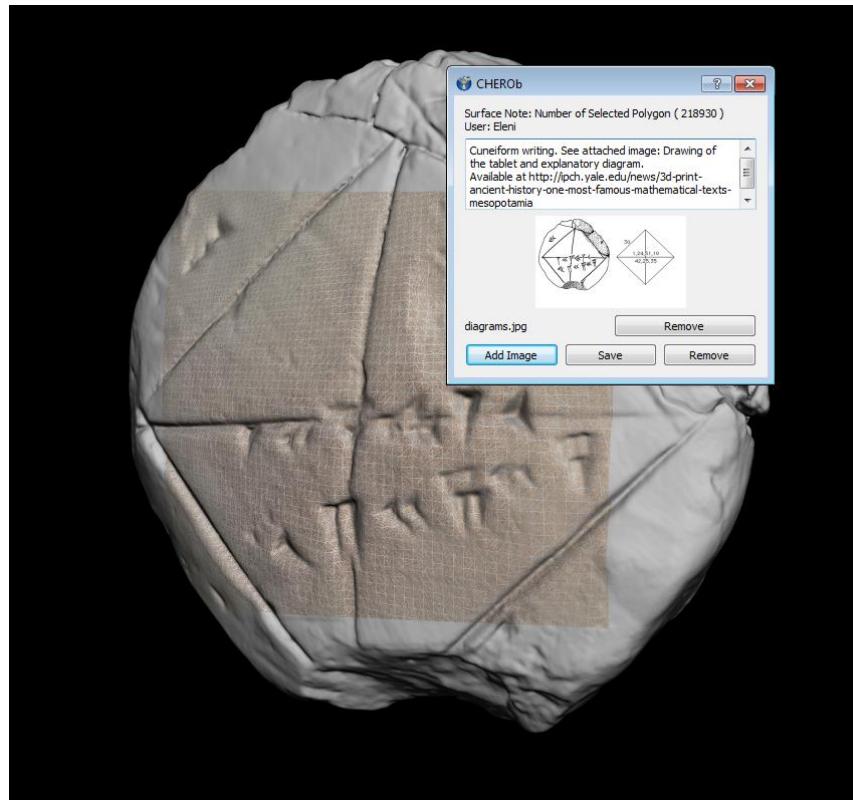


Figure 58. 3D model annotation window.

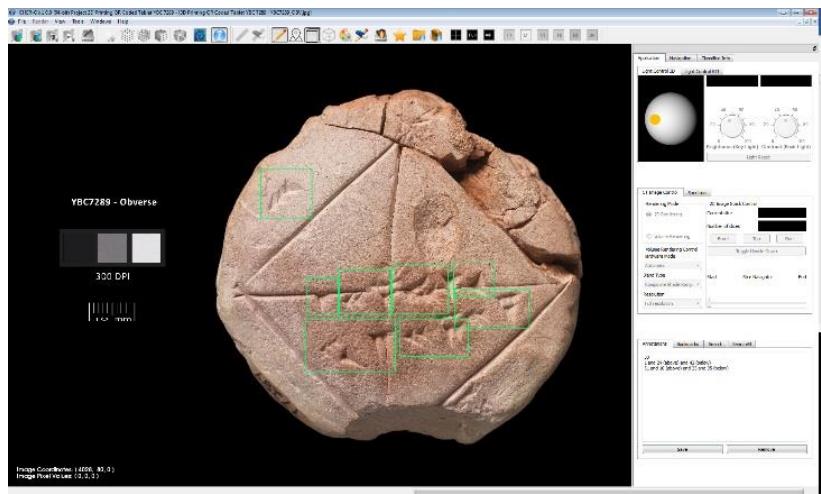


Figure 59. Annotated 2D image

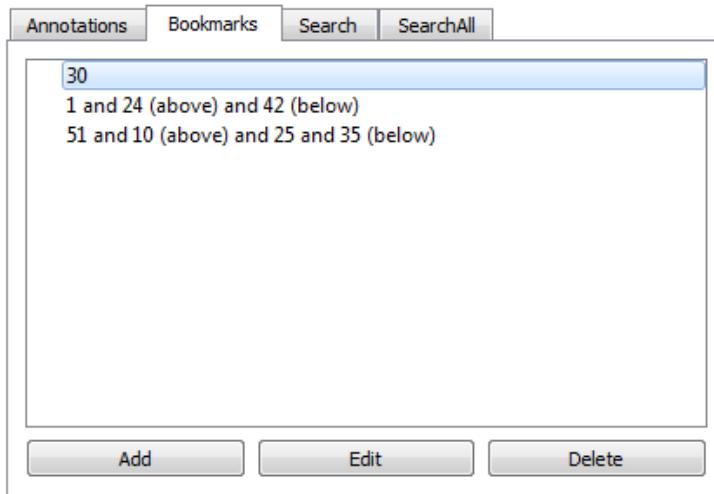


Figure 60. Application Tab. Detail showing list of bookmarks.

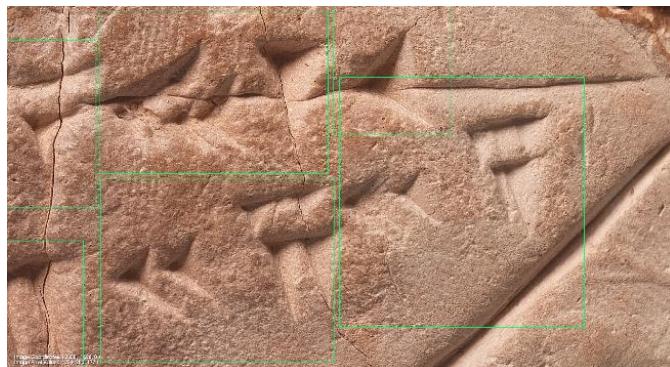


Figure 61. Screenshot showing detail of cuneiform writings

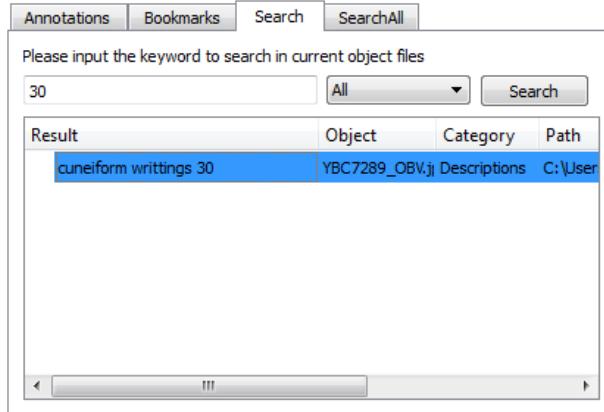


Figure 62. Search results for the word 30 in the 2D image of the tablet.

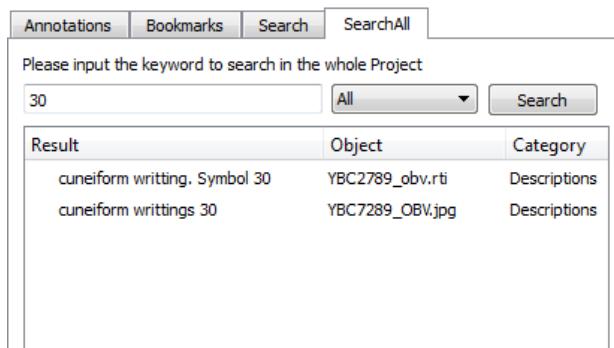


Figure 63. Search results for the word 30 in the whole CHE.

