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### Article

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## DigiArt: towards a virtualization of Cultural Heritage

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### 1. Presentation of the project

The main aim of DigiArt is to build on the pillars of mass 3D digitisation by enhancing and improving its process for the digitisation of cultural heritage. The ambition is to create a range of user friendly software solutions and commercially low-cost hardware to democratise the process of virtual curation and visits. With these tools, curators will be able to author dynamic scenarios into 3D cultural worlds with their heritage objects as elements for composing their stories. The DigiArt project is a consortium consisting of seven academic, industrial and museum partners: Liverpool John Moores University (LJMU, coordinator of the project, UK), Centre for Research and Technologies - Hellas (CERTH, Greece), National Centre for Scientific Research (CNRS, France), Museum of the Royal Tombs of Aigai (Greece), Pix4D (Switzerland), Vulcan UAV Ltd (UK) and Scladina Cave Archaeological Centre (Belgium). The consortium secured 2.9 million euros of funding and received 2.3 million euros of this from the European Union's "Horizon 2020 Research and Innovation programme" (grant agreement No 665066).

The objectives of the project are:

1. To develop highly efficient methods for gathering 3D data of high quality from large and distributed sites by automated means;
2. Produce and make available to cultural heritage workers a new state-of-the art Open Source 3D scanner system built from low cost and commercially available hardware;
3. Create a suite of software that will enable the analysis of highly redundant point-cloud data from scanners;
4. Develop innovative methods of generating semantic meaning from 3D models and through this semantic meaning find connectivity that will realise an "internet of historical things";
5. Use the 3D content to be the landscape for radically new immersive experiences to remote and on-site visitors;
6. To see our technologies adopted by an expanding community of cultural heritage workers.

The novelty of DigiArt lies in its consortium partners who are archaeologists, anthropologists, electrical, mechanical, optical and software engineers who are working together to develop innovative and intuitive solutions for the acquisition and presentation of archaeological sites and cultural objects. The convergence of their ideas means that the aims of the project are driven by the cultural heritage workers with the engineers to challenge the current status quo in their field. Museum curators, archaeologists and anthropologists do not speak the language of engineers and important things get lost in translation. Also, the museum partners are responsible to ensure that the solutions and innovations would translate to the sector and be usable without specialist knowledge.

It is also for this reason that the selection of the cultural partners was extremely important. They had to represent a range of environments, objects and visions that would ensure that the resulting technologies and tools would cater for a wide range of sites and museums. Firstly, the Research Centre in Evolutionary Anthropology and Palaeoecology of the Liverpool John Moores University curates an anthropological collection consisting of more than 2000 skeletons ranging from the Iron Age to the Late Medieval period. The collection is housed in secure laboratories but it lacks exhibition rooms. Both Scladina Cave and the Vergina Palace of the Aigai archaeological sites offer very different environmental constraints. While the cave is a narrow underground site with fairly stable conditions (low light and high humidity levels), the palatial site of Vergina covers more than 1 ha and is subject to many climatic variations (sun, wind, rain...). In addition, both Scladina Cave and Vergina have objects that are extremely varied. In the case of Scladina these are mostly lithic artefacts and fossilized bone, for Vergina these consist of architectural columns, gold jewellery and frescos, for example.

The first challenge of the project was to find ways of developing highly efficient methods for gathering 3D data of high quality from large and distributed sites by automated means. In this process of data acquisition, it is important to consider what the current state of the art of the field is. The use of 3D technologies in the capture of large sites has been increasingly adopted by archaeologists (Ducke *et al.*, 2011; Emaus & Goossens, 2015; Galeazzi, 2016; Katsianis *et al.*, 2008; Lojek J., 2012). For example, Les Fraux Cave (France; Burens-Carozza *et al.*, 2013), Pompeii (Italy; Apollonio *et al.*, 2012; Remondino, 2011), the Etruscan Necropolis of Tarquinia (Italy; Remondino, 2011) and Happisburgh (UK; Ashton *et al.*, 2014) highlight the huge variation in quality and the constant evolution of the techniques and the issue in 3D modelling. The main constraint that is faced by

