digital cultural heritage: FUTURE VISIONS

Edited by Kelly Greenop and Chris Landorf

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CHER-Ob for Cultural Heritage Research:
Unsleben Jewish Cemetery Case Study

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The symposium Convenors received a total of 33 abstracts. All abstracts underwent a double-blind peer review by two members of the Symposium Organising Committee. Authors of accepted abstracts (24) were invited to submit a full paper following presentation of their draft papers at the symposium. All submitted full papers (8) were again double-blind peer reviewed by two anonymous reviewers and given the opportunity to address reviewer comments. Papers were matched as closely as possible to referees in a related field and with similar interests to the authors. Revised papers underwent a final post-symposium review by the editors before notification of acceptance for publication in the symposium proceedings.

Please note that the paper displayed as an abstract only in the proceedings is currently being developed for an edited book on digital cultural heritage.

Innovative new data collection and digital visualisation techniques can capture and share historic artefacts, places and practices faster, in greater detail and amongst a wider community than ever before. Creative virtual environments that provide interactive interpretations of place, archives enriched with digital film and audio recordings, histories augmented by crowd-sourced data all have the potential to engage new audiences, engender alternative meanings and enhance current management practices. At a less tangible level, new technologies can also contribute to debates about societal relationships with the historical past, contemporary present and possible futures, as well as drive questions about authenticity, integrity, authorship and the democratisation of heritage.

Yet for many, gaps still exist between these evolving technologies and their application in everyday heritage practice. Following the success of a sister conference in Brisbane, Australia in April 2017, this symposium focused on the emerging disciplines of digital cultural heritage and the established practice of heritage management. The symposium aimed to provide a platform for debate between those developing and applying innovative digital technology, and those seeking to integrated best practice into the preservation, presentation and sustainable management of cultural heritage.

The symposium was designed to encourage critical debate across a wide range of heritage-related disciplines. We welcomed papers from practitioners and academics working in cultural heritage and related fields such as architecture, anthropology, archaeology, geography, media studies, museum studies and tourism. We particularly encouraged papers that explored the challenges of digitising tangible and intangible cultural heritage, those that identified issues with digitisation and digital interaction, and those that addressed the theoretical challenges posed by digital cultural heritage.

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digital cultural heritage: FUTURE VISIONS London Symposium

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CHER-Ob for Cultural Heritage Research: Unsleben Jewish Cemetery Case Study

Abstract

The use of digital techniques for data capture, analysis, interpretation and dissemination is becoming a standard for cultural heritage research, including archaeological, historical, architectural and conservation studies. Nevertheless, specific software that meets the needs of cultural heritage professionals is still at an early stage of development. As a result, highly specialized or generic image processing, viewing and analysis software is being used in combination with databases and data management systems, adding another level of complexity to interdisciplinary cultural heritage studies. This paper introduces CHER-Ob (Cultural HERitage-Object), a new open-source integrated platform for cultural heritage research developed to meet documentation, data management and analysis, collaboration and sharing needs. The conceptual design of CHER-Ob, its compatibility with commonly used imaging data types (2D and 3D images, Reflectance Transformation Images (RTI), Computed Tomography (CT)) and textual information, and its features and functionality, such as the multilevel annotation framework, the automatic report and video generation, the metadata schema, the bookmark, screenshot, searching, sorting and filtering options are discussed. As a case study, a dataset from the historic Unsleben Jewish Cemetery in Bavaria, Germany, derived from the 'Unfolding Communities' project was analysed and different approaches for interacting with diverse datasets at a collaborative research environment are presented. Considering the different stakeholders, the complex and diverse dataset of historical/archival information and imaging data, the intangible aspects of the cemetery and its connections to the lost Jewish community, the Unsleben Jewish Cemetery case study is ideal to demonstrate the features of CHER-Ob.

Keywords: 3D digital modelling; Reflectance Transformation Imaging (RTI); Aerial imaging; Data integration; Multidisciplinary study; CHER-Ob

Introduction

Cultural heritage studies cover a broad area of research and their various aspects and dimensions can be explored only in a multidisciplinary research environment. The diverse nature of the data collected varies from 2D and 3D images to numerical instrumental analysis results, unstructured textual and oral information. Rapidly developing imaging and analytical technologies influence not only the quality and quantity of data captured, but also the way experts from different disciplines access and interact with the heritage record. Systems that provide holistic approaches to data interpretation, easy retrieval of information, tracking of the development of projects and sharing of their results are prerequisites for the success of any interdisciplinary cultural heritage project.

CHER-Ob (Cultural HERitage-Object), a new open-source platform, was developed to encourage cooperative research and enhance the interaction between cultural heritage professionals and digital technologies. It proposes a new methodology for managing 3D and 2D visualizations as well as textual and conservation science data, analysis and evaluation, documentation and sharing of information. The software and the source code, a detailed manual and a quick guide, an introductory video, and further educational materials as well as sample projects are available online (Yale University 2016; Shi 2017; Yale Graphics Group 2016; Kotoula, Akoglu and Wang 2017).

