

Projecting our Past to the Future - Challenges and Results: The Case of Asinou church

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Abstract

In this paper, we present some of the novel results of the Marie Curie Initial Training Network for Digital Cultural Heritage (ITN-DCH) project, describing briefly the work done focusing on the project's first case study: the Panagia Phorvotisa of Asinou, an UNESCO World Heritage Listed (WHL) monument in Cyprus. The paper introduces some challenges and the importance of multidisciplinary, sustainable research and development in the emerging domain of DCH in Europe. The different methodologies address these challenges through a professional network of partners including Academia, Research and Industry. The paper describes the 3D documentation of the church and how the data acquired can be used and re-used in Mixed Reality (MR) applications using also Deep Learning techniques, as well as in Education.

CCS Concepts

•**Computing methodologies** → Neural networks; Mixed / augmented reality; Virtual reality; •**Applied computing** → E-learning;

1. Introduction

Europe's cultural legacy is one of the most diverse in our world, constituting an attraction for millions of tourists from every part of the planet. It has also economic dynamics that trigger the development of financial activities and jobs, reinforcing social and regional cohesion in the continent. The need for a high quality sustainable training in CH, is now more pressing than ever. Technology has changed the way we perceive CH, and DCH research can boost the development of highly personalized MR services and make the CH assets re-usable in a wide range of real-life applications (tourism, education, creative industry). In addition, CH is a fracturable, non-renewable resource, suffocating from several threats such as environmental factors, man-made destructions, deterioration and looting. For these reasons, it is now a matter of urgency to document, protect and preserve our cultural inheritance, by first identifying the challenges of such an attempt.

2. Aims and Challenges

The challenge calls for cooperation among all the CH related disciplines, professionals, experts and stakeholders, from Research, Academia and Industrial sector: the fundamental nodes of the Triangle of Knowledge (Figure 1). Although this necessity was rec-

ognized even earlier than 2007[†] and the adoption of the European agenda for Culture, there is a worldwide lack in focused research, training and standardization measures for cost-effective e-documentation, preservation and reuse of CH artefacts integrating various scientific fields, CH institutions and end-users (universities, research centers, libraries, museums, media, policy makers, social groups, etc.).

Therefore, the ITN-DCH project aimed for the first time to analyze, design, research, develop and evaluate an innovative framework incorporating the latest advances and research methodologies that can cover all the phases of the lifecycle of a digitized CH asset [IDC*17]. It provided research training in the areas of archaeology, architecture, museology, computer science, survey engineering, material sciences, civil engineering, information systems, computer graphics/vision, etc. In conjunction with current standardized leading actions, e.g. Europeana, the 20 ITN-DCH Marie Curie fellows were encouraged to jointly research on, co-create and co-distribute state-of-the-art personalized CH e-services and applications addressed both to society and creative industry (art, games, etc.).

[†] <https://epthinktank.eu/2014/12/16/cultural-heritage-policy-in-the-european-union/> (accessed 11.07.2017)

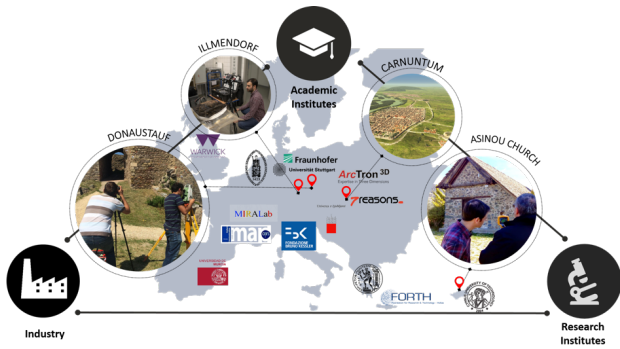


Figure 1: ITN-DCH Triangle of Knowledge & Innovation Hub.



Figure 2: 3D Model of Asinou Church with texture mapping using the produced photogrammetric images. Images were processed with Agisoft Photoscan.