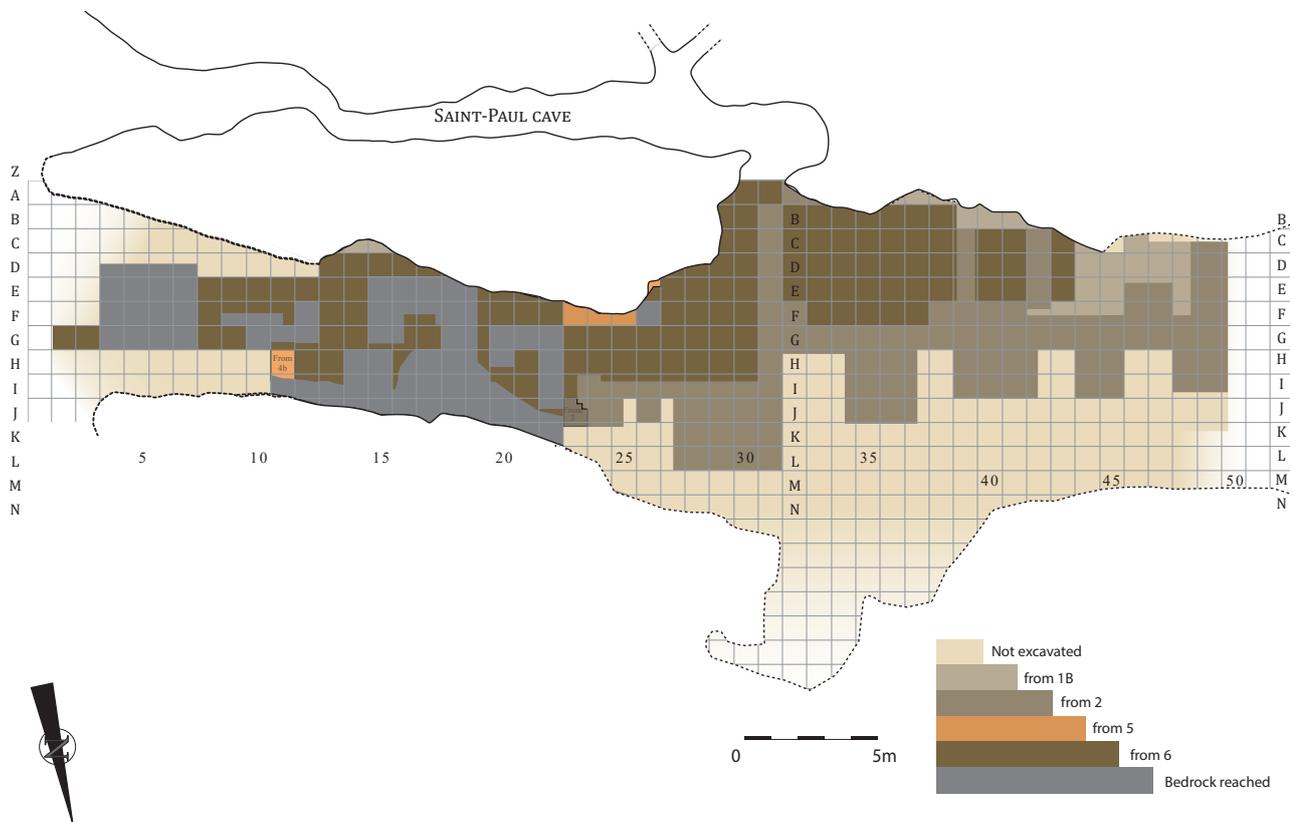


Fig. 1 – Handmade 2D mapping of the Scladina Cave.

all of these projects is either the lack of quality or the size limit of the 3D environments being scanned. In DigiArt, engineers have been working on finding a balance between data capture of large sites, data accuracy and visual accuracy. The use of Unmanned Aerial Vehicles (UAV or drone; Küng *et al.*, 2011; Vautherin *et al.*, 2016) facilitates covering large areas and those areas difficult to reach. Nevertheless, drones can only carry a small load. This is especially important if one considers the aim is to make these solutions cost-effective and user-friendly for cultural heritage workers. The use of video, photo and laser scanning is compared and combined in this project.