Previous work and current software limitations

Cultural heritage datasets consist of a variety of files in different formats, including imaging, numerical and textual data. In case of visual information, digitized drawings and photographs, provide evidence for the previous states of objects or sites. For example, the Yale's Dura-Europos photographic archive presents a vivid picture of life in a Roman city in the third century A.D. (http://media.artgallery.yale.edu/duraeuropos/). 2D images and 3D models document the existing remains, as in the case of the excavations at the Neolithic site of Çatalhöyük in Turkey (http://www.catalhoyuk.com). 3D virtual reconstructions emphasize the appearance, use and function of sites across time. 3D modelling techniques enable the visualization and verification of hypothetical scenarios, a characteristic example is the use of computer graphics for the visualization of Portus, which was the maritime port of Imperial Rome (http://www.portusproject.org). Although digital technology offers new possibilities for cultural heritage research, the limitations of the available software packages including (1) the lack of software compatible with all commonly used file formats, (2) the lack of enhanced methods of interaction with digital files, and (3) the existence of software for a small community of experts, have an impact on cultural heritage research and practice.

The current common practice aims to reach conclusions and provide answers to research questions by an independent exploration of each dataset, leading to observation and characterization of features, before the attempt to integrate the available evidence. During such explorations, the need to use multiple software packages is one of the limitations. For example, in case of Reflectance Transformation Imaging (RTI) technology, the currently available viewers (Malzbender, Gelb, and Wolters 2001; Palma et al. 2010; Hunt, Lundberg, and Zuckerman 2014) do not enable comparative simultaneous analysis of RTIs and other 2D or 3D visualizations, even though previous studies have proved the value of integrated imaging approaches for an in-depth analysis of objects and sites (Miles et al. 2014; Robinson et al. 2015; Jones et al. 2015).

Additionally, 3D software packages focus on image and geometry processing rather than the interpretation and analysis of 3D models in correlation to other available evidence in the form of 2D images or texts. Although online 3D tools, like 3D Heritage Online Presenter (3DHOP) (Potenziani et al. 2015), 3D Semantic Annotation Portal (3DSA) (Hunter and Yu 2011) and 3D ICONS (D'Andrea et al. 2012), provide a means of communication between the viewer and the 3D model via annotations, their contribution at a larger research perspective is limited, due to the absence of cooperative research tools and export functions. Similarly, powerful specialized software for Computed Tomography (CT) data (Graphics 2016) offers useful analytical tools for the exploration of volumetric models but provides an extremely narrow view of the object under examination, since features of great importance cannot be visualized, including the colour of the digitized object.

Software packages released for fragments matching (Arbace et al. 2012; Andreadis, Papaioannou, and Mavridis 2015) and simulation case studies (Papadopoulos 2010), are valuable for cultural heritage research but their high level of specialization limits their use to a small community of experts. Other options taken under consideration are the qualitative analysis software, which proved to be valuable research tools in particular in social sciences, characterized by advanced data organization and incorporating different data types (Friese 2014; Bazeley and Jackson 2013), but unfortunately not compatible with commonly used imaging formats such as RTIs and 3D models.

An open source platform for shared analysis in cultural heritage research

The main goal of CHER-Ob is to enhance the way that researchers access and interact with several types of complimentary information from various sources, such as scientific and imaging data. The software inherits components of management and documentation systems, annotation tools, viewers and digital imaging processing tools in a single platform, resulting in the enhanced interpretation of findings and informed decision-making. The main conceptual design of the software is based on two key parameters the Cultural Heritage Entity (CHE) and the Project. CHEs are collections of available information about tangible (object or sites) or intangible cultural heritage that represents the already existing knowledge. Projects are different types of studies focused on answering specific research questions about single or plural CHE(s) (Shi et al. 2016; Yale Computer Graphics 2016; Wang, Akoglu, and Rushmeier 2017).

When literature review, data collection and processing are completed, CHER-Ob users create one or more CHE(s), containing images and texts, which serve as the main sources of data to be studied in CHER-Ob project environment. During the development of a project, users explore the visualizations and their metadata, add bookmarks, annotations and new files, making use of search, sort and filter options. The evolution of the projects can be tracked by the navigation tool. Worth mentioning is that within CHER-Ob environment, the generation of new knowledge takes place in projects while users examine, analyse and interpret the data. Users' name and timestamp in addition to evidence-based statements are key features that are tracked protecting the intellectual rights of each contributor and preserving data provenance information. After the completion of the 'Project', users may combine new data to the initial CHE(s), extract sub-projects and merge with other projects. CHER-Ob encourages data sharing providing customizable automatic report and video generation options. CHER-Ob supports the following functions:

- enhanced access to textual and visual information
- viewing and annotating imaging data
- classifying, searching, sorting and filtering textual data
- report and video generation
- sharing data
- collaborative research.

In addition to 2D, 3D and volumetric data types supported by 'Hyper3D' (Kim, Rushmeier, and Ffrench 2014), CHER-Ob's functionality is broadened by the introduction of multiple RTI viewing. The annotation system supports five diverse types of notes. General annotations refer to files, while point, surface, polygonal and frustum annotations are used as pointers for features revealed during the examination of visualizations. 2D images can be embedded to annotations. Easy organization and retrieval of annotations are possible via the classification

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schema and the sort, filter and search options. The classification schema includes ten predefined categories that represent a simplified version of the Getty Classification of Works of Art (Baca and Harpring 1996) and an additional user-defined category. In addition to the already mentioned simplification, colour coding was also introduced to further enhance interaction with the imaging data.

Regarding geographical information, CHER-Ob relates to Google maps, enabling interaction with geographical information systems (GIS). The content of projects and CHE(s) can be exported via the automatic customizable reports in pdf and html formats, encouraging the distribution of information to non-CHER-Ob users for research, publication and archival purposes. Additionally, an integrated video generator based on the images and texts in CHER-Ob Projects and CHEs is useful for dissemination to a broader audience. The systems offer flexibility since users can contribute focusing either on the wider research scope or their individual research interests. Most importantly, CHER-Ob's compatibility with commonly used file formats and additional functionality enables an integrating hypothesis approach based on simultaneously and comparative analysis and interpretation of multimodal data, instead of individual exploration of each file type using different software packages sequentially. In that way cultural heritage professionals have a higher chance to provide answers to research questions and reach evidence-based conclusions (Figure 1).

