Cultural Heritage Through Time

Project Deliverable

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Introduction

Temporal studies are central to Cultural Heritage research for the investigation of changes, from landscape to architectural scales. Temporal analyses and multi-temporal 3D reconstruction are fundamental for safeguarding and maintaining all forms of Cultural Heritage. Such studies form the basis for any kind of decision regarding intervention on Cultural Heritage, helping assess the risks and issues involved.
Using heritage-sensitive approaches in policy, practice and design can help to smooth the transition from past to future, can contribute to economic and environmental sustainability, foster community, social cohesion, intergenerational relationships and place-attachment, even in a Europe marked by mobility and migration. This is especially the case for heritage in urban contexts, as the European population becomes ever-more urbanized. Heritage is also subject to growing processes of democratization, and this makes it a relevant and useful concept for various forms of public participation, including creating networks for cultural and political cooperation.
Time-varying information, although generally available for heritage sites and monuments, is often treated separately and not regarded as a fully integral and unique source of evidence. Heritage research should be performed using 3D techniques in order to precisely survey and model the present state, while non-existing (missing) parts or changes through time could be reconstructed using archival data, archaeological analyses, historic photographs or drawings when referring to a past state, or other 3D acquisition when describing a future state. Temporal analyses and multi-temporal 3D reconstruction are fundamental for the preservation and maintenance of all forms of Cultural Heritage and as a basis for decisions relating to interventions and valorisation.
The aim of the CHT2 project is to fully integrate the fourth dimension (4D) into Cultural Heritage studies for analysing structures and landscapes through time. CHT2 will collect heterogeneous material (multi-temporal aerial and terrestrial photographs, maps, drawings, etc.) and combine it with contemporary 3D models. These geo-referenced and metric products will be the basis for quantitative analyses about territory transformations or architectural changes, visualization purposes, preservation policies, future planning or possible business applications. Therefore CHT2 will produce time varying 3D products, from landscape to architectural scale, to envisage and analyse lost scenarios or visualize changes due to anthropic activities or intervention, pollution, wars, earthquakes or other natural hazards. For landscapes it will be possible to chronologically highlight transformations and investigate how urbanization influenced change. For cities, time-varying 3D models will allow the rediscovery of lost areas or buildings. Finally, for architecture or buildings, starting from a 3D model of the actual situation, changes will be highlighted and missing parts will be reconstructed based on historic information. The heterogeneous information necessary for the project's accomplishment will be sought from national museums and archives with the support of the associate partners. A final project exhibition is planned to show the time-varying 3D products generated for the different case studies. The CHT2 project will rely on an interdisciplinary and international consortium in order to exploit leading expertise in the fields of 3D modelling, data integration, landscape archaeology, GIS, heritage conservation and preservation.

Description of the research

The main aim of the CHT2 project is to merge heterogeneous information and expertise to deliver enhanced four dimensional (4D) digital products of heritage sites. CHT2 will fully integrate the temporal dimension, its management and visualization, for studying and analysing Cultural Heritage structures and landscapes through time. In predefined case studies, CHT2 will collect heterogeneous archive material (e.g. multi-

temporal aerial and terrestrial photographs, historical maps, ancient drawings and paintings, etc.) and fully assimilate them with modern-day 3D digital models produced using geomatics techniques (laser scanning, photogrammetry, etc.).

These combined geo-referenced historical materials and 3D metric products derived at the present time will be the basis for: i) quantitative analyses in geographic information system (GIS) software about territory transformations or architectural changes; ii) visualization purposes; iii) preservation policies; iv) future planning, etc. Therefore, CHT2 will develop a novel methodology for time-varying 3D products, from landscape to architectural scale, to analyse lost scenarios or visualize changes due to anthropic activities or intervention, pollution, wars, earthquakes and other natural hazards.