The second aim is to create a faster and accurate scanner for the capture of 3D objects (Arevalillo-Herráez *et al.*, 2016; Gdeisat *et al.*, 2015; Gdeisat *et al.*, 2016ab). Curators are often hampered by the time and complexity of scanning and processing 3D models of objects. This is the main reason why the uptake of virtual 3D collections is slow. In

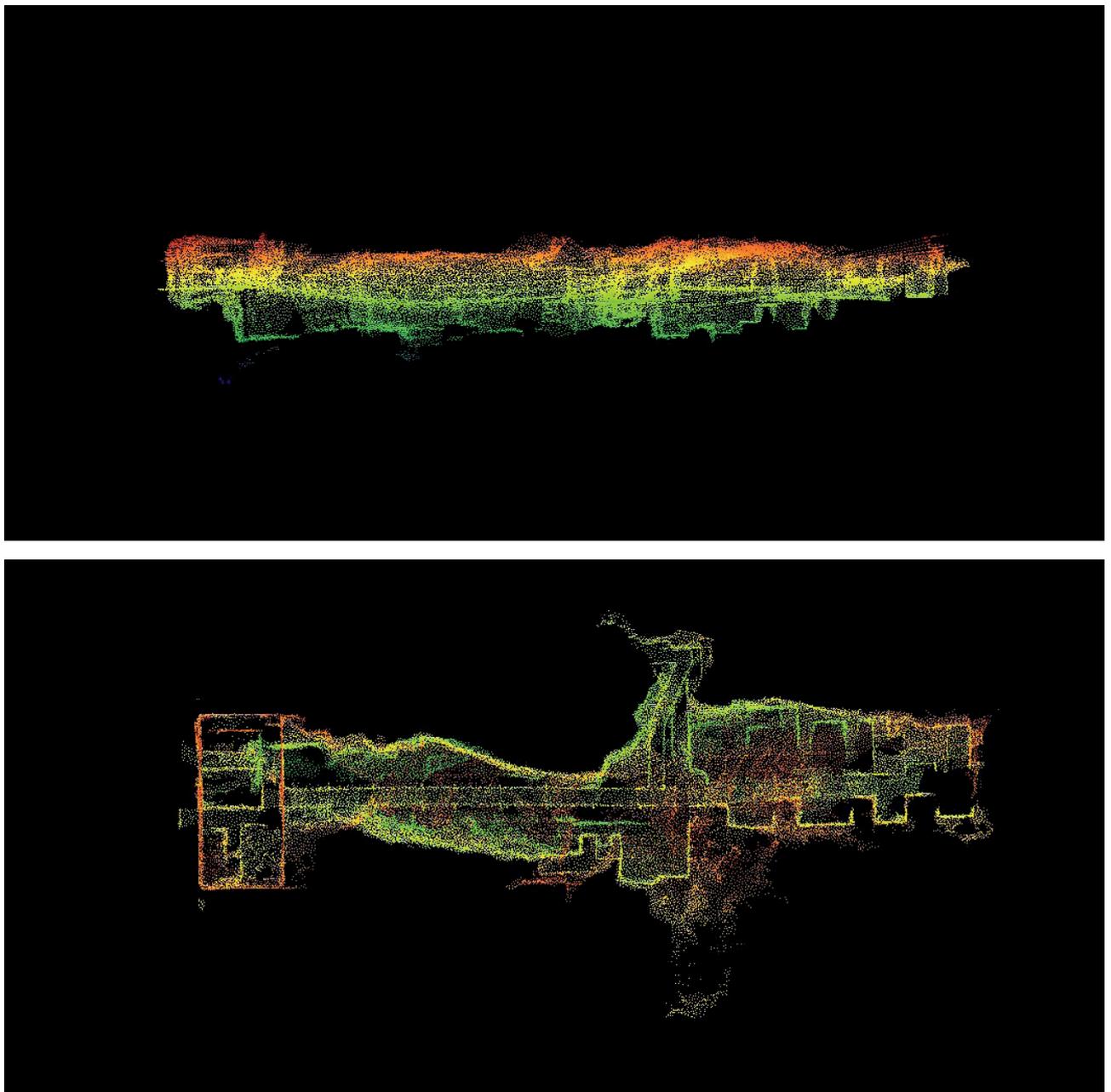


Fig. 2 – Different views of the LiDAR point cloud of the Scladina Cave.

