

An Introductory Video Generator for Disseminating Cultural Heritage Projects

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Abstract

There are many different activities in cultural heritage research, such as digitization, data visualization, information analysis, and dissemination. Much effort has been made to develop better technologies for data capture and processing in cultural heritage. However, digital images and models will become less meaningful if there is not an efficient way to incorporate their cultural context. In this paper, with a focus on how to disseminate the results of cultural heritage research, we propose an introductory video generator based on the open source software CHER-Ob for shared analysis. Given a cultural heritage project, a researcher can simply generate an introductory video for others to easily understand it by selecting preferences and annotations. A series of animated shots of 2D and 3D objects will appear in a user-specified order in the video subtitled by annotations, illustrations, and maps. This idea is useful for integrating cultural and digital resources as well as providing a convenient way for researchers to disseminate cultural heritage findings to the public.

CCS Concepts

• **Computing methodologies** → **Graphics systems and interfaces**;

1. Introduction

The study of cultural heritage involves various fields including digitization, data processing, visualization, information collation, and publicity. In addition to data acquisition that many computer graphics and computer vision techniques can handle, a successful project in cultural heritage research requires effective interaction and communication of information among experts from different backgrounds. A notable piece of work is CHER-Ob [SKA*16], which is an open source platform for shared analysis in cultural heritage. With powerful features such as the cultural heritage entity, an efficient annotation system, and automatic report generation, the software attempts to overcome the limitations of current tools on large-scale data management, annotation and analysis methods, and documentation and sharing in cultural heritage research. Built using the Qt and VTK libraries, CHER-Ob provides a holistic approach to visualization and annotation of a number of data formats including 2D images, reflectance transformation imaging (RTI) data, 3D mesh models, computed tomography (CT) data, and hyperspectral images. Multiple users can select a region and make different types of annotation on cultural heritage objects in point, surface, polygon, or frustum note mode. CHER-Ob also makes it easier to share results of cultural heritage research by collecting all the data and notes in a project and generating a PDF report that summarizes relevant information. This is one of the valuable efforts to bring cultural context back to digitized data.

Although the automatically generated report is a quick way to share the summary of cultural heritage projects, it gathers all the information but not users' preferences on how the information should be presented. Moreover, people from different backgrounds may find it less intuitive to locate what they want in a PDF report. Static texts and figures also lack viewer engagement and offer little experience of storytelling. To overcome these limitations, we propose an introductory video generator that is compatible with all the existing functions in CHER-Ob. We provide users the possibility of specifying a set of preferences when generating an introductory video. This format of deliverables in cultural heritage research enables idea propagation among experts and to a broader audience. Our main contributions include:

- **Integrated Video Generator.** We build an integrated generator in CHER-Ob to produce introductory videos for cultural heritage projects. Several resolutions and video codec options are provided. Notes and associated figures in the original annotation system can be easily imported to the final video.
- **Intuitive Animation Scheme.** Users are able to choose objects to show in the introductory video and specify the order and duration of 2D and 3D frames. According to theories of visual attention, an intuitive animation scheme is designed including bilateral filtering and smooth camera transition.
- **Geographical Information.** A Google maps tab is added so that researchers can attach geographical information to cultural her-

itage objects. This feature compensates for the lack of maps in CHER-Ob and makes it possible to interact with geographical information systems (GIS) in cultural heritage such as Arches [MDAW12].

The goal of this work is not to describe novel video techniques, but to illustrate the novel idea of easily generating a video from data examined by an expert.

2. Related Work

There are many areas related to our work in cultural heritage, to name a few, software systems for information organization, psychological basis of interaction and dissemination, and storytelling methods from various types of data.

Systems for Information Integration. Different technologies are used to capture different types of data such as 2D images, 3D models, RTI data, and CT data. Therefore, many current systems are specialized in visualization and processing and can only support a limited number of data formats in general. For example, many people use MeshLab [CCR08] for visualization of 3D mesh models and geometric operations, but it does not support 2D data or annotations. Similarly, there are data processing tools particularly for 2D images such as GIMP [KM98]. The RTI viewer [PCC*10] provides a view of cultural heritage objects under different lighting conditions, with a very basic annotation interface integrated with bookmarks. Hyper3D [KRF*14] is a prototype system designed to support visualization of miscellaneous data formats, but it lacks the functionality of information collection, analysis, and dissemination. To bring cultural context back to digitized data, web-based systems such as IIIF [III11] and 3DSA [YH14] make it possible for researchers to attach annotations to cultural heritage objects. However, they only work for 2D and 3D objects separately and the annotations are not exportable or interactive, causing difficulties in analyzing and sharing. Many researchers propose to classify and cluster information related to certain topics with efficient tools [GBBS11, HCS12, BvdWWdR14], but such information is hard to be aligned with visualized data. To the best of our knowledge, CHER-Ob [SKA*16] is one of the most powerful tools so far to visualize different formats of data and put them together with corresponding hypertext annotations. We use CHER-Ob projects as our input to the introductory video generator and produce storytelling clips that are easy to disseminate.