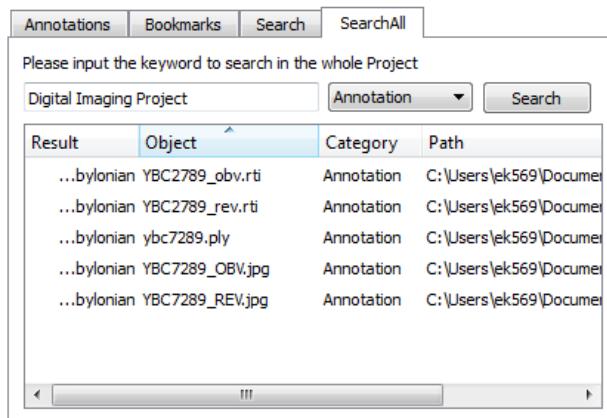
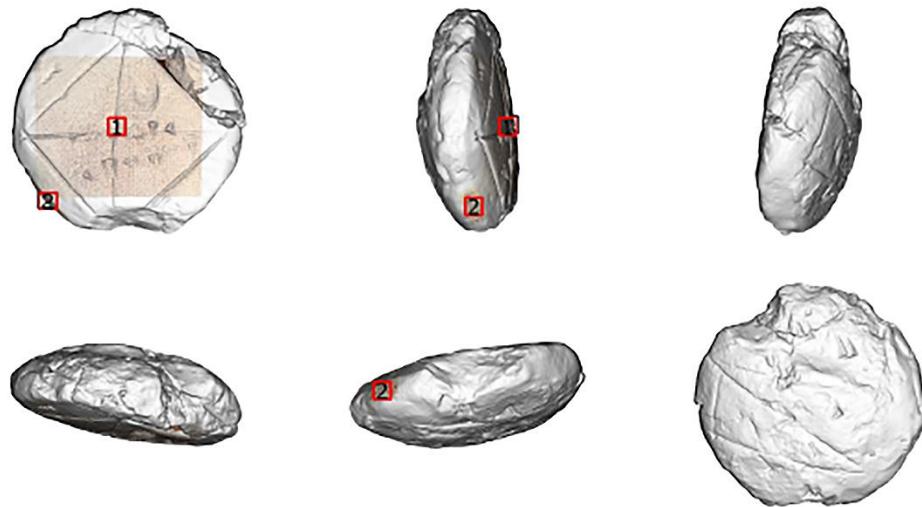


Figure 64. Search result for the phrase Digital Imaging Project in the whole CHE and filtered only in general annotations.

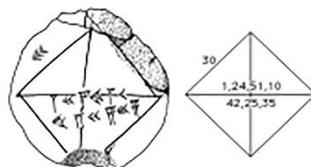
Object 5: ybc7289.ply



3D model of the tablet, from the archive of the IPCH Digitization Lab. The tablet YBC 7289 was digitized as part of the Yale Babylonian Collection Digital Imaging Project in 2014. <http://babylonian-collection.yale.edu/history/current-projects> <http://ydc2.yale.edu/babylonian-collection-digital-imaging-demonstration-project>

Surface Note 1:

Category: Stylistic Analysis and Descriptions



Cuneiform writing. See attached image: Drawing of the tablet and explanatory diagram. Available at <http://ipch.yale.edu/news/3d-print-ancient-history-one-most-famous-mathematical-texts-mesopotamia>

Surface Note 2:

Category: Exhibition / Loans and Legal Issues

Yale Babylonian Collection label YBC 7289

Figure 65. Report part showing all the annotations of the 3D model.

4.2. CHE “QR coded 3D prints”

4.2.1. Create

- i. Click File> New> Cultural Heritage Entity.
- ii. Fill the “Cultural Heritage Entity” Dialog box
 - a. Add user mode and name
 - b. Load objects (QRCode_SAMPLES.jpg; QR_sample_2cm.wrl)
 - c. Specify location and name for CHE
- iii. Fill the categories with available information
 - a. Object/work: 3d model of a QR coded rectangle.
 - b. Physical dimensions/ measurements: 3D printed in four sizes: 1.3, 1.5, 1.8, 2 cm.
 - c. Creation: Created in Yale IPCH on December 2015.
 - d. Materials and techniques: 3d model created in 3DS max, textured mapped and exported in wrl format in accordance with 3D printing requirement.
 - e. Stylistic analysis and descriptions: Linked to <http://ipch.yale.edu/news/3d-print-ancient-history-one-most-famous-mathematical-texts-mesopotamia>.
 - f. Exhibition/ loans and legal issues: Yale IPCH.

After loading the two objects will appear on your screen in tiled mode (Figure 66).

Revisit the information classified in the categories on the Cultural Heritage Entity Tab (Figure 67).

4.2.2. Develop the CHE

- i. Add general annotations to the loaded objects
 - a. QRCode_SAMPLES.jpg: 2D image of 3D print samples in full colour sandstone material, printed by shapeways. size 1.3 x 1.3 cm. to max 2 x 2 cm (Figure 68).
 - b. QR_sample_2cm.wrl: 3D model of QR coded box.
- ii. Annotate the 2D image (Figure 69)

- a. Specify the dimensions of the 3D prints depicted using point annotations under the category “Physical Dimensions / Measurements”, represented by the red cross symbol.
 - b. Specify the readability of the 3D prints using surface annotations under the category “Stylistic Analysis and Descriptions”, represented by the green rectangle symbol.
- ii. Annotate the 3D model (Figure 70)
- a. Add a surface annotation to the 3D model and attach the 2D image of the texture mapped QR code generated in <http://www.qrcode-monkey.com/>

You can access easily the models and the annotations on the Navigation Tab (Figure 71).