addition, curators are concerned not only with the use of the object for display to the public, but also aim to have these virtual objects represent the real object as accurately as possible. This is one of the challenges the project is aiming to address especially because the project will transfer cultural objects from reality to virtual reality (VR) and to this “internet of historical things”. The semantic software engineers are tasked with finding meaning in the 3D objects and connect them through this meaning. They are developing recognition algorithms that will connect objects automatically based on their meaning (Ioannidou et al., 2016; Spampinato, 2016). So, people connected to the virtual museum will not only be able to virtually manipulate the artefacts, see them through optical filters (not directly visible on the objects like X-rays), but they will be able to find similar objects within the collections of the museum they are visiting or inside those of other museum of the community. This will result in the “Internet of the Historical Things” where cultural heritage will be accessible from anywhere, anytime.

As a culmination of the innovations mentioned above, the 3D content that is captured will be the landscape for radically new immersive experiences to remote and on-site visitors. The objects will be placed inside their context or where they were discovered in the 3D reconstruction of the archaeological sites through the use of augmented and virtual reality.

These three different cultural partners offer highly variable challenges, which broadly cover the spectrum of constraints inherent to most museum institutions. The creation of an all-in-one solution for museum will indeed allow them to be adopted by the entire cultural heritage domain. As mentioned above, the cultural heritage user is central to this



Scladina 2D (3D > on screen)

Fig. 3 – Photogrammetry of the transversal profile 50, farthest part of the cave investigated to date, where the top of the sedimentary filling is in contact with the ceiling of the cave (Scladina-CO2015 Trans 50 [in y=25] C[in x=50]-I[in x=25]).

engineering innovation project and therefore adds real added value for the stakeholders of the cultural heritage world because it will make sure that specialized knowledge of 3D digitalization and virtual reality of gaming techniques is not required to create a truly immersive cultural visit.

## 2. Scladina Cave v3.0

In 2015, the three main caves (Scladina, Saint-Paul and Sous-Saint-Paul) composing the network of Scladina (Fig. 1) as well as the immediate outside surroundings were digitised using photogrammetry and 3D scanning (LiDAR) techniques. The LiDAR resulted in a high-precision ( $< 1$  cm) topographic model of the  $\sim 90$ m long cave system (Fig. 2). The photogrammetry is based on more than 6000 HD pictures, action camera and UAV videos (Fig. 3). The UAV was designed especially for the cave by the engineers, combining power, velocity and stability. Combined, both acquisition techniques offer a 3D textured model of the cave system with a precision that has never existed before (Fig. 4).

The current visit of Scladina is a guided tour of the cave system. The space has mostly been excavated and is therefore empty. In some areas deeper inside the cave the guide points out sedimentary profiles that allow him to explain the ways in which the cave was filled. Back in the museum, the visitor can view some objects that were found in the site, such as the Neanderthal child remains, stone tools and prehistoric animal bones. Although the visit is informative and receives good feedback from visitors, the objects are disconnected from the cave and it takes a lot of imagination for the visitor to visualise the cave when it was full of sediments or what it looked like during the time Neanderthals lived there.

The Scladina Cave visitor experience created by DigiArt will instead provide a fully immersive visit to the cave. It will present different scenarios, including media such as



Fig. 4 – Superposition of LiDAR and UAV 3D data within the Scladina Cave.

pictures, videos, 3D models of objects (Fig. 5) and animated avatars which will provide complementary information concerning the process of filling of the cave over time and the discovery of the Neanderthal child. Together, these media will innovate the ways in which the site is presented by placing the visitor in the centre of the experience. Through intuitive manipulations, they will be able to interact with their environment where objects are placed back inside the cave – in the location where they were discovered – while offering playful interactions (manipulation of objects, 3D animations...).