CHT2 will go beyond this state-of-the-art by creating new evidence-based methods that can be used in assessing and analysing past and future directions of change in the heritage field, thereby developing the concept of reconstruction for preservation and safeguarding, and data sharing for lost or hidden heritage assets. The project will create an integrated information system providing both multiple solutions to the information demand from multiple stakeholders and functions: management, preservation or analysis. The programme of work will generate easy-to-use and easy-to-learn methods and tools for understanding 4D models, such that the entire European heritage community will have the chance to access an affordable, transferable, functional and usable framework of methods and tools. CHT2 will engender a collective awareness platform for Cultural Heritage understanding, leveraging the emerging "network effect" by combining open online social media, distributed knowledge co-creation and data from real environments ("Internet of Things") in order to create awareness of problems and possible solutions that will require collective effort and enable new forms of collaborative research and innovation).

The methodological innovation will consist of a structured pipeline for generating diachronic 3D models at geographical, urban, architectural and object scale. The digital reconstruction will be based on historical and philological considerations that will generate a feedback on the quantitative 3D data originating from instrumental measurements for hypothesizing a possible reconstruction of a certain scenario in a past state. Such reality-based 3D data will also produce a feedback on the historical hypotheses, enriching them and generating a loop that allows refinement of the 4D reconstruction to the optimum level possible from the present day and historical data. A specific effort will focus on managing within the same data flow different levels of uncertainty embedded in the historical interpretations - potentially quite high - with the lower, although not negligible, uncertainty of survey methods for gathering the current state of a scenario. Although a unique logic will drive the project, two specific project threads will be developed for different survey scale ranges.

Specific 4D visualization solutions will be developed to allow the browsing in space and time of the digital outcomes originated by CHT2. Although up to now research and development in this topic have been mostly focused on either the “process” or the “product”, not considering the “user”, a proper adaptation of the 4D information accessible through the web will be undertaken by defining different user profiles such as students, scholars, tourists, etc. Such visualization will be possible on the web in order to allow interaction between different types of end user, and for ubiquitous access to such 4D digital resources.

The project will outline an interdisciplinary methodology to make and exploit 4D models of Cultural Heritage sites at different scales: landscape, urban and buildings. The fourth dimension of time will be introduced into the three-dimensional geometric modelling, based on real data, in order to create a multi-temporal representation of a site. This will provide scholars from various disciplines (topographers, geologists, archaeologists, architects, philologists, etc.) with new tools and working methods that support the study of the evolution phases of heritage sites, both to develop hypotheses about the past and to model future developments. The possibility to "see" the dynamic evolution of a building, site, city or territory compressed in diachronic model, gives the possibility to better understand their present shape according to their history.

Two different threads will be considered for developing a time-varying analysis of 3D scenarios:

1. At the landscape (territorial) scale, the use of digital aerial photogrammetry and airborne laser scanning (ALS), as well the use of re-photographing techniques coupled with GIS systems, will allow

analysis of the same scenarios at different times, with the possibility of comparing image-based or ALS-based DTMs with historical maps. In this case the 3D measurement and instrumental analysis will be predominant, with a contribution of the non-technical disciplines in the interpretation of the time varying 3D coming out from instrumental results. The collected data will be used to obtain a proper interpretation of historical mapping and previous aerial maps and to derive spatio-temporal information. Using this 4D approach it will be possible to highlight the transformation of a landscape thought time and to hypothesize future changes due to anthropogenic and natural factors. This type of knowledge is a key factor for all those entities (e.g. cultural, political, or administrative) responsible for managing a territory.

2. At the architectural scale (defined as a single building/building agglomerate/ archaeological site scale), the use of Terrestrial Laser Scanning (TLS) and close-range photogrammetry will allow the generation of detailed 3D representations that will be used as a starting point for 3D reconstructions of the assets to be analysed. Here the contribution of the humanities (history, archaeology, archival data, old iconographic representations) will consist in an active contribute generating data to be added to the true 3D measurement of the current state. This will contribute to creating a believable representation of the building in previous historical phases, according to a strictly scientific approach and a traceable process that takes great care of representing reconstruction uncertainties in the resulting models. Such an interdisciplinary approach will facilitate a methodology aiming at discovering historical transformations of a building not directly evident from a single source. The results of the process are the 3D models of the building, represented in its different historical phases, which play a pivotal role as synthesizing knowledge of the heritage asset under investigation. This type of representation through time defines both a point of arrival of the phases of the study, and acts as a new starting point for a more advanced historical discussion about the Cultural Heritage object in question.
3. The urban scale represents the intermediate position between landscape and architectural scale in which the technologies of the previous two approaches can be mixed, and the methodology that the project aims at developing can be further enhanced by means of a hybrid approach. The project's partners have the multidisciplinary knowledge and the instruments to verify and develop the proposed methodology through a well-established number of case studies selected in accordance with the local Cultural Heritage administrations.