Psychological Findings. Although the original version of CHER-Ob is able to automatically generate sharable PDF reports based on all the associated annotations, the report is just a list of texts and static screenshots. It also contains every single bit of information even if some readers are not interested in some content, making it less user friendly. Nowadays, more and more human-computer interaction (HCI) experts argue that video works better than text-based mediums in education [Sch02], entertainment [KPK*01], and advertising [App06]. According to physiological and social studies, researchers claim that video comprises other mediums, presents quick and rich content, engages audiences, prompts shares, incites action, enhances social communication, enables convenient and accessible production, and reaches the widest market [Cla16, KH10]. One inspiring piece of research investigates

user experience on a website for art and culture [VKK*01], which shows a strong interest among museum visitors in streaming multimedia rather than active interaction, namely “less clicking, more watching”. These psychological findings encourage us to develop an introductory video generator for better dissemination of cultural heritage projects.

Storytelling from Data. As digital technologies are more accessible and broadly applied in cultural heritage research, it becomes an important issue to enrich the digitized data with cultural context, such as historical notes, physical descriptions, stylistic analysis, and conservation information. A step further is to make the digitized data with cultural context known to the public, so that more researchers can contribute public value to society and people can conveniently learn from state-of-the-art research. Among many efforts is storytelling from cultural heritage data [MDC02]. For example, there is a storytelling-based application for an anthropomorphic guide to a historical site presented through a mobile device [LD12], where the basic structure of storytelling is merged with the requirements coming from the communication of the specific knowledge about the historical site. To provide exciting opportunities for individual users to take virtual journeys, interactive storytelling techniques are embedded within still and video panoramas captured by a spherical camera for cultural heritage sites such as Charles Church in Plymouth and the town of Launceston, UK [KW09]. Similarly, the Digital Longmen Project uses cultural heritage data to build a virtual reality (VR) system in order to offer an immersive experience [WJS*17], where it also optionally adopts a motion capture system to give users more degrees of freedom in storytelling. In addition, there are research efforts to intuitively control the camera and automatically generate camera trajectories, which allows inspection of a virtual object by navigating over its surrounding space [MCS16]. Other creative ideas include serious games, video games designed for educational objectives, that are considered as a new tool to learn cultural content in an engaging way, complementing the current mediums such as museums, exhibitions, and books [MCB*14]. The field of serious heritage games concerns itself with recent advances in computer graphics, VR/AR, and artificial intelligence, whose main strengths may generalize to the areas of communication, visual expression of information, collaboration mechanisms, interactivity, and entertainment [AML*10]. There are also attempts of storytelling for intangible heritage, including the ShadowStory system [LTJ*11] inspired by traditional Chinese shadow puppetry that promotes creativity, collaboration, and intimacy with traditional culture among children, as well as interleaves children’s digital and physical playing experience. To summarize, the research above is inspiring but their methodologies are not easy to generalize to other topics or projects. To overcome this, we design a comprehensive scheme for the video generator based on previous research.

3. Methodology

In this section, we elaborate on the methodology of our CHER-Ob integrated generator for introductory videos in three steps. First, the organization of cultural heritage data and associated information is examined in CHER-Ob, which helps the design of our video generator. Parameters that users can specify are also discussed. Second,

we propose an animation scheme inspired by psychological findings, which offers more friendly experience to viewers. The operations for six different types of notes in both 2D and 3D are clearly defined. Moreover, we explain how Google maps APIs [Goo10] are added in the Qt-based software, making it possible to interact with current GIS in cultural heritage research.

3.1. Video Generator

The original version of CHER-Ob organizes cultural heritage entities (CHE) in a project as the basic container of cultural heritage information. Each CHE has some digitized data, such as 2D images and 3D models. These data are linked to associated information including general annotation, a list of notes on different parts, illustrative pictures, etc. In our generated introductory videos, we expect to cover the basic content in a CHER-Ob project in an efficient way, starting with several dialogs.

In order to enable users to customize videos according to various needs, we first design a video setup dialog. The information of title, author, and affiliation is extracted from the project, but the user can also modify how they appear in the video. We provide three different video formats, i.e. .avi, .mp4, and .wmv. They are generated using corresponding codecs (DIV3, MP42, and WMV2 in four-character code) that OpenCV provides. By providing these options users are able to create videos that are portable and compatible with their own working environment. We also provide three different options for video resolution, i.e. 800×600 , 1600×900 , and 1600×1200 , covering common aspect ratios of 4:3 and 16:9. Lower resolution videos are quicker to generate and easier to spread via smartphones and tablets, while higher resolution ones are of better quality and more suitable for official publication. The last few parameters are the duration time for each 2D or 3D frame and the transition time between 2D or 3D frames. Keyframes remain static for a certain period of time as specified so that viewers can have the appropriate amount of time to appreciate each object. The transition time is relevant to the animation scheme and makes it more viewer friendly in terms of visual perception. Dolly in 3D observation describes how far the camera is from the object. Users are also able to choose if they want frames that show general annotation to appear in the introductory video.

After the video setup dialog, users select the objects to be presented in the generated video. A list of all objects in the CHER-Ob project is shown to users with a “Select All” button that can easily gather all of them. Then for each object, users are able to decide the notes to be presented in the generated video in a dialog with the name of current object at the top. The “Skip All” button skips remaining dialogs of notes and generate the video with default preferences. Note that in both object filter and note filters, entries in the tree widget are draggable. Therefore, it is convenient for users to select and reorder content in the introductory video.