At the end of the project, the Scladina Cave experience will be available in two versions of the same product depending on whether visitors are physically inside the cave or not. The in-situ experience (inside the cave) will be based on augmented reality. Equipped with 3D glasses or tablets, visitors will walk into the cave and experience it as never be-

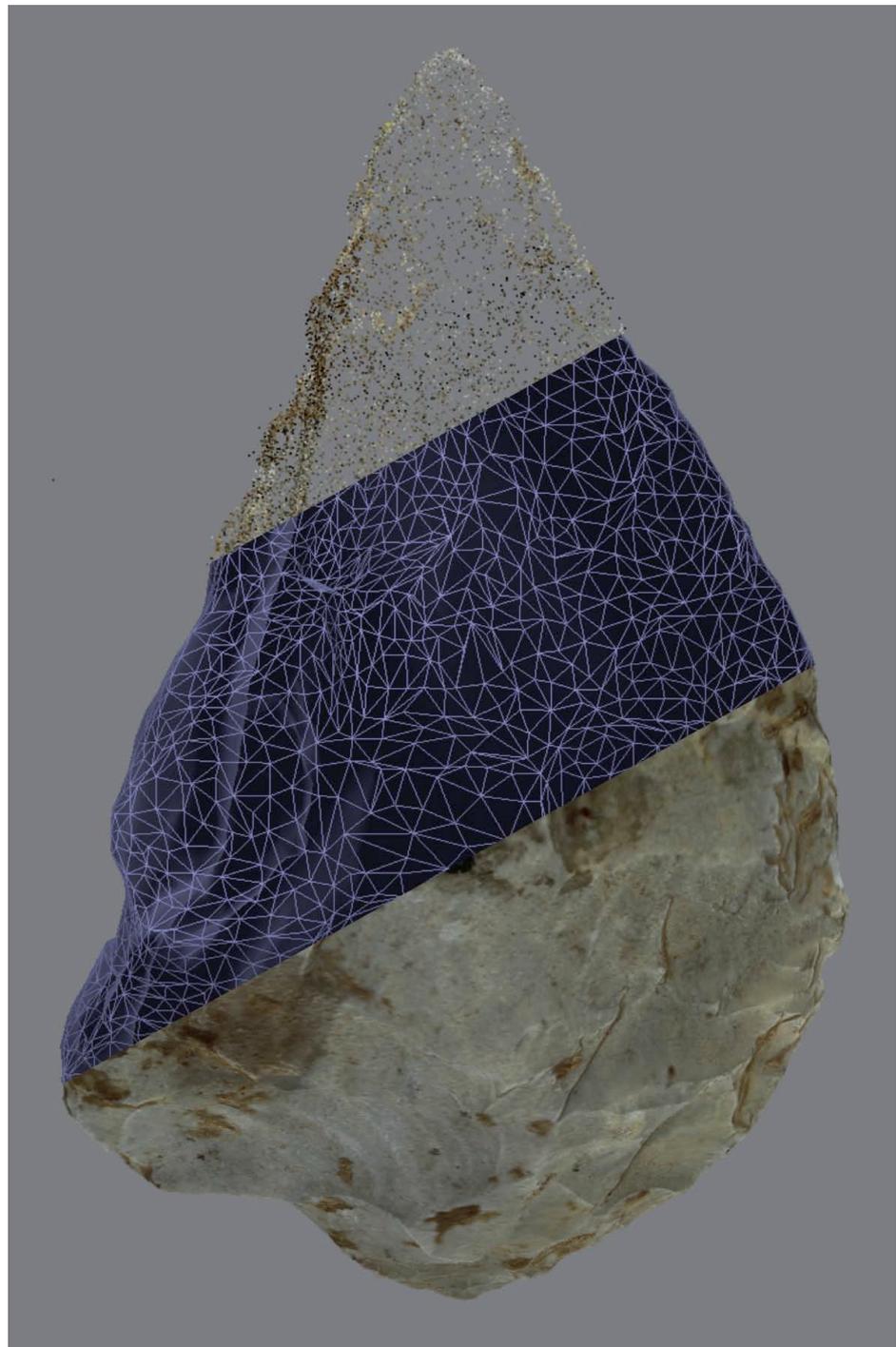


Fig. 5 – 3D model of a scraper made on flint (Scladina Unit 5; Sc82-333; L: 8,75 cm) highlighting the different steps from tie point cloud (upper part) to mesh (middle part), to the 3D textured model (lower part). Scale: 2/1.