4.

Polimi

The Italian unit chose as test site the Roman Circus of Milan. The Circus was an open-air venue for chariot and horseraces and also the place dedicated to the celebration of the Emperor's greatness. The Milan's circus was also adjacent to the defensive walls with which shared the western part. This particular location has probably resulted in a number of peculiarities, such as the absence of the Arc of Triumph on the apex of the curve. Although the circus was one of the most important of the empire, today only few traces are still visible: a tower of the city walls, a tower of the Carceres reused as a bell tower formerly belonging to the Monastero Maggiore (Figure 1a), and some sections of the walls or foundations in the private properties nearby, sometimes hidden in their interiors or in the basements (Figure 1b).

a)

b)

Figure 1. The remains still visible inside the garden of the archaeological museum: a) tower of the carceres; b) tower of the city walls.

Historical sources report the existence of the circus until the Lombard's era. From that period, as happened to other monuments in Milan, the materials of the roman structures were used in other buildings construction.

This monument was the best choice to propose the new methodology because it's now no longer visible and, except for the experts, is unknown by the majority of the citizens. The 4D reconstruction of this building will allow not only a better knowledge of its structure useful for the archaeologists, but also a better comprehension of the ancient time to the people living in Milan and to tourists.

The most important part of the research will regard the collection of archival data from which the reconstruction has to start: ancient maps, old drawings and documentation of the excavations conducted since the end of the WWII will be fundamental to understand the shape of the Circus. This passage is indispensable because there are not big portion of the structure still on site and also because during the years, since the remains have been excavated, lots of evidence have been destroyed. This part will be accomplished with the help of experts from the Superintendence of Milan, essential in both collecting the data and understanding them.

After this step, a 3D reality-based survey will be done using modern technologies such as laser scanning and photogrammetry to integrate and update the data. This will be a crucial part for the 4D reconstruction of the circus, especially because the remains are spread all over the area inside private houses and difficult to be seen. These 3D data will be combined with a topographic survey (total station + GPS) to georeference all the remains, make them coherent among each other and finally to update the dimensions and proportion of the structure.
All the material collected and produced will be then uploaded in a GIS and overlapped on the modern cadastral map, with a geodatabase connected to all the position of the remains, containing all the information and images from the archival data and from the survey.
The 4D modelling will be identified by a series of layers showing the structure of the city before and after the construction of the circus, and the 3D modelling of the actual city to better understand the shape and the dimensions of the monument and, more important, the changes during the eras.

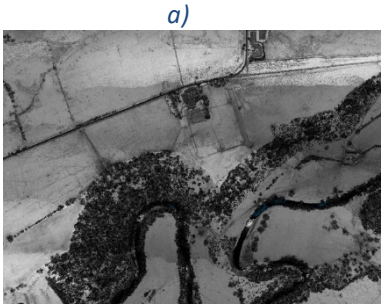
NCL

The test area selected by the English partner regards two forts and a settlement related to the Adrian's Wall, in particular Birdoswald, Corbridge and Beckfoot (Figure 2). The sites were chosen because characterised by natural hazards, such as coastal or fluvial erosion and floods.

In AD 122 the Roman Emperor Hadrian ordered a wall to be built, dividing Britain in half. Stretching over 117 km (80 Roman miles) from Bowness on the River Solway on the north-west coast of England to Wallsend on the River Tyne in the north-east, it was to become one of the most heavily defended frontiers of the Roman Empire. The Wall, complemented by a sophisticated system of outposts and coastal watch stations, offers a remarkable glimpse of ancient society. The Wall today is a designated UNESCO World Heritage Site since 1987, and its surrounding landscape is very different to that of Roman times, although significant portions are still visible in coastal, rural and urban settings.

a)

b)



c)

d)

Figure 2. Sites investigated in this research by the NCL unit: a) the reconstructed path of the Adrian's wall; b) the settlement of Corbridge; c) the fort of Birdoswald; d) the fort of Beckfoot).