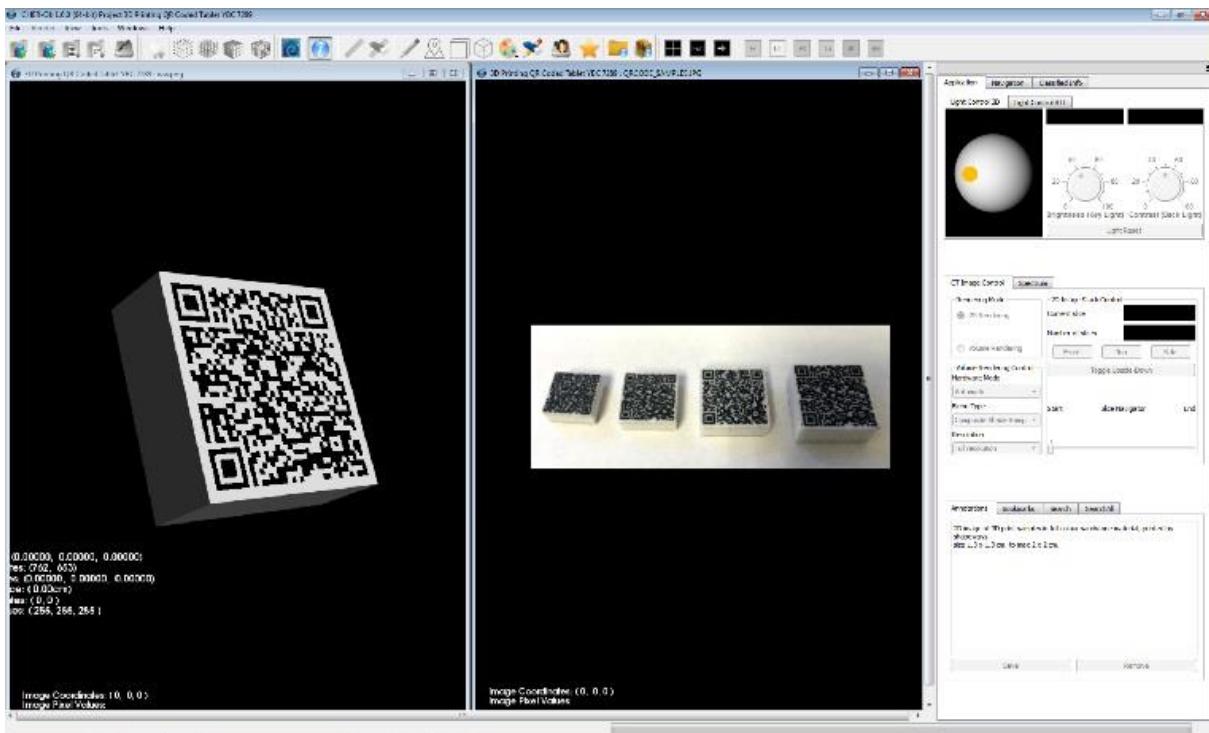


Figure 66. The initial stage of CHE.

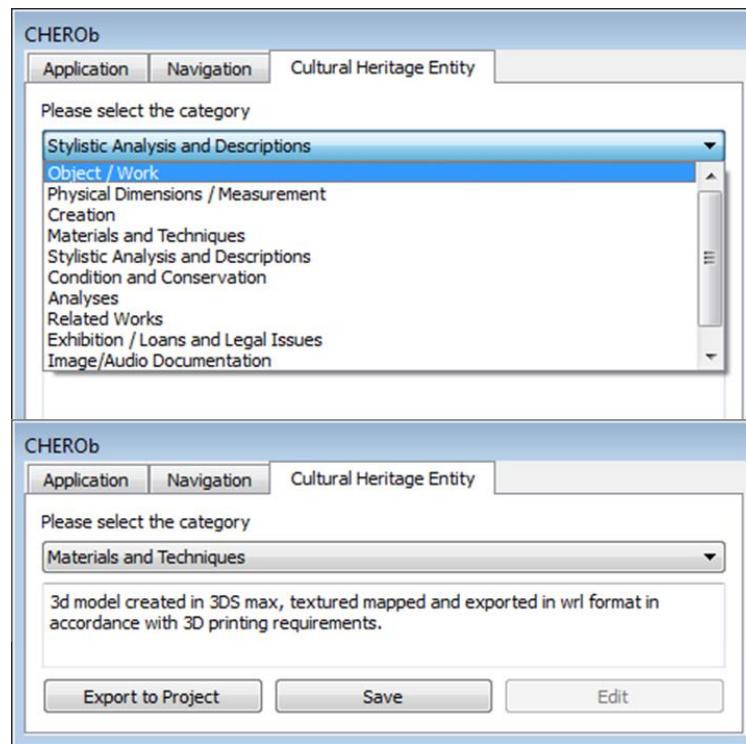


Figure 67. Cultural Heritage Entity Tab. Select category from the dropdown list and view and/or edit the existing information.

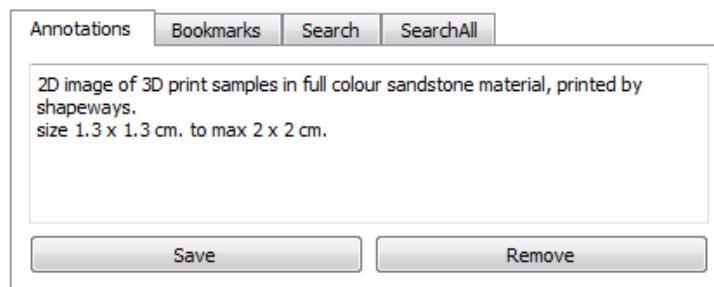


Figure 68. General annotation

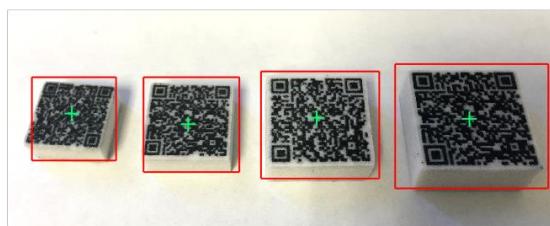


Image Coordinates: (0, 0, 0)
Image Pixel Value:

Figure 69. Screenshot of annotated 2D image.



Figure 70. Screenshot of annotated 3D model and annotation window with attached 2D image.

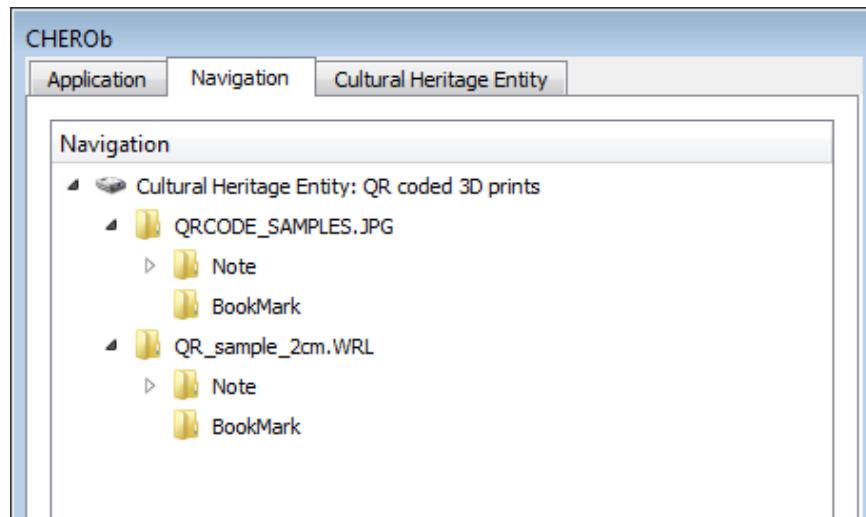


Figure 71. The Navigation Tab.