Case Study

Unsleben Jewish Cemetery

The Unsleben Jewish Cemetery, founded in 1856, is located about 1 km from Unsleben village on a hill to the east, expanding from the southeast to the north in Bavaria, Germany. The cemetery was founded by the Jewish community in Unsleben, which had around 60 families during the 1860s that were completely integrated into the social life of the city until the 1930s. Measures taken against Jews by the Nazi government, such as forbidding private and commercial relationships between Jews and non-Jews resulted in a large emigration movement and the closure of the synagogue in Unsleben in September 1938.

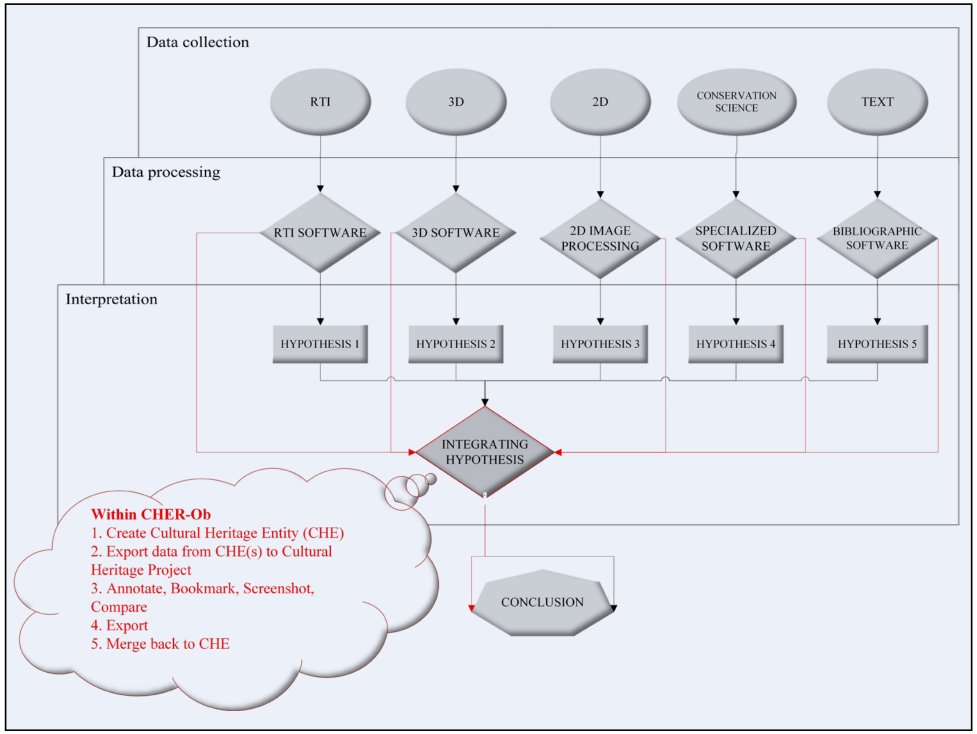

Figure 1. A generic representation of cultural heritage research. Black arrows show the conventional pipeline and red arrows shows the integrated interpretation phase in CHER-Ob.

According to the cemetery book, 229 people were buried in the cemetery from 1856 to 1942. During the Nazi era 13 tombs and 66 name plates were destroyed. The cemetery now consists of 216 tombs with the state of preservation of the existing tombs varying. After the World War II, the cemetery was protected as a historic landmark by the State of Bavaria. New features introduced around 2000 include a limestone wall and, close to the entrance, a memorial honouring the victims of the Holocaust. The cemetery is no longer operational, but it is accessible to visitors and Jewish traditions such as putting pebbles on graves are still observed.

The 'Unfolding Communities' project

Unsleben Jewish Cemetery has been part of the 'Unfolding Communities' project among other Jewish cemeteries in Northern Bavaria like Bad Neustadt. The project combines anthropological and historical research with technological applications, such as assessing the condition and any state of deterioration of gravestones through digital documentation (Caine, Tagar, and Or 2014). The 'Unfolding Communities' project consists of in situ activities (cleaning and documenting the cemeteries, digital image data capture) followed by processing, further data analysis and generation of a web-page for the dissemination of the available information and visualizations (http://judaica-unsleben.de/). This framework may well be adapted for similar projects elsewhere.

The 'Unfolding Communities' project has a multilingual complex nature, tangible and intangible components, as well as a cross-cultural educational work. Undoubtedly, digital documentation of the Unsleben Jewish Cemetery and its interpretation by different stakeholders necessitates an advanced tool for interaction and management of data, research and decision making. Image and video from Unmanned Aerial Vehicles (UAV) and close-range photogrammetry datasets were used for the 3D digital reconstruction of the site. Interactive relighting datasets of individual tombstones were acquired for the generation of RTIs, useful for enhanced visualization of inscriptions and surface topography. Stone characterization and degradation data were collected in an attempt to define the state of preservation and identify the provenance of the materials. Historical and archival information assists in revealing evidence for destroyed tombstones, while information about the lost Jewish community sheds light on the intangible significance of the cemetery. Considering the aerial and close range photogrammetric 3D models and 2D images, RTIs, stone characterization and degradation data in addition to historical/archival information, the intangible aspects of the cemetery and its connections to the lost Jewish community, Unsleben Jewish Cemetery is an ideal case study for introducing CHER-Ob. The multiple categories and data types allow for the testing of how well such a complex set of data can be integrated and what its limitations might be.