3. Methodology

The structure of the project allowed both vertical and horizontal research training activities. The vertical approach lies on a unique pipeline that complementarily covers the full spectrum of DCH and ensures proper integration of the fellows’ research and training: starting from data acquisition, processing, modelling, rendering, semantical enrichment, etc. The horizontal approach completes all the aforementioned by targeting at management, dissemination, outreach and exploitation activities such as the organization, attendance and active participation at scientific events (e.g. European Researchers’ Night) and international conferences.

Taking into consideration the complexity of CH documentation, ITN-DCH has implemented four (4) case studies as a proof of concept: Asinou church (Cyprus), Carnuntum (Austria), Donaustauf castle (Germany), Ilmendorf (Germany). In the following section, it is presented how the project’s first case study favored extensive 3D documentation, by demonstrating a plethora of possibilities for its 3D data use and re-use.

4. Outcomes/Results

4.1. 3D documentation of Panagia Phorviotissa - Asinou church

The UNESCO WHL monument of Asinou constitutes a very challenging object for 3D geometric recording due to its diversity in shape, size, colour, lighting conditions, unique frescoes and requirements of high accuracy. Several data acquisition techniques were applied in order to ensure the holistic 3D documentation, resulting in geometrically and colour accurate 3D model (Figure 2). Furthermore, valuable relics of the church were 3D documented and later harvested by the Europeans.

The Table 1 provides an overview of the methods and the equipment used.

4.2. The use of the 3D model for Mixed Reality applications

Based on the rich data model of Asinou we have developed a series of applications, concerning real-time rendering and animation for virtual characters, which cover the tangible and intangible spectrum

	Method	Equipment	Object size
Active	Electronic tachometry	Reflectorless total station Topcon GPT-3003	Area around the Asinou church
	Laser scanning	Z+F IMAGER 5010X	Detailed 3D documentation
Passive	Close range terrestrial photogrammetry	CanonEOS 1D-mII, lens 28-80mm f/3.5-5.6	Details and colour accurate textures
	Aerial photogrammetry	DJI Phantom 2, GoPro Hero 3	Exterior of the monument

Table 1: Overview of 3D data acquisition methods used at the first case study

‡. Towards that end, it was deemed necessary to digitise the liturgy and the priest of the monument.

We are proposing a complete pipeline [PFSP15, PKG*17b] for robust authoring of life-size virtual characters as well as group and crowd simulation [PMVG16] in Augmented Reality (AR) using smart devices (Mobile AR). Our virtual characters are infused with a wide range of different human capabilities like speech, locomotion and gestures by integrating the Smartbody animation platform [Sha11] in our glGA framework [PPGT14]. We have employed this pipeline for the development of a virtual tour within the church, provided by the virtual priest. Figure 3 illustrates the 3D reconstruction of the priest with our mobile, rapid reconstruction method [PKG*17a] and the final result used in our applications.

The virtual tour has been also developed in Holographic AR

‡ <https://goo.gl/etbj1T> (accessed 20.07.2017)



Figure 3: Left: The real priest of Asinou church while reconstructed with our mobile, rapid reconstruction method [PKG*17a]; Right: the final result in mobile AR [PKG*17a].

(untethered) and specifically in Microsoft HoloLens ¶ [PKG*17a], presenting mostly the intangible part of the church, like historical events and information about some of its frescoes. The user is able to interact with the virtual narrator by performing gestures and speech commands.

Finally, the virtual tour is also available on the Oculus Rift (Desktop VR) [PKG*17a] and allows for full pose tracking (translation and orientation). This enhances the immersive user experience, making it feel exceptionally real. In order to convey the intangible aspect, we have captured and included elements of the liturgy. The users have the possibility to communicate interactively with the priest §.