The video writer in OpenCV takes images frame by frame in order to make a video. In addition to the title frame where the project name, authors, and affiliation are listed on a black background, object frames have a layout that the object appears in the middle, subtitles are shown in a darkened region at the bottom, and in the bottom right corner is either a geographical screenshot in a general

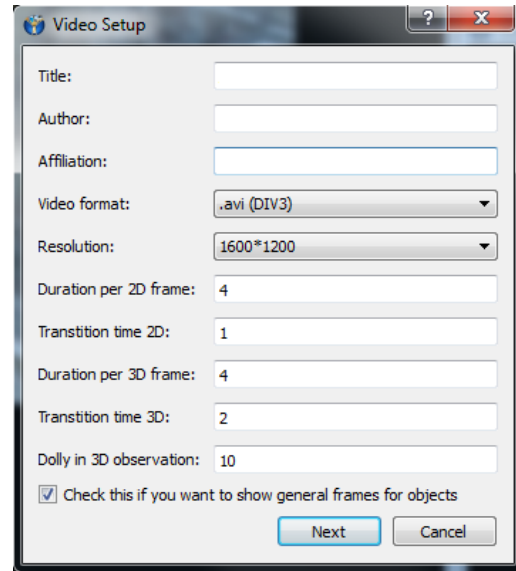


Figure 1: Video setup dialog. This is the first step to generate introductory videos, where many parameters can be specified according to different needs.

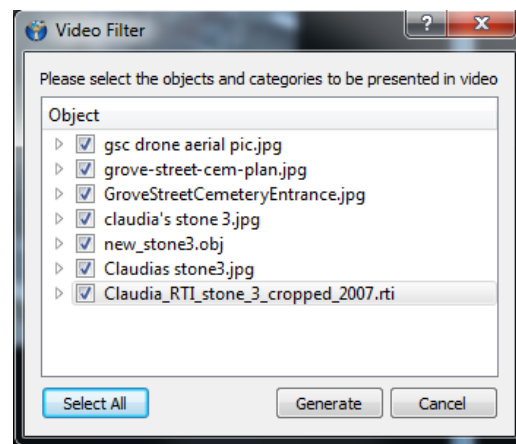


Figure 2: Video object filter. Entries are draggable in this dialog, so users can select and reorder objects in the video more conveniently.

frame or an associated image in a note frame. More examples are shown in the following sections.

3.2. Animation Scheme

First we discuss the animation scheme for 2D cultural heritage objects, such as images and RTI data. The general frame of a 2D image is the resized original image with the general annotation as subtitles. The intensity of the original image is reduced by 30% in the subtitle region. For RTI data, we change the light azimuth from 0 to 2π with a fixed elevation to produce frames with the general annotation, so viewers can appreciate different appearances of the object under changing lighting conditions. After the general frame is fin-

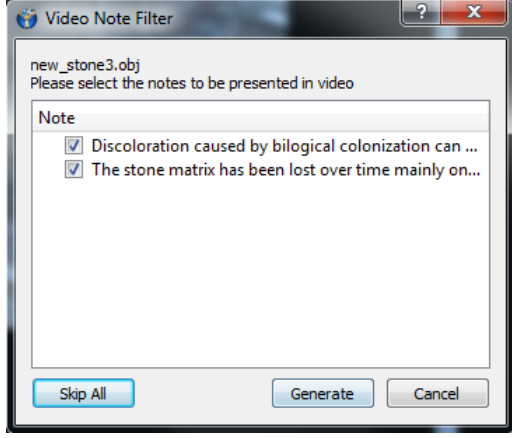


Figure 3: Object note filter. Entries are also draggable, so users can select and reorder notes of each object in the video more conveniently.

ished, 2D note frames are generated using the following animation scheme.

Since there are three different types of note on a 2D cultural heritage object in CHER-Ob, i.e. point note, surface note, and polygon note, viewers are induced to pay attention to a specific region on the image. The region of interest (ROI) to be presented in video is defined according to the type of note. We decide to use a circle of radius that equals to 1/20 of the image height for point notes, so that it gives a noticeable effect. An identical rectangle ROI is used for surfaces notes. We also use a circle to represent polygon notes, whose center is the center of all polygon vertices, and radius the longest distance from the center to one of polygon vertices. Inspired by attention models in psychology, such as attention enhances spatial resolution [YC98], we keep the note ROI and perform bilateral filtering on the background to produce a plausible experience.

$$\tilde{I}(x) = \frac{\sum_{x_i \in \Omega} I(x_i) \cdot f_r \|I(x_i) - I(x)\| \cdot g_s \|x_i - x\|}{\sum_{x_i \in \Omega} f_r \|I(x_i) - I(x)\| \cdot g_s \|x_i - x\|} \quad (1)$$

\tilde{I} is the filtered image. I is the original input image to be filtered. x are the coordinates of the current pixel to be filtered. Ω is the window centered in x . f_r is the range kernel for smoothing differences in intensities. g_s is the spatial kernel for smoothing differences in coordinates. Gaussian functions are used in our implementation. Bilateral filtering preserves edges and reduce noise to make a better smoothing result. Performing this on the background produces an illusion of lower resolution on the non-ROI region, the intensity of which is reduced by 30% as well to enhance contrast. Therefore, our 2D animation scheme is expected to draw people's attention to annotated regions. Smooth transition between 2D keyframes is implemented by image interpolation to make the video more perceptually friendly.