fore. The objects will be visible where they were found in the cave, the sediments will re-appear where there is now a void and they will be able to find out more than ever before in what is now a connected visit. The off-site visit will be experienced as a new generation of FPS-like (First-Person Shooter) video games using the VR equipment (such as *Oculus Rift*). The visitor will walk through a completely reconstructed 3D model of the cave. By using VR technologies, they will be able to interact with the objects inside the cave, manipulate them and remove modern equipment, such as the metallic footbridge, to see the cave without it. This would not be possible without this technology. Although the process of creating these immersive virtual experiences sounds complicated, the aim is to develop simple tools for neophytes that will allow for frequent updates of the Scladina visitor experience to provide regular novelties and/or the elaboration of themed visits to keep the visitor wanting to return over and over again.

### 3. What's next?

The project has already challenged the engineers to think of ways in which to capture accurate data in a variety of cultural heritage settings. These have resulted in the development of new UAVs, adjustments in software and translating these to user-friendly tools to create virtual museums.

Frequently, archaeologists and curators are concerned by the use of all these new technologies and are conscious of the opportunities they provide, whether these are for preservation purposes (Mathys *et al.*, 2013), scientific analysis (Abrams, *in press*; Bello *et al.*, 2013; De Groote, 2011) or presentation to the public (Ververidis *et al.*, 2015). Unfortunately, most of the solutions developed to date are not affordable (due to costs associated with hardware and time) and seem difficult to master by most people. The tasks ahead for DigiArt are to make data acquisition faster and easier while maintaining its accuracy. There is much benefit to be gained from semantic meaning extraction such as connecting objects across sites, identification and classification, but these can only be implemented and become meaningful when there is a substantial database of 3D objects (Ioannidou *et al.*, 2016; Spampinato *et al.*, 2016).

Also, the user-friendly software being developed to create the virtual visitor experiences must be easy to use and understand. It must be written in language cultural heritage workers are familiar with or is easy to learn. Feedback from the museum partners in the consortium to the software and hardware developers are therefore fundamental to this project.

The final challenge will be to ensure the distribution and uptake of the DigiArt innovations by a wide community of cultural heritage workers. The tools will enable them to create their own 3D generated content and provide the landscape for setting-up and offering radically new immersive visitor experiences. Only then, when European cultural heritage communicates through DigiArt, through these experiences whether they are within museums, archaeological sites or from their own homes, will “*The Internet Of Historical Things*” truly exist.