CHER-Ob Cultural Heritage Entity

The CHE named 'Unsleben Jewish Cemetery' summarizes the contents of the available historical information. It classifies and organizes the already existing knowledge about the site, which survives as digitized plans and hardly legible hand-written text in German and Hebrew. The CHE 'Unsleben Jewish Cemetery' aims to integrate available information and facilitate easy retrieval of names and dates of those buried within the cemetery as well as the location of their graves. For example, CHER-Ob users can search for a specific name of someone interred within Unsleben Jewish Cemetery and retrieve all the available information, including dates of birth and death and location of the grave in the cemetery. The CHE includes a digitized historic plan derived from the cemetery archive, enriched with textual information. The latter were added as point annotations under the category Stylistic Analysis and Descriptions, colour coded green in CHER-Ob environment. The annotations contain name of deceased, date of birth and death, Cemetery Plan Number and Cemetery Book Number.

Since images can also be included in the annotations, a section of the cemetery book associated with each entry was attached to the point annotations to facilitate easier deciphering and translation of illegible text. The tabs on the right side of the screen provide enhanced access options. Annotations can be reached through the 'Navigation' tab, metadata can be viewed and edited through the 'Cultural Heritage Entity' tab and other functions such as adding general annotations, search, filter, and bookmarks are located at the ‘Application’ tab (Figure 2). This example demonstrates the use of CHER-Ob for documenting data, managing 2D images and textual data, and analysing archival and historical information. All the information included in the CHE is expandable via projects.

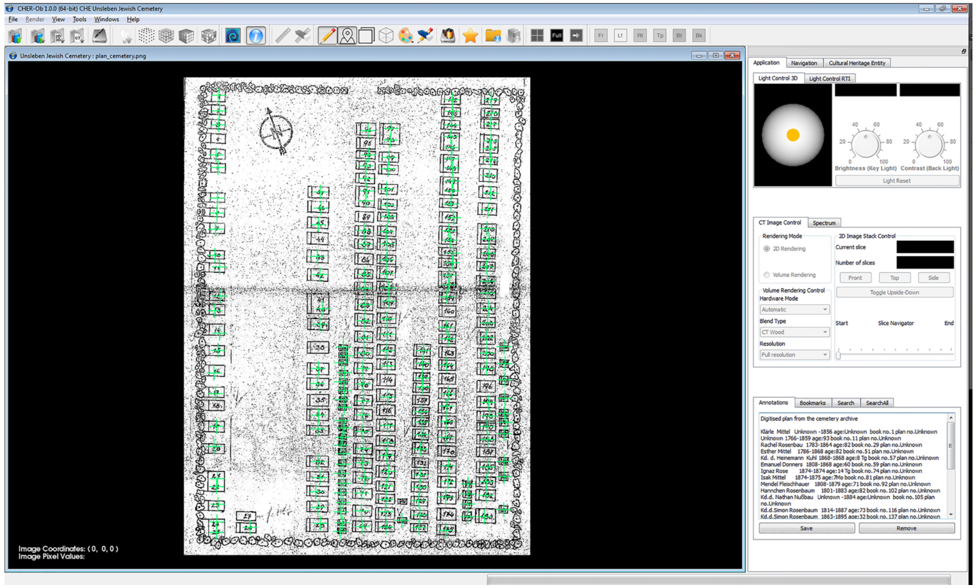

Figure 2. Screenshot from CHER-Ob after the creation of CHE ‘Unsleben Jewish Cemetery’. It shows the annotated digitized historic plan derived from the cemetery archive. General and point annotations refer to archival information and are classified under the stylistic descriptions.

CHER-Ob Projects

The fundamental areas of research for the Unsleben Jewish Cemetery within CHER-Ob were (1) documentation and management of the available dataset, (2) evaluation of 2D and 3D imaging data, (3) translations of text and inscriptions from German and Hebrew to English and (4) comparison of the results of fieldwork with the archival information. Documentation and management of the available data were considered crucial points of the project because of the need to ensure the best use of

available diverse dataset. 2D and 3D images had been used as the means of documentation as well as for online presentation and dissemination purposes. RTI’s efficiency for the visualization of inscriptions was evaluated in comparison to static 2D images. Translations into English were necessary as a way to reach a broader audience, including a large number of descendants of the Unsleben Jewish community who migrated to the USA. Last but not least, historical information and recently acquired data during fieldwork were brought together in an attempt to reveal information either not included in the archive or non-existing due to damage. To achieve these goals independent projects were created in CHER-Ob, such as the Unsleben Jewish Cemetery 2D Imaging Project, Unsleben RTIs Project and the Unsleben Memorial Project.