The animation scheme for 3D cultural heritage objects is another approach. 3D frames are generated by manipulating properties of the VTK camera, primarily the camera position P_c and focal point

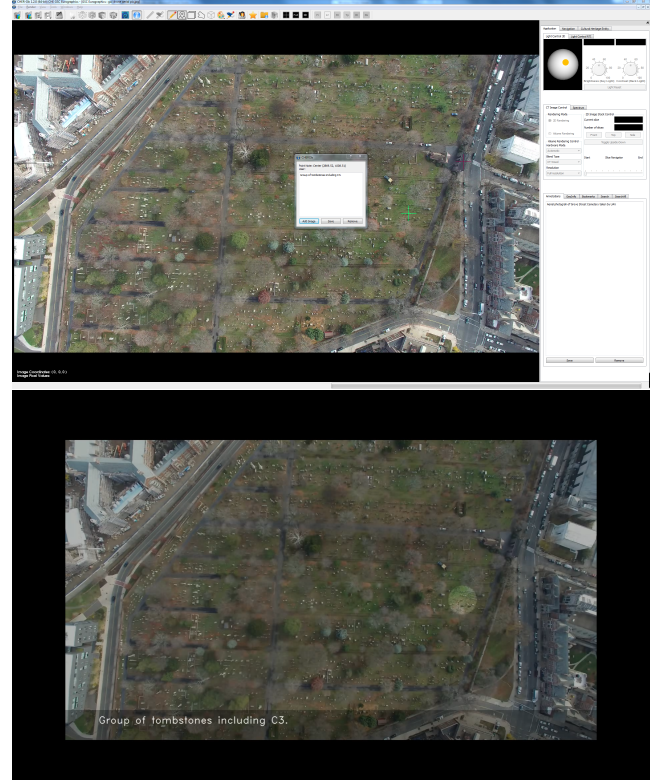


Figure 4: 2D animation scheme for point notes (top: CHER-Ob interface, bottom: video frame). A highlighted circle centered on the note's position is presented in video frames with subtitles at the bottom.

P_f . For the general frame, we rotate the 3D model by 360 degrees with the general annotation as subtitles to deliver a full view in the video. There are three different types of note for 3D mesh models, point note linked to a triangle, surface note linked to a bunch of triangles, and frustum note linked to all the triangles covered in a frustum. The intuition is that we prefer to inspect parts of a 3D object from right above, so we need to compute mesh normals. Given a triangle with the coordinates of three vertices P_1, P_2, P_3 known, the normal vector can be computed using the cross product.

$$\vec{n} = \overrightarrow{P_1P_2} \times \overrightarrow{P_1P_3} \quad (2)$$

For 3D point notes, we set the focal point to be the center of the selected triangle and set the camera position to be a point a distance from the focal point along the computed triangle normal. For 3D surface notes, we set the focal point to be the center of all selected triangles and set the camera position to be a point a distance from the focal point along the normal of the triangle on which the focal point is projected. For 3D frustum notes, we set the focal point to be the center of the selected frustum and set the camera position so that it rotates ϕ (0 to 2π) around the frustum for a full view. The distance from the focal point to decide the camera position is specified by the dolly parameter λ in video setup dialog.



Figure 5: 2D animation scheme for surface notes (top: CHER-Ob interface, bottom: video frame). A highlighted rectangle encircling the note area is presented in video frames with subtitles at the bottom.

Annotations and associated images are put in the subtitle region to explain details of the 3D cultural heritage object.

$$\text{Point: } P_c = \sum_{i=1,2,3} P_i / 3, \quad P_f = P_c + \lambda \vec{n} \quad (3)$$

$$\text{Surface: } P_c = \sum_{i \in S} P_i / |S|, \quad P_f = P_c + \lambda \vec{n}_j \quad (4)$$

$Proj_S(P_c)$ is in triangle j

$$\text{Frustum: } P_c = \sum_{i \in S} P_i / |S|, \quad P_f = P_c + \lambda \vec{v}_\phi \quad (5)$$

Smooth camera transition is implemented by spherical linear interpolation (Slerp) of camera positions and focal points between two consecutive 3D keyframes. Compared with linear interpolation (Lerp), Slerp is more capable of keeping track of the camera motion, so that users can better understand the relative positions of notes. For example, it is less likely for the camera to penetrate an object using Slerp. Denote the relative coordinates of two 3D points to the object's center of mass as p_0 and p_1 , the spherical linear interpolation is computed as follows given a parameter $t \in [0, 1]$, where $\cos \Omega = p_0 \cdot p_1$.

3.3. Geographical Tab

There is not a convenient way to add geographical information to cultural heritage projects in the original version of CHER-Ob. In



Figure 6: 2D animation scheme for polygon notes (top: CHER-Ob interface, bottom: video frame). A highlighted circle centered on the polygon's center of an adaptive radius is presented in video frames with subtitles at the bottom.

order to integrate this function and enable CHER-Ob to connect to popular GIS tools in cultural heritage research, we design a new tab for geographical information using Google maps APIs. Google maps APIs provide web-based interactive methods to display and mark a map in JavaScript. Since CHER-Ob is a open source platform implemented in C++ using Qt and VTK libraries, we design a Qt-supported QWebView window that is used to view and edit web documents. This makes it possible to display an online map in the software. Users can simply interact with the map just as people do in a browser, including dragging to change visible locations and scrolling to zoom in or out. We are also able to call JavaScript functions by calling C++ wrapper functions, which is very helpful for adding geographical information to cultural heritage objects.