4.3. Project “3D Printing QR Coded Tablet YBC 7289”

4.3.1. Create

- Click File> New> Project.
- Fill the “New Project” Dialog box providing information about
 - the users and their affiliation,
 - the project description and keywords
 - the project name and location

The Project “3D Printing QR Coded Tablet YBC 7289” aims to document and assist in decision making regarding the QR coding of the 3D model of the tablet YBC 7289 and its 3d printing. The technological and object oriented

requirements taken under consideration. The former consists of the size, shape, color and texture of the surface which hosts the QR code, the overall size of the 3d print and its material. The latter include the positioning of the QR code rectangle, its size, shape and color in relation to the object and the overall size in relation to the real object. You can revisit the project info by clicking Tools< Project Info or the Project info icon (Figure 72).

iii. Import files

- a. Click File< Import Object for loading two QR coded 3D models and two 2D images.
- b. Click File< Import Cultural heritage entity and select the 3D model (ybc7289.ply) from the CHE “YBC7289”
- c. Click File< Import Cultural heritage entity and select the 2D image (QRCode_SAMPLES.jpg) from the CHE “QR coded 3D prints”

After loading the files the Project appears on the screen in tiled mode as shown in Figure 73. Along with the files the project contains the annotations (Figure 74) and textual information deriving from each CHE accessible via the “The Classified info” tab (Figure 75). The provenance of each file can be easily tracked via the Navigation Tab (Figure 76).

4.3.2. Develop Project

i. Explore the objects

- a. The two QR coded 3D models of the tablet were examined in parallel with the scanned 3D model (Figure 77). Via the measurement tool (Figure 78) and the annotations (Figure 79), the user reach conclusions regarding the positioning of the QR code rectangle. Adding annotations taking under consideration the object-oriented and the technical requirements. The former derive from the CHE “YBC7289” and the latter from the CHE “QR Coded 3d prints”. A small QR code rectangle positioned on the reverse side of the tablet does not cover the cuneiform inscriptions, it is elevated and clearly distinguished but not dominant, mainly because of its size in relation to the size of the tablet. The presence of the

2D images of the 3D printed tablets provide the necessary documentation for the project (Figure 80).

4.3.3. Export

- i. Generate automatic report:
 - a. Click Tools < Generate report, select location and give a filename and choose file type (.pdf or .html) for exporting your project for presentation, online publishing, digital and print archiving and collaboration purposes (Figure 81).
- ii. Updating CHEs
 - a. Click File < Merge Objects back to CHE, select objects and specify location (Figure 82). The updated CHE includes the new files (Figure 83). In addition, more textual information can be included in the ‘Cultural Heritage Entity Tab’ (Figure 84).

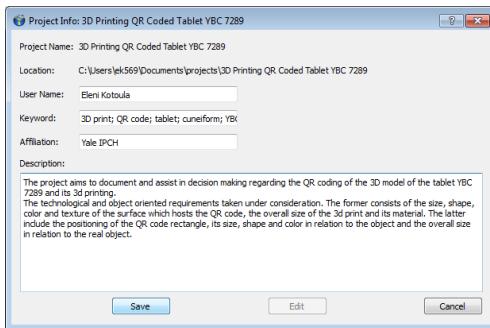


Figure 72. Project Info

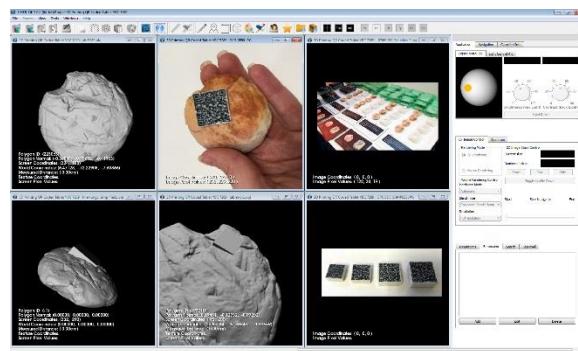


Figure 73. Initial stage of project after loading objects and CHEs.

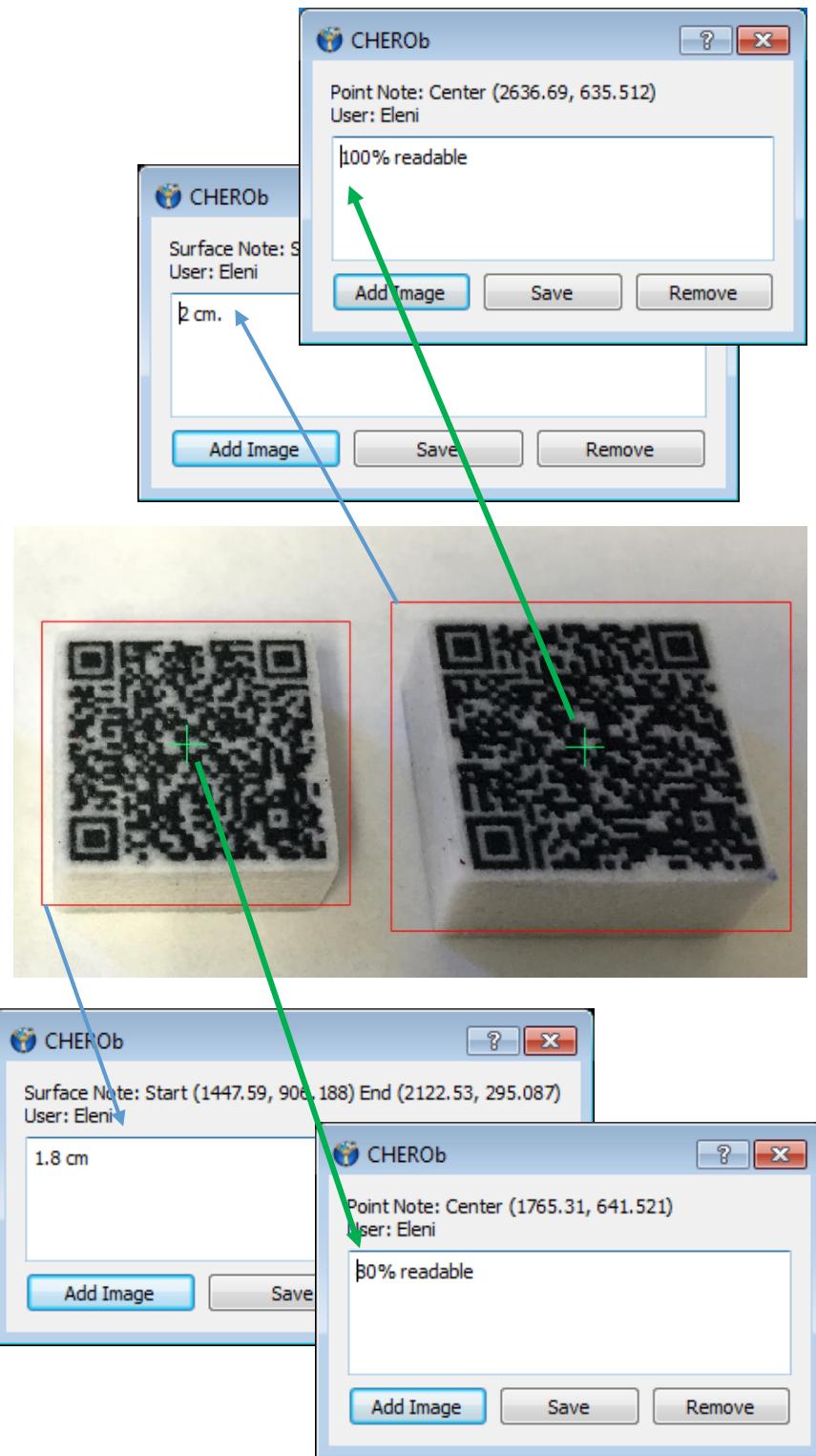


Figure 74. The annotations from the CHE are accessible in the Project.