Unsleben Jewish Cemetery 2D Imaging Project

The ‘Unsleben Jewish Cemetery 2D Imaging’ Project integrates satellite images, aerial and terrestrial photographs captured by members of the project team and visitors, before compiling them with other forms of 2D documentation, such as RTIs (Figure 3). Images of individual tombstones visualize the state of conservation and the stone deterioration features. In cases of well-preserved stones, details such as the name of the deceased and relevant dates are identifiable. Terrestrial general views of the cemetery help the user understand the positioning of the stones within the site. Aerial views provide another perspective and relate the site to the landscape. Combining the above with the cemetery plan and enriching with archival information, helped us to identify graves of families and correlate them to chronological information. CHER-Ob users can explore the available 2D images of the tombstones either independently or in synergy with the cemetery plan and aerial images. The latter is an enhanced methodology for accessing the heritage record. Annotations can be added for identifying interesting features represented in images as well as for developing cross-references across the dataset. For example, stone weathering patterns observed

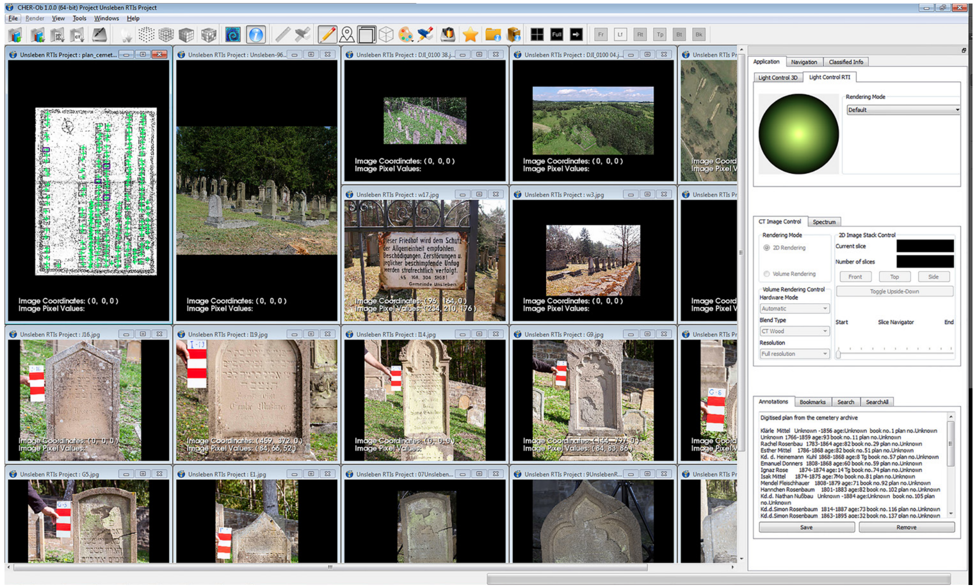

Figure 3. Screenshot from CHER-Ob. A general view of the ‘Unsleben 2D imaging project’ after compiling all the available information.

during visual inspection are identifiable in computer visualizations and are cross-referenced in CHER-Ob projects. This functionality assists in developing interrelationships not only across the dataset but also between the members of the team, by identifying overlapping research interests and the potential for interdisciplinary projects within the scope of the Unsleben Cemetery and beyond.

Unsleben RTIs Project

The ‘Unsleben RTIs Project’ aims to define the efficiency of RTI visualization for enhancing the legibility of inscriptions on tombstones, following previous successful application of RTI technology for the study of stones (Gabov and Bevan 2011; Duffy 2010). The ‘Unsleben RTIs Project’ is significant not only because it attempts to make the inscriptions readable for transferring the information about the lost Jewish community to the present and hopefully to the future but also reveals the ongoing weathering