When the annotation mode is on, users are able to make different types of note on an object, as well as mark its location on our map. Each object has a longitude and a latitude stored in the CHER-Ob .xml project file, which can be read and updated if necessary. For the simplicity of user interface, we design a "Mark Center" button that sets a marker in the center of the map to avoid the confusion that the user wants to drag but not to mark when clicking on the map. Every time the user updates the geographical marker for an object, the software saves a screenshot of the current map for the video generator and other purposes. Since there are usually many



Figure 7: 3D animation scheme for point notes (top: CHER-Ob interface, bottom: video frame). The camera looks towards the note's center from a distance along the triangle normal with subtitles at the bottom.

cultural heritage objects in a project, the marker of the current active object bounces for a better distinction. These APIs also offer four different styles, i.e. map, terrain, satellite, and satellite with labels. Researchers may want a certain style of map based on their interests such as urban planning and geomorphology.

4. Case Study

We demonstrate the video generator with a case study using data from Grove Street Cemetery. Grove Street Cemetery is known officially as the New Haven Burying Ground. It is located on the outskirts of the Yale University campus, in the city of New Haven. It was designated a National Historic Landmark in 2000.

The significance of Grove Street Cemetery is that it is among the first private, non-profit cemeteries in the world. Furthermore, it is also one of the earliest burial grounds to have a planned layout, with plots permanently owned by individual families, a structured arrangement of ornamental plantings, and paved and named streets and avenues. This has led historians to describing it as “a real turning point, a whole redefinition of how people viewed death and dying” [Hal08]. The conservation work on the other hand does not match the importance of the cemetery itself. To express the urgent need of a conservation project some pilot studies have been conducted and the results were shared with the stakeholders. Since

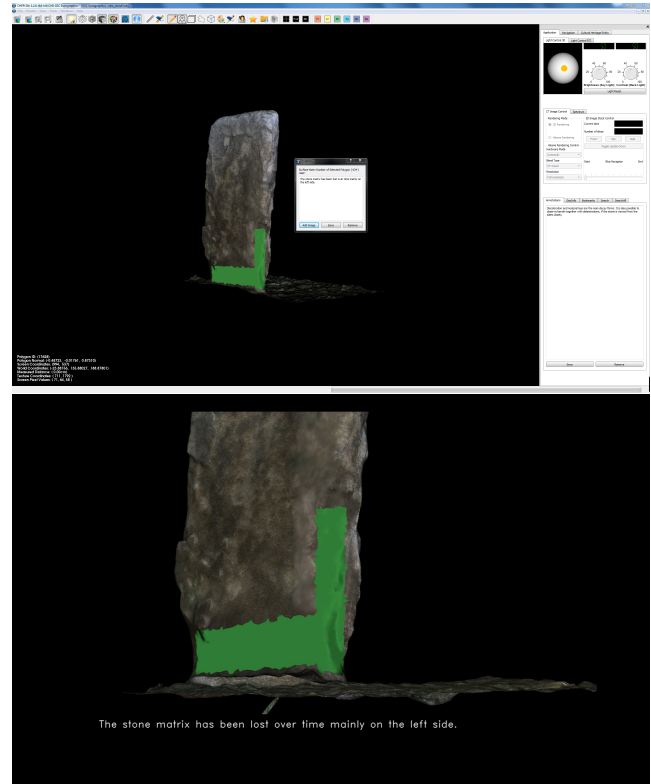


Figure 8: 3D animation scheme for surface notes (top: CHER-Ob interface, bottom: video frame). The camera looks towards the note's center from a distance along the normal of center triangle with subtitles at the bottom.

the stakeholders are not from the conservation related backgrounds it was necessary to present the expert views to non-expert stakeholders by using mainly visual tools. Thus, the visual weathering forms of stones were expressed in different images, 3D models of tombstones were generated and RTI were captured and processed for detailed surface views of the tombstones. A cultural heritage entity named Grove Street Cemetery was created in CHER-Ob and a tombstone was selected as a show case. The tombstone C3 Project was created with the available information in the Grove Street Cemetery CHE file. The Grove Street Cemetery in CHER-Ob included various 2D images and digitized plan drawings of the Cemetery, 3D model and RTI of the tombstone and archival information about the cemetery in general and selected tombstone in particular. Ultrasonic velocity (USV) measurements of the tombstone were also taken for the condition assessment of the tombstone as a part of the Tombstone C3 Project. The results were depicted and comments were added to the images with the help of annotation tools. The Grove Street Cemetery and the images were marked in the GeoInfo tab for future map reference to make finding the tombstone in the cemetery easier for project team members.

The newly introduced GeoInfo tab locates the cultural heritage object in question which is needed when the CHE is a heritage site, building, monument, group of buildings, and monuments. The