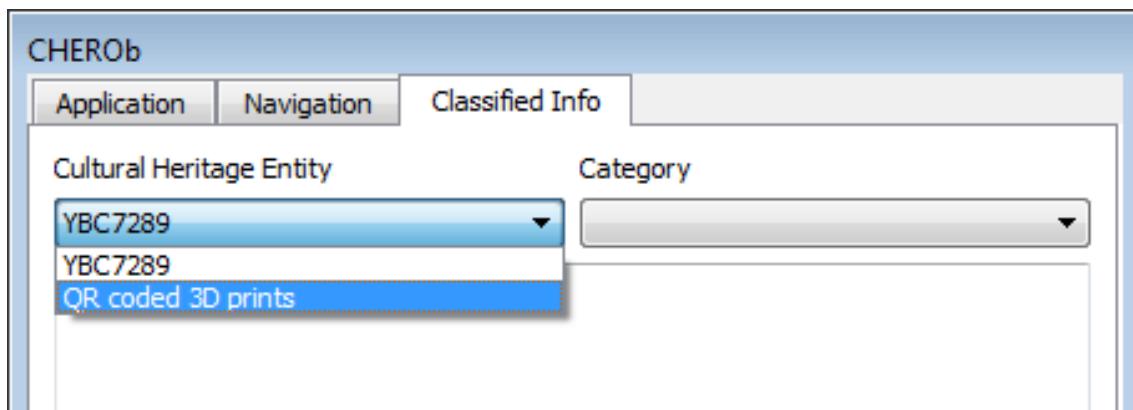


Figure 75. The classified info tab.