Aside the aforementioned VR and Holographic AR implementations, an AR feature has been developed that augments a paper-made ground plan of the church to its 3D model (marker-based tracking). It exploits Vuforia ¶, and is part of a smartphone application developed in Unity || (Figure 4), presenting the case study.

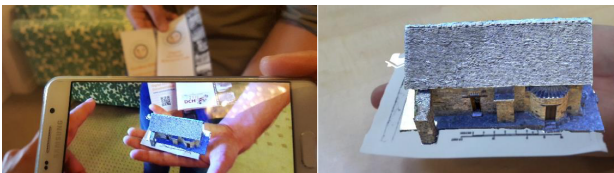


Figure 4: The applied AR technology in the application interface.

An intensive analysis can be found on [ZBP*16], where we describe how the gamification elements differentiate through AR and VR, how the gameplay is affected by the technology and how different AR and VR technologies are. For our Mobile VR applications, we have proposed an AR Inside-Out Positional tracking algorithm (MARIOPOT) [ZBPP16], suitable for modern, affordable cardboard-style VR HMDs.

¶ Original Video (HoloLens version): <https://goo.gl/NzwPo9> (accessed 15.07.2017)

§ <https://goo.gl/Ewp4ZH> (accessed 20.07.2017)

¶ <https://www.vuforia.com/> (accessed 20.07.2017)

|| <https://unity3d.com/> (accessed 20.07.2017)

To handle transformations and illumination of our virtual characters we have created a single algebraic framework that employs Geometric Algebra (GA) and Conformal Geometric Algebra (CGA) [Hil13] resulting in a powerful mathematical framework [PHP16, PTT14, PP17].

4.3. Application of Deep Learning on the Case study of Asinou

The research training received within ITN-DCH encapsulates also the latest technological advances that are shaping-up the field of Artificial Intelligence (AI). The possibilities of Deep Neural Networks† in pattern recognition constitute them as essential tools for creative data reuse. In this context, we have exploited the artistic style transfer using Convolutional Neural Networks (CNN's) to achieve innovative results in DCH: a monument that will self-narrate its history through byzantine frescoes.

4.3.1. Artistic Style Transfer of a Byzantine mural to video

Considering that Artistic Style Transfer is a Non-Photorealistic Rendering (NPR) technique [WS94], in order to resolve known issues [BW03, BNTS07, BS02], we have employed the algorithm of Ruder [RDB16], which exploits TORCH†.

For the initial run of the algorithm we gave as inputs to the system a photograph from the murals located on narthex's roof and the mobile captured video‡ of the virtual priest (Figure 5 top left and right). The generated outcome was a new stylized video§ and Figure 5 (bottom) depicts a selective frame that represents the achievement of the desired byzantine style. However, in contrast to the HoloLens video [PKG*17a], in these results the virtual priest does not recount the history of the church.

Therefore, we derived a new video || from different inputs: the Microsoft HoloLens video [PKG*17a] along with another byzantine mural**. The audio extracted from the HoloLens video was added to the new video to provide a sense of immediate engagement with the viewer in a wider storytelling and educational context. These are preliminary results and their evaluation will happen during the next months, targeting a wide audience from schools and universities to industrial partners.

4.4. Areas of re-use: The case of Education and Community engagement

Other areas where re-use of digitized CH artefacts can yield fruit is education. Arts and CH Education can force society's knowl-

† <https://www.slideshare.net/hammawan/deep-neural-networks> (accessed 14.07.2017)

† TORCH: <http://torch.ch/> (accessed 15.07.2017)

‡ Original Video (Mobile version): <https://goo.gl/Sf1erM> (accessed 15.07.2017)

§ Stylized Video (Mobile version): <https://goo.gl/oJxZzN> (accessed 15.07.2017)

|| Stylized Video (HoloLens version): <https://goo.gl/dh632G> (accessed 15.07.2017)