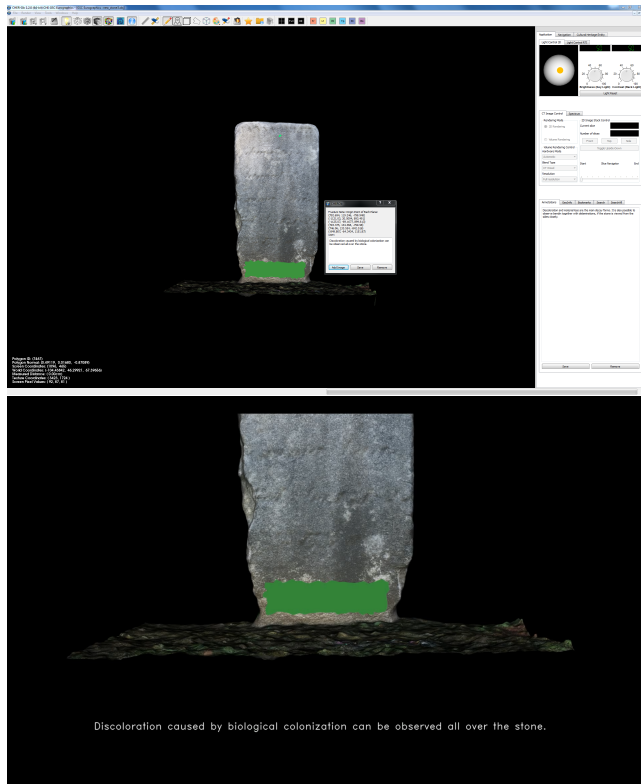


Figure 9: 3D animation scheme for frustum notes (top: CHER-Ob interface, bottom: video frame). The camera looks towards the note's center from a distance and rotates around the object with subtitles at the bottom.

GeoInfo function makes it possible to connect other GIS based software or tools which are popular in cultural heritage research. This information is also valuable when CHE and projects created by different users at different locations. Also it helps locate and orient images taken by different people. The plan drawing from the literature and aerial photographs of the cemetery from different time eras can be used to indicate the location of the tombstone. However, the orientations of the various drawings and photographs are different and it is difficult for third parties to comprehend the differences especially if they are not present at the time of capturing of the images or creating the CHE in CHER-Ob. In this case the GeoInfo tab is the source of objective reference for the orientation and location of the object. Geographical information is also shown in the video with a map screenshot at the bottom right corner. The sample CHE and generated video can be found in the supplementary material.

5. Evaluation

In cultural heritage studies, management of different kinds of data is one of the main issues. The open source software CHER-Ob provides a shared platform for different types of data in the form of 3D, 2D, RTI, and CT images together with the textual information. It also provides powerful tools for digital data analysis and result publication such as color coded annotation system which enable

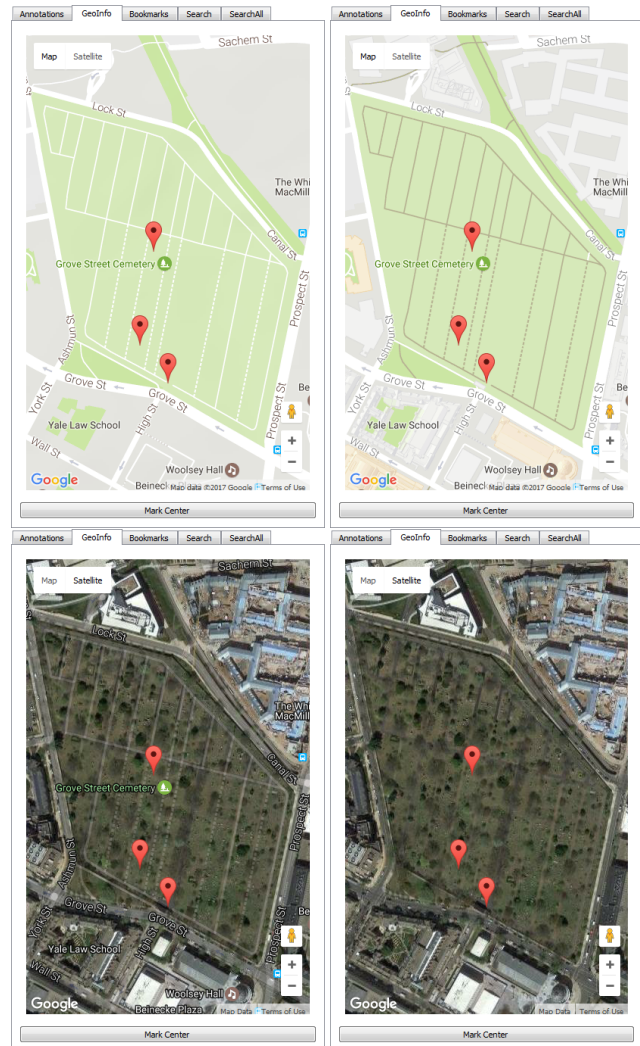


Figure 10: Four types of map in the geographical tab with markers for the location of cultural heritage objects. Top left: basic map. Top right: terrain map. Bottom left: satellite map with labels. Bottom right: satellite map without labels.

users to locate the area where they want to annotate and differentiate annotations in different categories. Data collected and modified during the study organized and presented in CHER-Ob for the decision making and for the future studies mainly monitoring of the marbles of Grove Street Cemetery.

The video generated by CHER-Ob for the stone condition assessment project was used for the presentation of the project to the non-experts who have no interest in reading the expert reports but have an indispensable role as decision makers in the conservation program of Grove Street Cemetery. CHER-Ob was also proposed as a monitoring tool for the Grove Street Cemetery conservation project. Since we need a regular revisiting and re-assessment of the stone damage, it helps researchers assess stone damage based on the determination of the condition of stones in Grove Street Ceme-

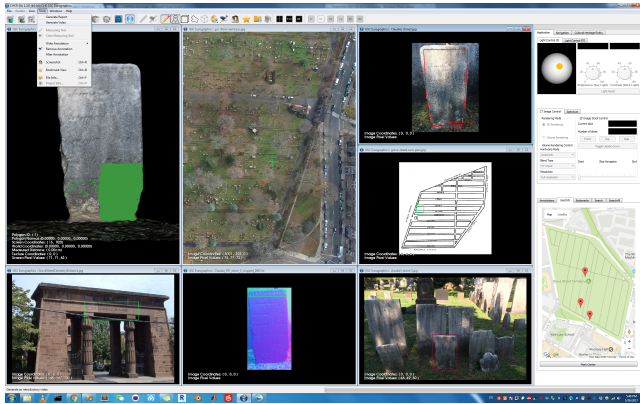


Figure 11: Screenshot of the full case study also showing the video generation tool.