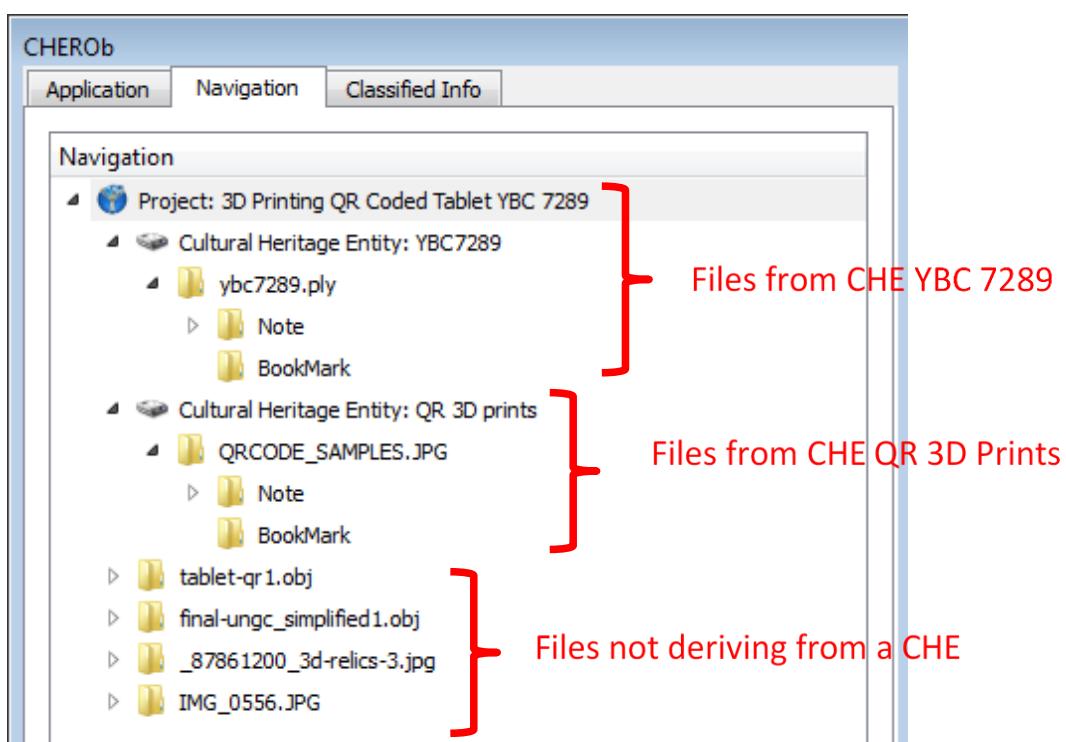


Figure 76. Navigation Tab

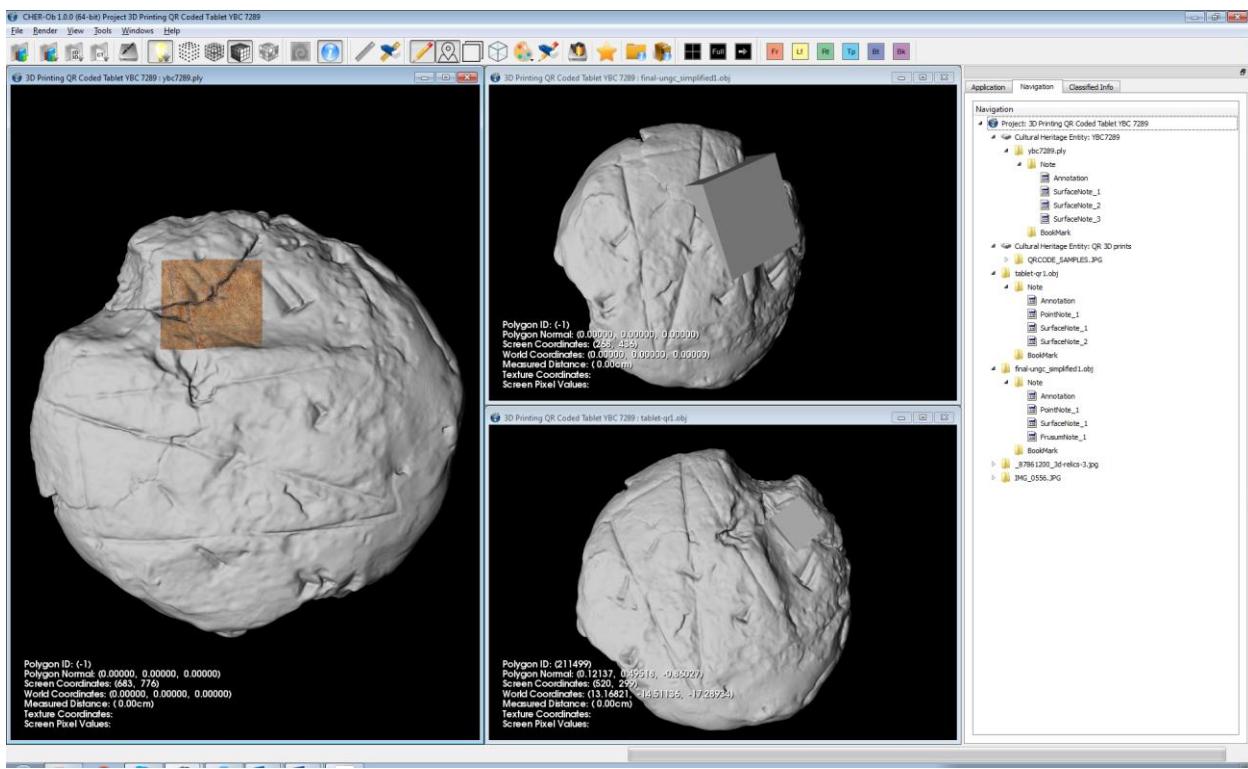


Figure 77. In parallel examination of the two QR Coded tablets

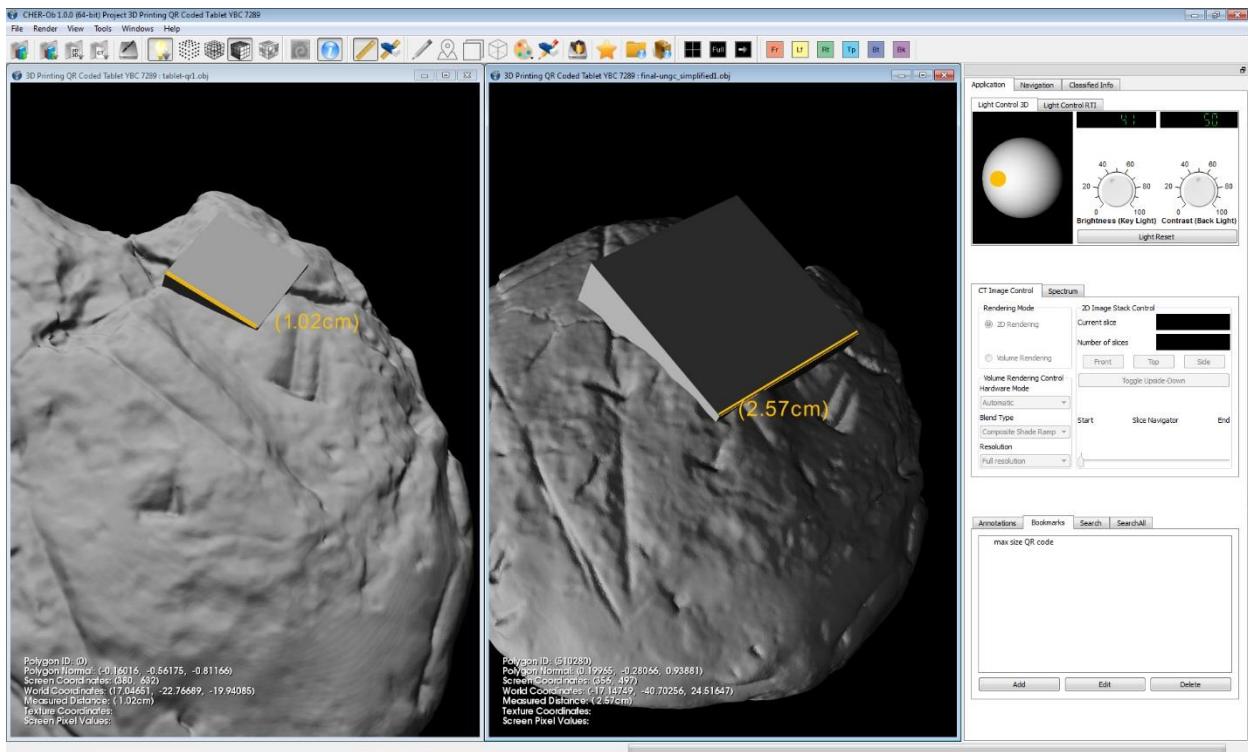


Figure 78. Measurements on the 3D models.

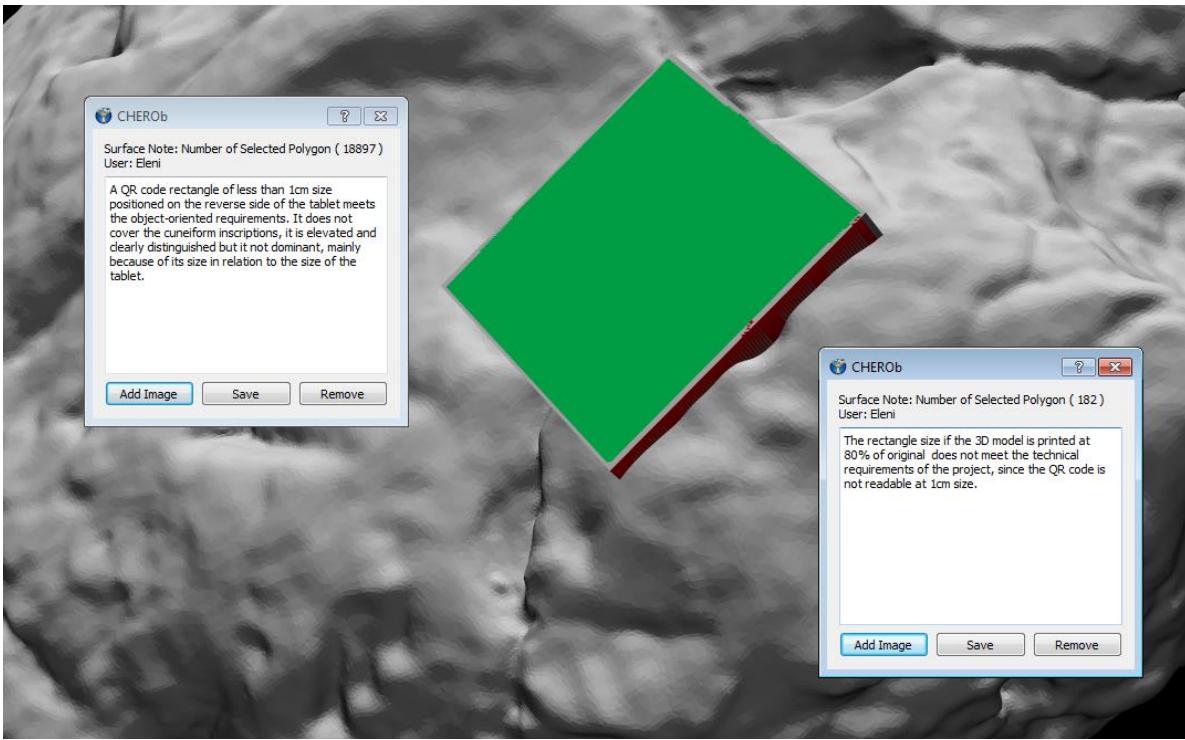


Figure 79. Adding annotations.