** Byzantine Mural: <https://goo.gl/WKvNZi> (accessed 01.08.2017)

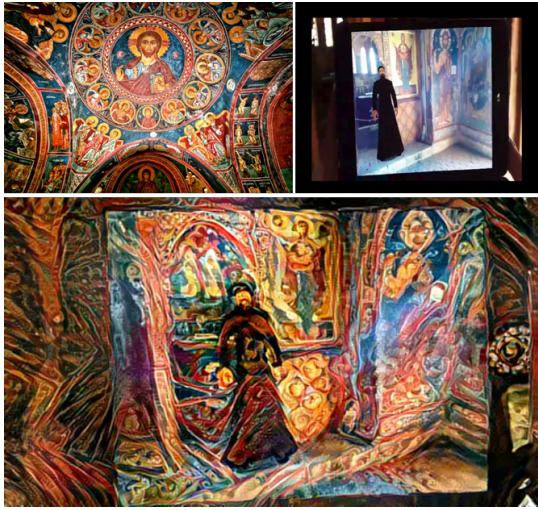


Figure 5: Left: Fresco located in the Narthex of Asinou church; Right: Frame from the original video; Bottom: Selective frame from the output video.

edge development and creativity [Gra02, OP08]. Aligned with Information and Communication Technologies (ICTs), can be effective and productive [OP11] at all educational levels: from preliminary school students to vocational and life-long learners.

4.4.1. Proposed evaluation model of a CH e-learning platform

We propose an e-learning model, where every WHL monument in Cyprus is a course addressed to different age group, and responds to the contemporary pedagogical and methodological dimensions that classifies ICTs according four main axes [OP08, ICB*16]. The suggested evaluation methodology focuses on revealing (1) at which level the multimedia used in the platform affects the learning experience of the students and (2) the possibility of the platform to act as an educational tool in the "hands" of the teachers inside classroom. We also consider diverse potential user groups (students, teachers, teaching inspectors) to evaluate the platform at its early development stage (formative evaluation) [Pos05], thus aiming at a user-centered approach that investigates whether their learning needs are met [Ree08, MV99].

4.4.2. DCH Artefacts Re-used in Community engagement practices

Taking into consideration the preliminary results of the above evaluation, we experimented on engaging also older users through creative activities during a local Workshop; part of an outreach Scientific event in Cyprus**. Parents with their children, both Cypriots and foreign tourists, engaged with the 3D printed model of the Asinou church (Figure 6). The Workshop was an excellent way to disseminate content of the project's acquired data in the

form of re-usable CH artefacts that can get adults and children involved to edutainment and raising awareness and interest about CH [IMAMY15].



Figure 6: An overall view of the Workshop on a creative approach to historical churches - the case of Asinou at Mediterranean Science Festival in Cyprus.

5. Conclusion and Discussion

In this paper we presented results of a sub-set of the fellows involved in our European funded project. From data acquisition to the creative and educational re-use of DCH artefacts, 20 fellows and 14 partners co-researched, developed and disseminated beyond state-of-the-art CH novel applications and services. Through the various secondments, summer schools and project meetings, they had the opportunity to cooperatively brainstorm, blend, and finally integrate their personal academic and professional backgrounds, thus creating new, specialized sub-fields in the area of e-documentation, preservation and digital presentation of CH, as the one that generated a creative, new, mash up video technique in storytelling.

In addition, the proposed unique pipeline that was followed, ensures the long-term use and sustainability of the digitized CH artefacts by investigating their re-usability in two major social contexts such as Education and Community engagement, as well as Games and Tourism.

We strongly believe that the most important accomplishment of the ITN-DCH project is that all the fellows were given the chance (a) to experience high level training on research and dissemination activities, forging their collaboration, communication and management skills as well as (b) to establish relationships for future, fruitful cooperations, thus forming significant partnerships and the next generation of researchers in the area of DCH.

Acknowledgements

This project has received funding from the European Union's Seventh Framework program for research, technological development and demonstration under grant agreement no 608013.

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