Figure 12: Screenshot of CHE in CHER-Ob with 3D model, 2D image, and RTI of the tombstone.

tery. The software can play an important role in the planning of the conservation studies, research, and interventions in the cemetery. The use of video generation is a formidable way to deliver periodic reports with the prioritized comments and highlighted information to the experts and non-experts. The geographical information tab is now available and makes it possible to use images captured by different scales and orientations which is very useful especially when the images are gathered from the archives and/or literature.

6. Conclusion

In this paper, we present an introductory video generator integrated in the open source software CHER-Ob, which enables researchers to disseminate cultural heritage projects in a more convenient manner. Our design takes data of various formats and their associated annotations in cultural heritage research as input and generates introductory videos according to different needs. Users can specify a bunch of video parameters and make it more viewer friendly by adopting the psychology-inspired animation scheme for both 2D and 3D objects. Through the case study of Grove Street Cemetery, we find that the original version of CHER-Ob works better with

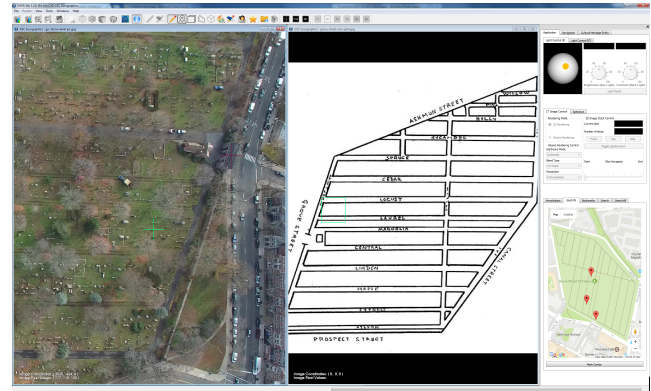


Figure 13: Screenshot from CHER-Ob showing the plan and aerial photograph of Grove Street Cemetery and active GeoInfo tab for reference.

proposed functions of introductory video generation and geographical information. This tool is helpful as a more convenient method for cultural heritage researchers to disseminate their ideas and findings to the public. Our future work includes bridging a gap between this system and existing GIS, and conducting a broader user study on how museum visitors like the automatically generated introductory videos. It will also be interesting to explore how to produce a concise resume over complex projects based on this approach.

References

- [AML*10] ANDERSON E. F., MCLOUGHLIN L., LIAROKAPIS F., PETERS C., PETRIDIS P., DE FREITAS S.: Developing serious games for cultural heritage: a state-of-the-art review. *Virtual Reality* 14, 4 (Dec 2010), 255–275. URL: <https://doi.org/10.1007/s10055-010-0177-3>. 2
- [App06] APPIAH O.: Rich media, poor media: The impact of audio/video vs. text/picture testimonial ads on browsers' evaluations of commercial web sites and online products. *Journal of Current Issues & Research in Advertising* 28, 1 (2006), 73–86. URL: <http://dx.doi.org/10.1080/10641734.2006.10505192>. 2
- [BvdWWdR14] BRON M., VAN DER WERF T., WANG S., DE RIJKE M.: A social bookmarking system to support cluster driven archival arrangement. In *Proceedings of the 5th Information Interaction in Context Symposium* (New York, NY, USA, 2014), IiX '14, ACM, pp. 295–298. URL: <http://doi.acm.org/10.1145/2637002.2637046>. 2
- [CCR08] CIGNONI P., CORSINI M., RANZUGLIA G.: Meshlab: an open-source 3D mesh processing system. *Ercim news* 73: 45–46, 2008. 2
- [Cla16] CLARINE B.: 11 reasons why video is better than any other medium, 2016. URL: <http://www.advancedwebmarketing.com/blog/11-reasons-why-video-is-better>. 2
- [GBBS11] GRIESER K., BALDWIN T., BOHNERT F., SONENBERG L.: Using ontological and document similarity to estimate museum exhibit relatedness. *Journal on Computing and Cultural Heritage (JOCCH)* 3, 3 (Feb. 2011), 10:1–10:20. URL: <http://doi.acm.org/10.1145/1921614.1921617>. 2
- [Goo10] GOOGLE: Google maps APIs | Google developers, 2010. URL: <http://developers.google.com/maps>. 3
- [Hal08] HALL P. D.: Symbolism, tradition, ritual, and the deep structure of communities. In *Handbook of Community Movements and Local Organizations*. Springer, 2008, pp. 34–59. 6