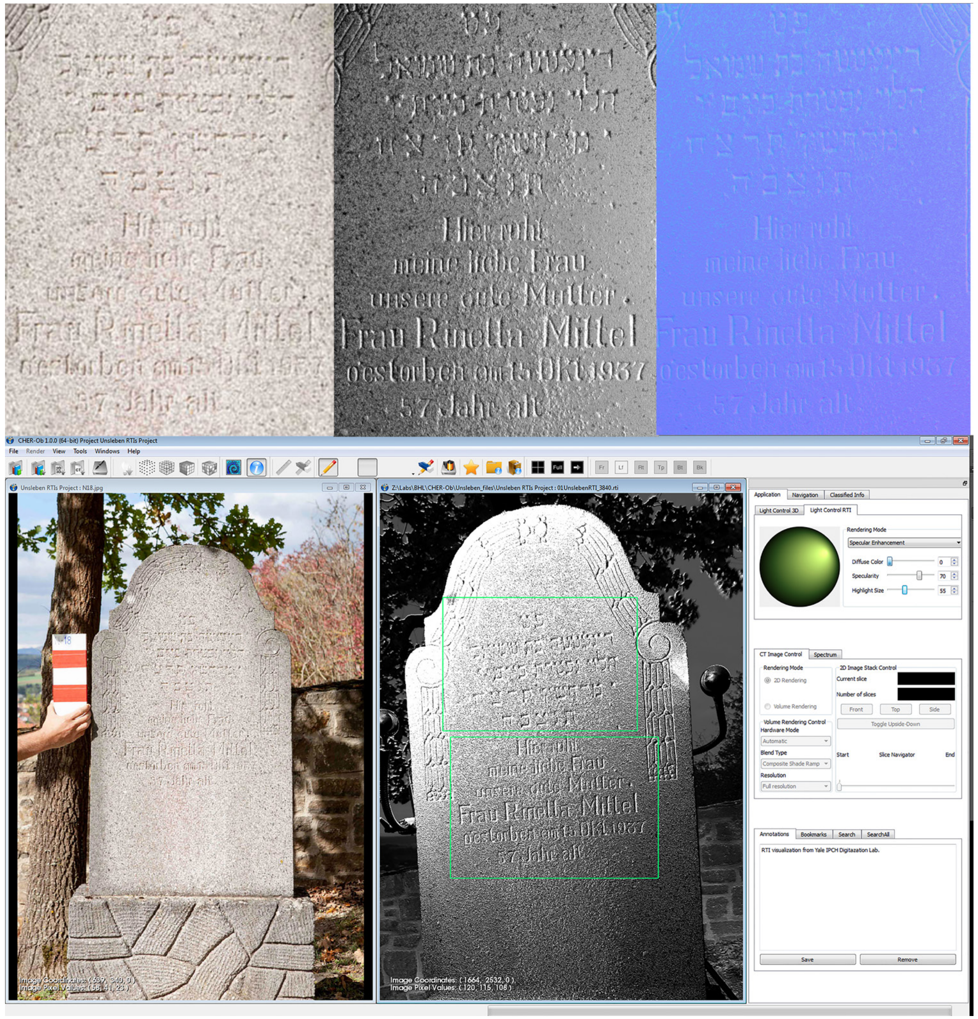

Figure 4. Digital image of gravestone inscription, RTI view in specular enhancement rendering mode and normal map (above from left to right) and a screenshot from CHER-Ob (below) showing the comparative analysis of the RTI visualization and the static 2D image during the development of ‘Unsleben RTIs Project’.

of inscriptions due to the different agents of stone decay. As shown in Figure 4, RTIs and static 2D images were imported into the project and annotated in a comparative mode. The simultaneous comparative analysis of RTIs and 2D images of tombstones made possible the evaluation of RTI contribution to the study of the inscriptions in a much easier and more practical way compared to individual visual analysis using widely popular RTI and 2D image processing software. Users add annotations to different tombstones visualization formats (RTI visualizations, 3D models and 2D static images) within the same software during their comparative analysis. In most of the cases these visualizations are complimentary approaches for the documentation and study of the stones and the annotations associated to each image type reveal different aspects of the tombstones. Thus, synthesis of the annotations deriving from different types of visualizations is an essential step before reaching robust conclusions. Within the same software users may examine the available data in a holistic mode, which includes interpretations based on different techniques as well as focused on different aspects of the site, incorporating different background knowledge. The strategies above are useful for broadening our understanding of the site and ability to analyse across a number of different aspects of heritage significance.

On the other hand, this functionality, non-existent before the release of CHER-Ob, enables a more convenient and straightforward comparative analysis of each visualization, regarding their contribution to the project's goal. Even after the completion of the project, via the annotations, users can track the provenance of each observation-characterization, creating an inbuilt historiography of the dataset itself, and the researchers to have analysed and contributed to it. With the assistance of search and filter options (primarily using names as search text), the location of the RTI visualized stones were pointed in the plan. Any inconsistency between the archival-historical and fieldwork data was noted and addressed.

Furthermore, in the future after a second RTI data capture of the tombstones over time, the comparative analysis of the same tombstone visualized in different file formats in addition to comparison of the same tombstone across time will be beneficial. Considering the inevitable material deterioration of the tombstones with time, additional RTI captures in the future will be beneficial for condition monitoring purposes. For example, quantitative RTI methodologies (Manfredi et al. 2013) can be applied for defining the rate of stone deterioration. Because of the multiple RTI viewing and annotation functionality, CHER-Ob can potentially be used for studies of weathering of the gravestones, following our initial visualization and stone characterization, and can ensure that the comparison of data over time will be possible and linked to the overall dataset for the site.

Unsleben Memorial Project

Another CHER-Ob project named 'Unsleben Memorial' was created based on all the available information of modern additions to the site such as the memorial close to the entrance. The data imported include a 3D model, different 2D images of the memorial and the initial CHE. In the project the location of the memorial was noted, in association with existing tombstones in the site documentation. The 3D model was annotated, using surface and volume annotations under different categories. The latter assists in assigning each annotation to the appropriate category based on the GCWA[1] schema and the former provides a way to distinguish annotations referring to the surface of the 3D model compared to its volume. The surface annotation was used for defining the position as well as the names inscribed on the plaque of the memorial. This annotation was added under the category 'descriptions' which is recommended for inscriptions and is colour-coded lime. The close range photogrammetry methodology used for the 3D digitization made it impossible to acquire sufficient data for the upper part of the memorial, because of its height. As a result, this part of the memorial has been poorly reconstructed. The volume annotation added under the category 'documentation' (in purple) serves as an explanation for the quality of the 3D digitization. The volume annotation under the category 'measurements' (in red) colour provides information for the size of the base of the memorial. Data derived from the CHE and the project are