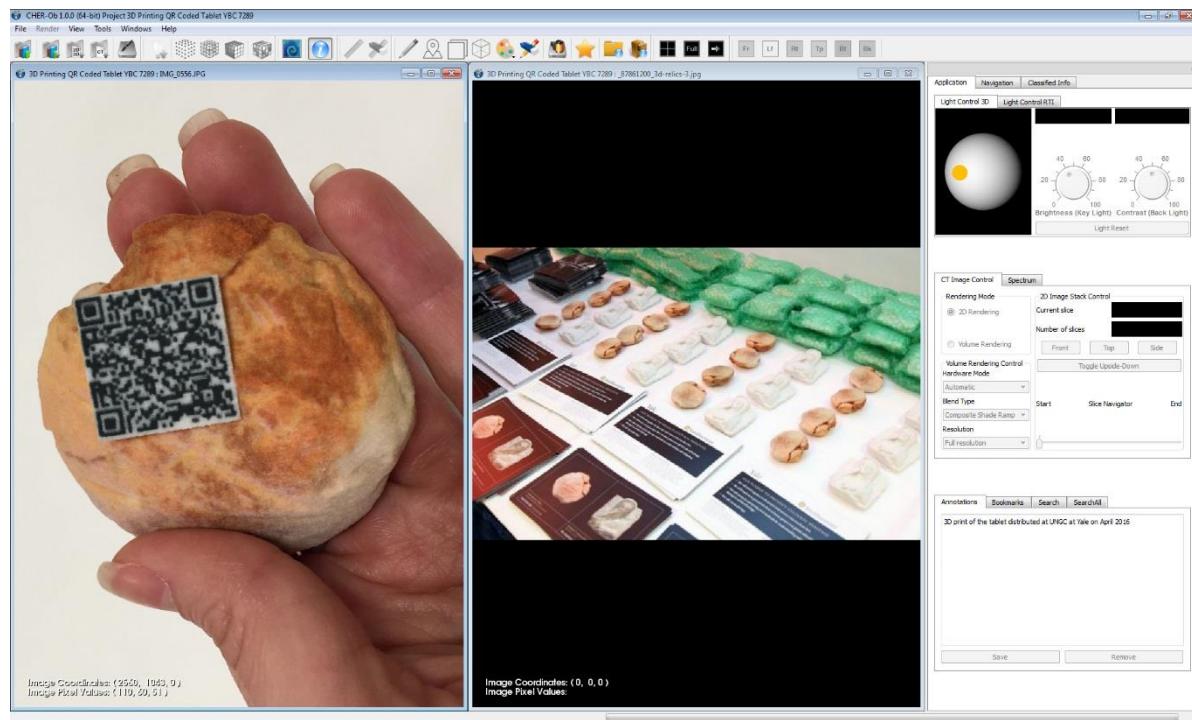


Figure 80. 2D images of the 3D printed tablets from the UNGC and the WEF.

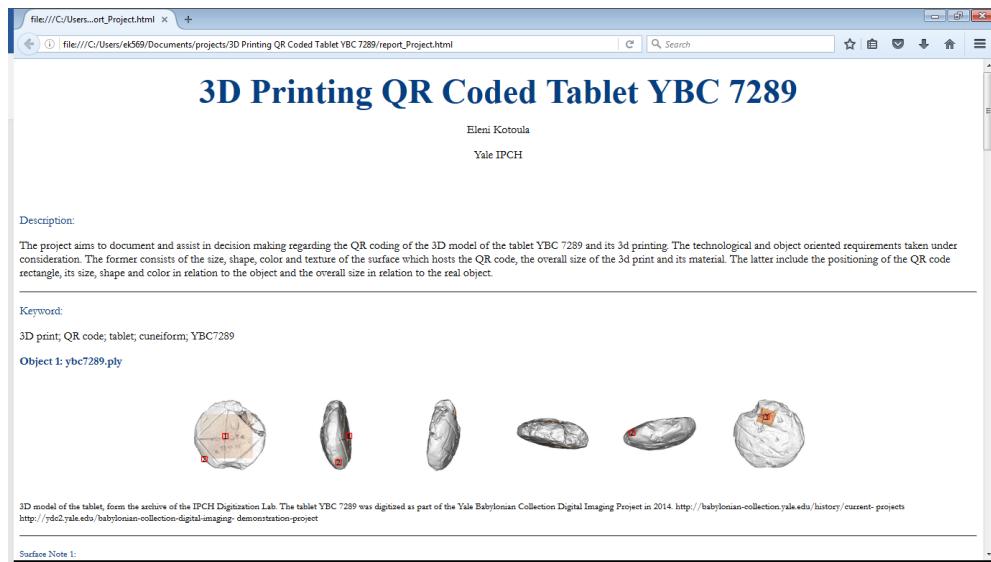


Figure 81. Screenshot of the exported report in .html format.

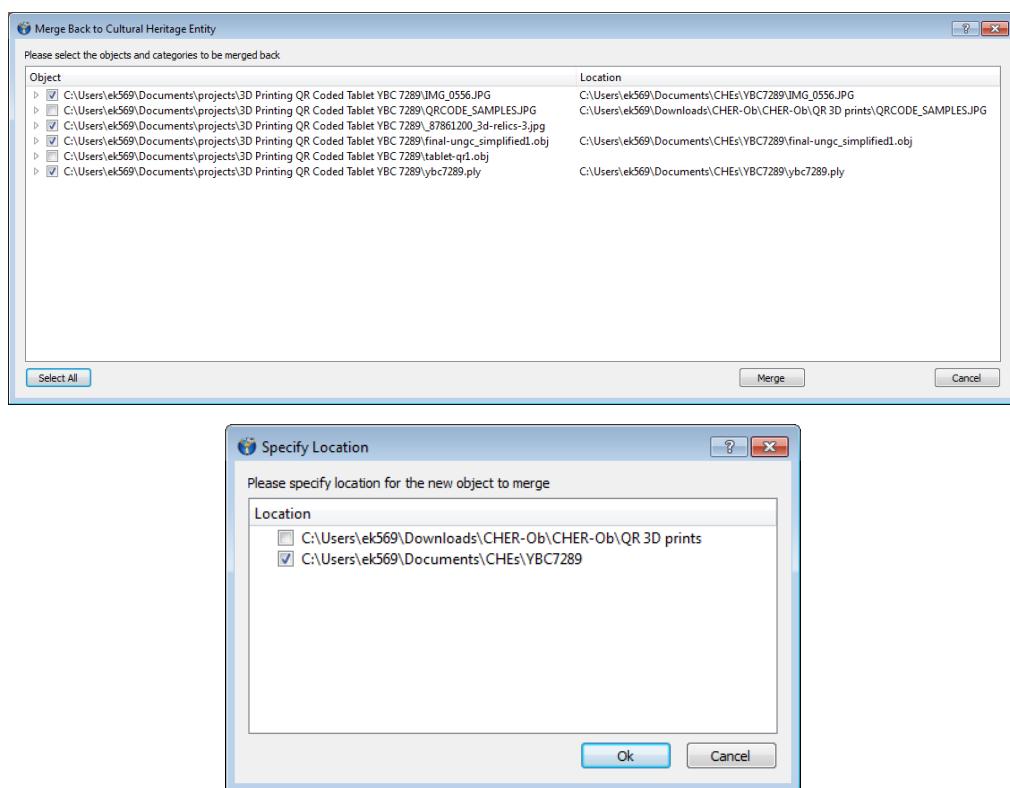


Figure 82. Merge object back to CHE dialog box and “Specify location” dialog box.