## Bibliography

- ABRAMS G., in press. Palaeolithic bone re-touchers from Belgium: a preliminary overview of the recent research through historic and recently excavated bone collections. In: Hutson, J. M. (ed.), *The Origins of Bone Tool Technologies*, Verlag des Römisch-Germanischen Zentralmuseums, Mainz.
- APOLLONIO F. I., GAIANI M. & BENEDETTI B., 2012. 3D reality-based artefact models for the management of archaeological sites using 3D Gis: a framework starting from the case study of the Pompeii Archaeological area. *Journal of Archaeological Science*, 39: 1271-1287.
- AREVALILLO-HERRÁEZ M., GDEISAT M., LILLEY F. & BURTON D., 2016. A spatial algorithm to reduce phase wraps from two dimensional signals in fringe projection profilometry. *Optics and Lasers in Engineering*, 82: 70-78.
- ASHTON N., LEWIS S. G., DE GROOTE I., DUFFY S. M., BATES, M. BATES R., HOARE, P. LEWIS M., PARFITT S. A., PEGLAR S., WILLIAMS C. & STRINGER C., 2014. Hominin Footprints from Early Pleistocene Deposits at Happisburgh, UK. *PLoS ONE*, 9(2): e88329; <http://dx.doi.org/10.1371/journal.pone.0088329>
- BELLO, S. M., DE GROOTE, I. & DELBARRE G., 2013. Application of 3-dimensional microscopy and micro-CT scanning to the analysis of Magdalenian portable art on bone and antler. *Journal of Archaeological Science*, 40(5): 2464-2476.
- BURENS-CAROZZA A., GRUSSENMEYER P., GUILLEMIN S., CAROZZA L., LEVEQUE F. & MATHÉV., 2013. Methodological Developments in 3D scanning and modelling of archaeological French heritage site: the Bronze Age painted cave of « Les Fraux », Dordogne (France). *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 40(5): 131-135.
- DE GROOTE I., 2011. Femoral curvature in Neanderthals and modern humans: A 3D geometric morphometric analysis. *Journal of Human Evolution*, 60(5): 540-548.
- DUCKE B., SCORE D. & REEVES J., 2011. Multiview 3D reconstruction of the archaeological site at Weymouth from image series. *Computers & Graphics*, 35: 375-382.
- EMAUS R. & GOOSSENS R., 2015. Low cost 3D-modelling of a complex archaeological site using aerial photography in the hinterland of Petra, Jordan. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XL(5), W4.
- GALEAZZI F., 2016. Towards the definition of best 3D practices in archaeology: Assessing 3D documentation techniques for intra-site data recording. *Journal of Cultural Heritage*, 17: 159-169.
- GDEISAT M. A., BURTON D. R., LILLEY F., AREVALILLO-HERRÁEZ M. & AMMOUS, M., 2015. Aiding phase unwrapping by increasing the number of residues in two-dimensional wrapped-phase distributions. *Applied Optics*, 54(34): 10073-10078.
- GDEISAT M. A., BURTON D. R., LILLEY F. & AREVALILLO-HERRÁEZ M., 2016a. Fast Fringe Pattern Phase Demodulation using FIR Hilbert Transformers. *Optics Communications*, 359: 200-206.
- GDEISAT M., QUDEISAT M., ALSA'D M., BURTON D., LILLEY F. & AMMOUS M., 2016b. Simple and accurate empirical absolute volume calibration of a multi-sensor fringe projection system. *Optics and Lasers in Engineering*, 80: 32-44.
- IOANNIDOU A., CHATZILARI E., NIKOLOPOULOS S. & KOMPATNIARIS I., 2016, submitted. Advances in Deep Learning with 3D Data: A Survey. Submitted to *Journal of ACM Computing Surveys* (July 2016).
- KATSIANIS M., TSIPIDIS S., KOTSAKIS K. & KOUSOULAKOU A., 2008. A 3D digital workflow for archaeological intra-site research using GIS. *Journal of Archaeological Science*, 35: 655-667.
- KÜNG O., STRECHA C., BEYELER A., ZUFFEREY J.-C., FLOREANO D., FUA P. & GERVAIX, F., 2011. The accuracy of automatic photogrammetric techniques on ultra-light UAV imagery. In: *UAV-g 2011-Unmanned Aerial Vehicle in Geomatics*: EPFL-CONF-168806
- LOJEK J., 2012. The use of 3D graphic modelling in geoarchaeological investigations (Bykowszczyzna archaeological site near Kock, E Poland). *Contemporary Trends in Geoscience*, 1(1): 31-37.

MATHYS A., BRECKO J., DI MODICA K., ABRAMS G., BONJEAN D. & SEMAL P., 2013. Agora 3D. Low cost 3D imaging: a first look for field archaeology. *Notae Praehistoricae*, 33/2013: 33-42.

REMONDINO F., 2011. Advanced 3D recording techniques for the digital documentation and conservation heritage sites and objects. *Change Over Time*, 1(2): 198-214, 292.