- [HCS12] HALL M., CLOUGH P., STEVENSON M.: *Evaluating the Use of Clustering for Automatically Organising Digital Library Collections*. Springer Berlin Heidelberg, Berlin, Heidelberg, 2012, pp. 323–334. URL: https://doi.org/10.1007/978-3-642-33290-6_35. 2
- [III11] IIIF COMMUNITY: International image interoperability framework, 2011. URL: <http://iiif.io>. 2
- [KH10] KAPLAN A. M., HAENLEIN M.: Users of the world, unite! the challenges and opportunities of social media. *Business horizons* 53, 1 (2010), 59–68. 2
- [KM98] KIMBALL S., MATTIS P.: GIMP, the GNU image manipulation program, 1998. URL: <http://www.gimp.org>. 2
- [KPK*01] KARAT C.-M., PINHANEZ C., KARAT J., ARORA R., VERGO J.: Less clicking, more watching: Results of the iterative design and evaluation of entertaining web experiences. In *Proceedings of IFIP TC. 13 International Conference on Human-Computer Interaction*. IOS Press, Amsterdam (2001), pp. 455–463. 2
- [KRF*14] KIM M. H., RUSHMEIER H., FRENCH J., PASSERI I., TIDMARSH D.: Hyper3D: 3D graphics software for examining cultural artifacts. *Journal on Computing and Cultural Heritage (JOCCH)* 7, 3 (Feb. 2014), 14:1–14:19. URL: <http://doi.acm.org/10.1145/2567652>. 2
- [KW09] KWIATEK K., WOOLNER M.: Embedding interactive storytelling within still and video panoramas for cultural heritage sites. In *15th International Conference on Virtual Systems and Multimedia* (2009), IEEE, pp. 197–202. 2
- [LD12] LOMBARDO V., DAMIANO R.: Storytelling on mobile devices for cultural heritage. *New Review of Hypermedia and Multimedia* 18, 1-2 (2012), 11–35. URL: <http://dx.doi.org/10.1080/13614568.2012.617846>. 2
- [LTJ*11] LU F., TIAN F., JIANG Y., CAO X., LUO W., LI G., ZHANG X., DAI G., WANG H.: Shadowstory: Creative and collaborative digital storytelling inspired by cultural heritage. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New York, NY, USA, 2011), CHI '11, ACM, pp. 1919–1928. URL: <http://doi.acm.org/10.1145/1978942.1979221>. 2
- [MCB*14] MORTARA M., CATALANO C. E., BELLOTTI F., FIUCCI G., HOURLY-PANCHETTI M., PETRIDIS P.: Learning cultural heritage by serious games. *Journal of Cultural Heritage* 15, 3 (2014), 318–325. 2
- [MCS16] MALOMO L., CIGNONI P., SCOPIGNO R.: Generalized trackball for surfing over surfaces. In *Proceedings of the Conference on Smart Tools and Applications in Computer Graphics* (2016), The Eurographics Association. URL: <https://doi.org/10.2312/stag.20161368>. 2
- [MDAW12] MYERS D., DALGITY A., AVRAMIDES I., WUTHRICH D.: *Arches: An Open Source GIS for the Inventory and Management of Immobile Cultural Heritage*. Springer Berlin Heidelberg, Berlin, Heidelberg, 2012, pp. 817–824. URL: https://doi.org/10.1007/978-3-642-34234-9_87. 2
- [MDC02] MCKERCHER B., DU CROS H.: *Cultural tourism: The partnership between tourism and cultural heritage management*. Routledge, 2002. 2
- [PCC*10] PALMA G., CORSINI M., CIGNONI P., SCOPIGNO R., MUDGE M.: Dynamic shading enhancement for reflectance transformation imaging. *Journal on Computing and Cultural Heritage (JOCCH)* 3, 2 (Oct. 2010), 6:1–6:20. URL: <http://doi.acm.org/10.1145/1841317.1841321>. 2
- [Sch02] SCHNOTZ W.: Commentary: Towards an integrated view of learning from text and visual displays. *Educational Psychology Review* 14, 1 (Mar 2002), 101–120. URL: <https://doi.org/10.1023/A:1013136727916>. 2
- [SKA*16] SHI W., KOTOULA E., AKOGLU K., YANG Y., RUSHMEIER H.: CHER-Ob: A tool for shared analysis in cultural heritage. In *Eurographics Workshop on Graphics and Cultural Heritage* (2016), The Eurographics Association. URL: <http://dx.doi.org/10.2312/gch.20161404>. 1, 2
- [VKK*01] VERGO J., KARAT C.-M., KARAT J., PINHANEZ C., ARORA R., COFINO T., RIECKEN D., PODLASECK M.: Less clicking, more watching: Results from the user-centered design of a multi-institutional web site for art and culture. *Museum and the Web* (2001), 23–32. 2
- [WJS*17] WANG Z., JIN X., SHAO D., LI R., ZHA H., IKEUCHI K.: *Digital Longmen Project: A Free Walking VR System with Image-Based Restoration*. Springer International Publishing, Cham, 2017, pp. 191–206. URL: https://doi.org/10.1007/978-3-319-54427-4_15. 2
- [YC98] YESHURUN Y., CARRASCO M.: Attention improves or impairs visual performance by enhancing spatial resolution. *Nature* 396, 6706 (1998), 72–75. 4
- [YH14] YU D., HUNTER J.: X3D fragment identifiers – extending the open annotation model to support semantic annotation of 3D cultural heritage objects over the web. *International Journal of Heritage in the Digital Era* 3, 3 (2014), 579–596. URL: <http://dx.doi.org/10.1260/2047-4970.3.3.579>. 2