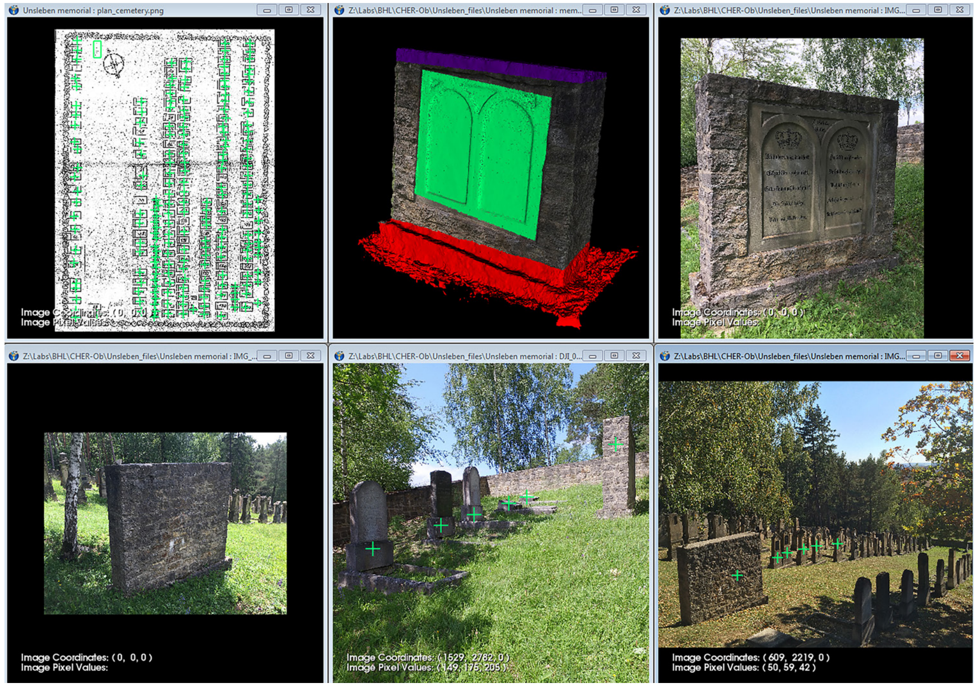

Figure 5: Screenshots from CHER-Ob project 'Unsleben memorial' showing imaging data for the memorial integrated with the archival information.

clearly distinguished in the 'Navigation' tab (Figure 5). During and after the development of the projects, the automatic report generation function was used for creating summaries of the projects, which include annotated imaging data and project information (Figure 6). After the completion of the projects, new data enriched the context of the CHE, which can be used for the creation of new projects.

Discussion

The above-mentioned projects developed in CHER-Ob showcase the potential of low cost, quick and easy-to-use digitization techniques, largely used for recording and documentation, analysis and interpretation, dissemination and as supportive material for conservation intervention and physical reconstruction. The case of Unsleben Cemetery CHER-Ob provides a single access point for 2D and 3D visualizations and textual data, assisting in data management of records and documents. But CHER-Ob not only provides enhanced access to various visualization and information, but also plays a crucial role in virtual visual analysis of the stones. This analysis reveals material evidence and the state of conservation, links the material remains to archival information and assists in the generation of new knowledge for the tombstones and the lost Jewish community of Unsleben.

Digitization technologies offer advanced opportunities for analysis and overcome constraints, such as dimensions, physical properties and geographical location. In the case of Unsleben Jewish Cemetery, RTI reveals the surface topography of individual tombstones, emphasizing details of low relief such as the engraved texts and surface deterioration. RTI, the advanced digital analogue to conventional raking light imaging has been largely used for enhanced legibility of inscriptions. Interactive relighting visualizations are crucial for the Unsleben Cemetery, since the legibility of inscriptions on the tombstones provide the material evidence for connecting existing remains to historical and archival information. Moreover, RTI views reveal surface topography, assisting in defining the weathering patterns on the stones, and by extension help define the state of preservation. 3D digitization enables more accurate illustration and offers an advanced perception of geometry as well as effective comparisons. The use of 3D models of tombstones instead of static 2D images assists in mapping major geometrical transformations, such as material loss, via virtual visual analysis. At a larger scale, aerial

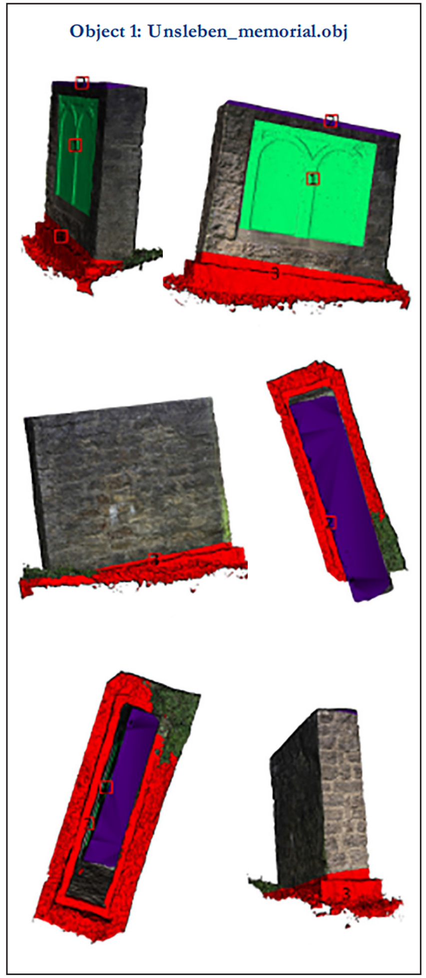

Figure 6. Screenshot from CHER-Ob report showing the representation of an annotated photogrammetric 3D model of the Unsleben Memorial.

photogrammetry (structure from motion) makes it possible to reconstruct the site and incorporate the findings of different visual representations. Archival information about the deceased and their family history and transcription of the engraved text has enriched the digital records of the CHE.

At the same time, this pilot study follows an alternative methodological approach. The diverse multimodal dataset was examined simultaneously in an integrated mode. Information in textual and numerical form was correlated to visualizations. Recently acquired data and historical information were compared in CHER-Ob, which enables the integration of different data types, such as digitised drawings and text from the cemetery archive and visualizations in the form of RTI, 2D and 3D digital images. CHER-Ob analysis reveals that the two datasets were complimentary. For example, tombstones and name plaques destroyed during the Nazi era were absent from the recently acquired dataset, but information can be retrieved from the cemetery archive. Similarly, modern additions, were not included in the historical archive, but were visualized in the fieldwork data. Based on the above, the project generated a more complete record for the site which would have been particularly time consuming and difficult using other computational tools, but was made possible with CHER-Ob integration of historical and contemporary data within one platform.