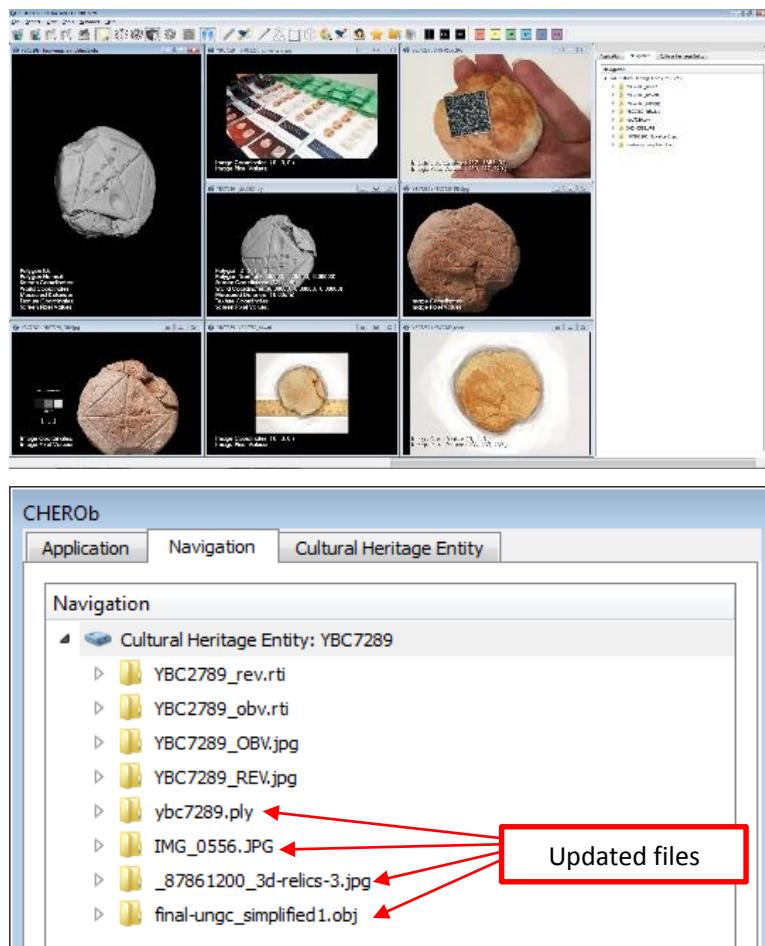


Figure 83. The Navigation Tab with highlighted updated files.

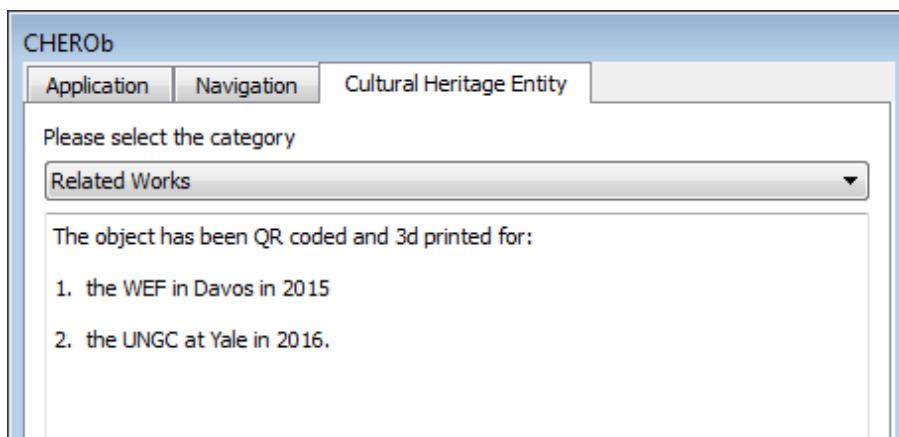


Figure 84. Updating textual information of CHE YBC7289, by adding the information about the 3D printed QR coded tablets under the “Related works” category.

5. Technical support

5.1. Troubleshooting

Q: What operating systems are required to open the software?

A: Currently CHER-Ob supports windows and Mac OS X.

Q: How can I compile CHER-Ob from the source code?

A: First, you can find the source code on github <https://github.com/WeiqiJust/CHER-Ob>. After download the source code, you need to install necessary libraries. We provide all post-compiled libraries except QT in the lib folder. Notice all the libraries provided are compiled using win32-msvc2008 with “Release x64”. The list of necessary libraries can be found in Readme.md in the lib folder. After the installation is done, for windows you can open the .sln file in windows folder using Visual Studio and rebuild the solution, for Mac OS, you can use .pro file under Mac folder to rebuild the project.

Q: During compilation, the system notice me that there are some files cannot be opened. How should I solve this problem?

A: Either the source files or the included files from libraries are not loaded correctly will lead to this problem. For the source files, they have already been loaded into the project .sln file. Please do not move and files in src/icons/images folders. For the included files, please make sure the paths and environment settings are correct. More details can be find in Readme (<https://github.com/WeiqiJust/CHER-Ob>).

Q: After compilation, the system notice me that there are some .lib or .dll files are missing, what should I do?

A: The problem is caused by library link and configuration error. You need to provide correct paths to the library .lib or .dll files so that your compiler can find these files. More details please refer to <https://github.com/WeiqiJust/CHER-Ob>.

Q: What kinds of data format are supported in CHER-Ob?

A: CHER-Ob provides support for various data formats, including 2D images (.png, .tif, .tiff, .bmp, .jpg, .jpeg, .exr), 3D models (.obj, .ply, .wrl), RTI (.ptm, .rti,) and CT data.

Q: I created a project and in the project folder, I found some .txt and .xml files. Can I modify or move them?

A: Please do not move or make changes to any files created by CHER-Ob outside the software. These modifications will lead to the errors of locating and opening these file in the software.

Q: I can't open my medical imaging data!

A: As noted above, CHER-Ob is only able to display medical images that are compliant with the DICOM standard. We apologize for the inconvenience.

Q: Why is only part of my .obj or .wrl file showing up?

A: CHER-Ob currently does not support the display of objects with multiple textures or multiple objects in the same .obj or .wrl file. This is a feature that we would like to add in future releases.

Q: My OpenEXR image is in grayscale or looks washed out!

A: As noted above, CHER-Ob can only display images with YCBCR encoding in grayscale. We apologize for the inconvenience and may add this feature in future releases.

Q: CHER-Ob crashed!

A: CHER-Ob may crash when your computer has insufficient memory to handle all of the files open in the software at once. Please make sure that you are not using too much memory by monitoring the Performance tab in the Windows Task Monitor.

If the crash is not caused by a memory issue, please see the following about seeking technical assistance.

5.2. Problems and Questions

Source code can be find in both GitHub (<https://github.com/WeiqiJust/CHER-Ob>). Bug reports can be posted on our GitHub Issue page or contact us (cher_ob@cs.yale.edu). If possible, please

include the file(s) that may help us reproduce the error and a description of your actions leading up to the problem.

If you need technical support or you have questions or suggestions regarding the software or its manual, please make a post in our GitHub Issue page. Please use this as your primary resource for assistance, as the questions and answers posted there may help other users with similar issues.

As a last resort, you may email cher_ob@cs.yale.edu for any problems and further cooperation. Please include the term “CHER-Ob” in the subject line of your email or it may not be answered. We ask you to ensure that an answer to your issue is not already available in these pages or on the forums before sending your message.

Acknowledgements

We are grateful for the guidance and encouragement of this project's principal investigators investigator, Professor Holly Rushmeier and Dr. Stefan Simon. We would like to thank the Seaver Institute for their generous support for the software's development. We would also like to Cultural Heritage Imaging (CHI) for providing the source code for the RTI Viewer. We are grateful to the Yale Babylonian Collection and IPCH Digitization Lab for providing access to data used as a case study in this guide.

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