As the primary aim of CHT2 is to merge heterogeneous information in order to deliver enhanced 4D heritage digital products, a variety of methods will be used including historic mapping, archival aerial imagery, Unmanned Aerial Vehicle (UAV) sorties, airborne laser scanning (ALS) and geophysical surveys.

In the first instance, an extensive archive search will be conducted in order to identify existing materials, with particular focus on historic aerial photographs, including the Historic England Archive and Newcastle University's archives.

The archival aerial photography will be complemented by other data provided by English Heritage and Newcastle University, including historic topographic maps, topographic and geophysical surveys and drawings.

The archival photographs of the English Heritage Archive, from 1948 to 1991 will be digitised, augmented with ALS data from the UK's Environment Agency for 2009, 2010, 2013 and implemented with UAV surveys with both RGB and NIR imagery as well as geophysics surveys.

USAL

The study case for the Spanish partner will be the Medieval Wall of Avila and in particular the Alcazar Main Door. This construction is the most important example of a military structure of the Spanish Romanesque style but also an exceptional model of the European medieval architecture.
The wall was used not only to defend the town of possible invasions or even to protect the people from possible pests or epidemics but also to control the trade of the city with the outside. There are nine gates giving access to the town, of which the most awesome is the Alcazar Main Door. In 1884, it was declared a National Monument and in 1985, the old city of Avila as well as its churches were included in the UNESCO´s World Heritage list in 1985. Some references state that the building dates back to 1090. Other researchers have argued instead that the wall's construction most likely continued through into the XII century.
Its large size is a clear example of a challenging CH sites for the recording and documentation processes. In spite of its linear nature (Figure 3), the towers and wall distribution, the gates, and neighbour city buildings make the data acquisition and processing difficult.

Figure 3. The Alcazar main Dorr of the wall of Avila.

As for the previous test site, also for the Avila's wall the first step will be to search in the archives of Duque de Alba Foundation, Local Museum and the Council of Avila for ancient maps, historical images, drawings, iconography, etc.
These documents will be used as basis for the study and the reconstruction and will be integrated with surveys with TLS, Photogrammetry and MMS technologies.
In spite of its linear nature, the distribution of towers and walls, the gates and neighbouring city buildings complicates data acquisition and processing. It will therefore be employed as a test site to apply and evaluate different geoinformatics technologies, ranging from close-range photogrammetry to recent Mobile Mapping Systems (MMS). Due to the lack of previous metric support for CH management, the selected technique for initial documentation will probably be TLS as it provides a rich representation with high resolution and accuracy, coupled with a close-range photogrammetric survey to provide the texture to the 3D model and with a UAV survey to complete the upper part.

SSSA

The test objects are several fortresses in Krakov. During the meetings with representative of the City Monuments Conservator, City of Krakow (Halina Rojkowska-Tasak), Historic Museum (Piotr Opaliński) and Cracow Polytechnic (Dr Krzysztof Wielgus) test region of Cracow Fortress was daftly selected, selecting various types of forts interesting from a historical point of view (Figure 4).

a) *b)*

Figure 4. Some of the Krakow Fortresses studied in the framework of CHT2: a) Fort Kościuszko; b) Fort Sudoł.

Selected objects belong to I and V Circuit Defence. It was the sector with the greatest strategic importance in Krakow Fortress because of its proximity to the Russian border.
Objects were divided into three categories:

1. Fortifications of the most interesting in terms of military significance and architectural form
2. Fortifications important
3. Fortifications other

Some of them (Fort Kościuszko, Fort Sudoł, Fort Batowice, Fort Węgrzce) have archival data that will be collected, manly historical plans and maps. Starting from this documentation, historical 3D models will be prepared in CAD software from the scanned plans with the assistance of a specialist, experienced with the Cracow Fortress history, implementing all available data, which might be interesting for 3/4 D presentation. An example is spatial data (maps, orthophotomaps, Digital Terrain Models DTM etc.) shared by the Main Office of Geodesy and Cartography (Głowny Urząd Geodezji I Kartografii GUGIK).
New registration will be instead performed for Fort Batowice and For Węgrzce using Terrestrial Laser Scanning (TLS) and Unmanned Aerial Vehicle (UAV).