SPAMPINATO C., PALAZZO S., JOALLAND P. H., PARIS S., GLOTIN H., BLANC K., LINGRAND D. & PRECIOSO F., 2016. Fine-grained object recognition in underwater visual data. *Multimedia Tools and Applications*, 75(3): 1701-1720.

VAUTHERIN J., RUTISHAUSER S., SCHNEIDER-ZAPP K., CHOI H. F., CHOVANCOVA V., GLASS A. & STRECHA C., 2016. Photogrammetric accuracy and modelling of rolling shutter cameras. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, III(3): 139-146.

VERVERIDIS D., NIKOLOPOULOS S. & KOMPATSIARIS I. 2015. Transforming your website to an augmented reality view. In: *Proceedings of the 14th IEEE International Symposium on Mixed and Augmented Reality, IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, poster, Fukuoka: 4 p.; [http://mklab.itl.gr/files/VerveridisISMAR15\\_POSTER.pdf](http://mklab.itl.gr/files/VerveridisISMAR15_POSTER.pdf)

### *Abstract*

DigiArt is a Europe-wide project aimed at providing a new, cost efficient solution to the capture, processing and display of cultural artefacts. The project will change the ways in which the public interact with cultural objects and spaces in a dramatic way. This project is unique in its collaborative approach: cultural heritage professionals working directly with electrical, mechanical, optical and software engineers to develop a solution to current issues faced by the museum sector. The innovations created by the engineers are driven by the demand of the cultural heritage sector. The diversity of the objects and spaces of the three test museums are challenging the engineers to provide a tool useful for a broad variety of indoor and outdoor museums in the future. This goes from using Unmanned Aerial Vehicle (UAVs or drones) to fly and record large sites, to using scanners to record fine jewellery.

As a case study, we present here the use-case of Scladina Cave. At the end of the project, the Scladina Cave Archaeological Centre will offer two different visitor experiences. The first uses virtual reality, which will be available anytime, anywhere, to anyone with an internet connected device. The second will use augmented reality technologies within the cave site. The augmented reality visit of the cave will enhance the tour of Scladina by offering visits that would not be possible where it not for the augmented reality, where 3D objects and animations will contribute to offer a new 3D-immersive experience.

*Keywords:* DigiArt, Cultural heritage, Digitisation, Virtual Reality, Augmented Reality, Scladina Cave.

### *Résumé*

DigiArt est un projet paneuropéen dont le but est de concevoir une nouvelle solution à faibles coûts pour la numérisation et le traitement 3D des objets patrimoniaux. Le projet va profondément modifier la vision et l'interaction que le public peut avoir avec les vestiges archéologiques. Par les partenaires qui le composent, le consortium est assez unique puisque les acteurs du monde culturel sont entourés d'ingénieurs actifs dans différents domaines (électricité, mécanique, optique et informatique). L'ingénierie se retrouve ici au service du monde muséal qui guide pas-à-pas le développement matériel et logiciel. Les contraintes imposées par les acteurs culturels (diversité de sites archéologiques et d'objets) mettent à l'épreuve les ingénieurs qui doivent proposer des solutions innovantes et faciles d'utilisation, compatibles tant avec des petits objets que de grands espaces qu'ils soient extérieurs ou intérieurs. Cet enregistrement peut se faire à la fois par des vols de drones pour les sites ou l'utilisation de scanners pour la joaillerie fine.

En tant que partenaire, la grotte Scladina bénéficie en premier lieu des développements liés à ce projet. Au final, deux nouvelles expériences de médiation seront proposées aux visiteurs. La première, basée sur la réalité virtuelle, externalisera la visite du site sur des supports connectés. La seconde utilisera la réalité augmentée pour plonger les visiteurs de Scladina dans une nouvelle expérience immersive. Dans Scladina, le public pourra alors y manipuler des objets 3D replacés virtuellement dans la grotte, à l'endroit de leur découverte, ou visualiser des animations 3D qui compléteront de manière ludique et immersive la visite de la grotte.

*Mots-clés:* Projet DigiArt, Patrimoine culturel, numérisation, réalité virtuel, réalité augmentée, grotte Scladina.

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