CHER-Ob provided the necessary tools to researchers for accessing the data within this single platform to lead holistic analysis. Considering that cultural heritage research of a site is never-ending, CHE and Projects in CHER-Ob are documents of the research process for future reference. Co-operative research including projects developed by historians, archaeologists, imaging specialists, conservators and linguists is enabled using CHER-Ob, with data being merged and broadened to enhance our understanding of the material evidence of the site as well as its intangible aspects. The advanced sharing options, including reports and videos, cannot provide the full functionality of CHER-Ob, but they are useful for writing project summaries, creating a digital and/or physical archive and sharing findings with non-CHER-Ob users.

Being able to disseminate the project findings was useful since there are many contributors from different institutions and with different research interests. These materials might be used for public engagement, for encouraging members of the local community and descendants of the Unseleben Jewish families to emphasize the intangible aspects of the project, via sharing their own family histories. The main platform for dissemination of reports in web-based file formats and short introductory videos made with the CHER-Ob software is the world wide web, which is easily accessible by the public. The dissemination of these materials can potentially motivate members of the public to get further involved in the project. Members of the public can generate new material within CHER-Ob, since the software is available for free download and can be used by everyone. It is accompanied by a detailed user manual and further educational material is available online for free. Although video and audio files cannot be added into the annotations of the current version of the software, the stories of the community can be added as texts.

Within CHER-Ob, the links formed between various data types, reflecting diverse aspects of the project, are considered an efficient methodology for further analysis and interpretation of the site. The innovative approach proposed by CHER-Ob is not limited to overcoming technical deficiencies of other platforms for comparative simultaneous analysis, but also act as a catalyst for understanding the knowledge production process during cultural heritage studies, incorporating digital records. For example, the visualizations added to the system by digital heritage experts were linked to the historical/archival information and then annotated by stone conservation scientists and heritage experts. Within CHER-Ob the contributions of each member of the team can be tracked via name tags and time stamps. Thus, at any phase during the development of the project, it is

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possible to identify how new knowledge about the site is produced. The new knowledge in the project is mainly relevant to the memorial and the stones (condition reports, inscriptions, exact positioning at the cemetery) but also includes the study of archival information.

Undoubtedly, the digital toolkit of cultural heritage researchers is continuously expanding, as demonstrated by the adaptation of novel visualization techniques primarily as means of documentation and recording. This has a major influence on the way researchers access and interact with the heritage record, and by extension, it becomes the foundation of analysis and interpretation of cultural heritage. For example, cultural heritage professionals used to document archaeological/historical sites, buildings and objects in 2D formats, such as drawings and photographs. Today, the use of 3D digitization is becoming popular for cultural heritage recording and documentation. As a result, professionals and researchers access and interact with the records in a way that offers more possibilities for further analysis in 3D space compared to conventional recording, such as structural, visibility and lighting analysis. These new methodologies assist in interpretations regarding the materials and techniques used in the past, the form, function and use of sites, building and objects.

The past decades' focus had been on the development of efficient digitization techniques, but now the focus is shifting from the development of technology and the lengthy list of digital innovations, to people as technology users and the development of effective research methodologies for enhanced interaction between humans and data. CHER-Ob is considered an attempt towards this goal because it proposes a new research methodology for accessing and analysing cultural heritage data in various file formats at a comparative mode simultaneously. This new methodology is not limited to a small community of experts, since the software was designed to be accessible by all cultural heritage professionals without a computational background knowledge. Also, the proposed methodology encourages collaboration across disciplines in the CHER-Ob virtual research environment, for example materials added by experts with different backgrounds can be used and annotated by other members of the team. During the development of the CHER-Ob platform, we had the opportunity to explore the interrelationships between scholars, digital records and visualizations, and understand the impact of methodological choices, including software, in interpretative approaches.

Conclusion

This paper introduced CHER-Ob, the new open-source integration platform for cultural heritage research developed to overcome inefficiencies of widely used computational tools. The most commonly used data types and the limitations of systems employed in cultural heritage research are discussed. A case study, focused on the Unsleben Jewish Cemetery, part of the 'Unfolding Communities' projects, was presented, with an emphasis on CHER-Ob's potential for a holistic research approach, flexible enough to meet the needs of interdisciplinary cultural heritage studies. Additionally, CHER-Ob initiates a discussion for the integration of multimodal datasets and the dynamics of cultural heritage research, having as a starting point its three main concepts; people, sites and technology, but expanded towards methodological choices and interpretations.

Future development goals are the incorporation of different roles assigned to users and personalization, as well as interoperability with data repositories and a closer look at terminology and controlled vocabularies. The users are defined as Creator, being the user who has the unlimited access and modification permit on the CHE(s) and Project Files; Modifier, being the user who has the permit to view and modify the Project Files and Viewer; who can only view and share the information that are permitted by the Creator. Each user may have access to a personalized interface according to professional and role requirements. The connection between data repositories such as ADS (http://archaeologydataservice.ac.uk/), management/inventory systems such as ARCHES

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(http://archesproject.org/) and online image viewers like MIRADOR (http://projectmirador.org/) with CHER-Ob will be explored, having as a goal to provide automatization to the process of data input to CHER-Ob and export to other systems. Ideas that will be considered for the future development of CHER-Ob are the re-design of the user interface, audio and video files additions to the list of compatible data types, CHER-Ob web application, further enhancement of filtering options via selective viewing of annotations, global bookmarks for revisiting a combination of views. Finally, CHER-Ob will be benefit from the experiences of the user community, the contribution of the developer community with the continuous and active support of the project team.

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Endnotes

1 GCWA is Generalised Closed World Assumption, a type of logic that assists in database analysis.