Heritage Science

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The Future of Heritage Science and Technologies: Papers from Florence Heri-Tech 2022

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The nexus between cultural heritage and cutting-edge technology has exceptional prospects for understanding, preserving and enhancing the material legacy of humanity. Cultural heritage treasures can now be widely investigated and accessed thanks to advanced technologies. These instruments not only enable the identification of inherent materials and their degradation pathways but also today can facilitate the creation of authentic, lifelike, and full-scale reconstructions.

Users can experience immersive trips to ancient civilizations, exploring heritage sites, and interacting in previously unheard-of ways with cultural items through virtual reality (VR) and augmented reality (AR) applications. Information and Communication Technology (ICT)-based devices also encourage interdisciplinary cooperation and creativity in the study and conservation of cultural resources. Data analytics, artificial intelligence (AI), and machine learning algorithms are becoming powerful tools for enabling academics, archaeologists, scientists, and conservators to examine extensive amount of information, interpret intricate patterns, and get fresh perspectives on past environments. Open-access repositories, including semantic information, as well as 3D digital models of artworks, enable group involvement in historical preservation and conservation projects by utilizing the combined knowledge and experience of various stakeholders. The investigation, analysis, and preservation of cultural items can now be achieved without risking damage to the items and often without removing sample material, thanks to the integration of non-invasive techniques such as hyperspectral imaging. Additive manufacturing, often referred to as 3D printing, offers innovative solutions for conservation challenges, enabling the creation of custom-fit replicas for damaged or missing components of heritage structures.

In this framework, the Collection "The Future of Heritage Science and Technologies: Papers from Florence Heri-Tech 2022" gathered 11 scientific papers by prominent authors participating at the Florence Heri-Tech International Conference, held in Florence, Italy, on 16–18 May 2022. The papers, selected underwent a rigorous peer review process conducted by experts chosen by the Heritage Science Journal showcase the remarkable potential of various technologies to advance and enhance research within the Cultural Heritage field, paving the way for future studies in this domain.

In the first paper [1] of the collection, "the use of reflectance Hyperspectral Imaging (HSI) in the Visible (Vis) and Near Infrared (NIR) range is combined with Deep Convolutional Neural Networks (CNN) to address the tasks related to ancient Egyptian hieroglyphs recognition". The methodology is applied to the case study of hieroglyphs in a wooden coffin belonging to the Egyptian collection of the Franciscan Ethnographic Museum in

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Fiesole, near Florence (Italy). A calibrated portable HSI camera was used to acquire hyperspectral data. Principal Component Analysis (PCA) is used to process HSI data, with the aim of facilitating the visualisation of salient features which might not be discernible to the naked eye. Two different approaches are tested for hieroglyphs segmentation: PCA followed by a CNN (for segmentation separately to each selected PC image), and CNN segmentation directly applied to each spectral image of the HSI data cube (single bands masks segmentation). The case study demonstrates the effectiveness of both methods, with the best results achievable by using single band masks. The study suggests that "the automated segmentation workflow can greatly benefit from the use of HSI images, particularly in the presence of degraded symbols, and highlights the potential of the proposed methodological approach as a new tool for segmenting HIS data".

The implementation of Artificial Intelligence-based methods is also used in Capece et al. [2] with a primary focus on the enhancement of user experience in cultural spaces. In detail, the work explores the use of advanced systems and technologies focusing on "human–computer interaction and the multilingualism of digital culture". It discusses "the evolution of user experience in personalized enjoyment and use of cultural places", as well as "the limitations and opportunities presented by data management and user privacy in using such systems". Moreover, it delves into the use of "sensors and devices to track user movement in the real world and translate inputs into commands through hand gestures, speech recognition, head movements, tangible interfaces, or a combination of these elements". This allows the user to "explore the diversity and richness of tangible and intangible cultural heritage through new forms of interaction and knowledge transfer, amplifying and personalizing the user experience".

The "liveliness of the world of research in the field of technologies for the digital development of museums and how many technologies commonly used in industry are increasingly finding their way into the cultural sphere" is described in Furferi et al. [3]. The authors provide "an overview of current methods and studies related to the use of technologies such as Artificial Intelligence (AI), Augmented Reality (AR), and Additive Manufacturing (AM) in museums". The paper highlights the potential for these technologies to improve public experience and education in the cultural sphere. The survey includes the implementation of various ICT tools to create interactive environments, establish new standards "of cooperation and interaction among museum educators, and form visual culture as a fundamental component in individual creativity". These tools are aimed at enhancing the visiting experience, improving engagement, and boosting interest in museums. Additionally, there is a trend of research focused on leveraging technologies such as "2.5D reconstruction, 3D acquisitions, linguistic tools, storytelling, and more", to enhance the fruition of artifacts in traditional museums. The use of modern communication technologies is also emphasized to explain the context of displayed objects or collections and personalize the interaction with users based on their experience, intentions, and level of understanding.

Dealing with the issue of Additive Manufacturing (or 3D printing), the importance of such a technology in the field of conservation, with a particular focus "on the most suitable material along with the ideal printing position that could provide moulds to produce anatomical wax facsimiles of artworks", is the main effort in the paper by Moga et al. [4]. It hints at many benefits deriving from the use of Additive Manufacturing for the preservation of original Artifacts: 3D printing allows conservators to create accurate replicas of e.g. wax anatomical sculptures without directly handling the original delicate artifacts, minimizing the risk of damage. Moreover, replicas produced through 3D printing can be used to test various conservation and restoration treatments before applying them to the original works, ensuring the effectiveness of the chosen approach. By carefully selecting materials and printing positions, 3D printing enables the production of moulds that provide maximum quality and fidelity in reproducing the original volumes of wax anatomical sculptures and help reducing the need for manual manipulations during interventions on cultural heritage objects.

To demonstrate the effectiveness of Multi Band Imaging (MSI), authors in Bolong et al. [5], performed such a technique "to obtain infrared-reflected false colour, ultraviolet-reflected false colour, and ultraviolet luminescence images of the Northern Wei Dynasty (386–534 CE) murals of Cave 254 in the Mogao Grottoes, China". Moreover, they used additional analytical instrumentation, including "a liquid chromatography–mass spectrometer, confocal Raman microscope, scanning electron microscope, energy dispersive X-ray spectrometer, and portable X-ray fluorescence spectrometer". In order to map the strata and identify the pigments in the local sections of various colour areas, non-invasive and minimally invasive analyses were carried out. The work also carries out a brief discussion of the connection between the mural's painting techniques and pigment colour shifts. The results of this investigation will open up fresh avenues for understanding murals from the Northern Wei Dynasty.

Colour assessment of aged inks is also studied in Xu et al. [6], where authors propose an experimental method for assessing the changes in the iron gall inks during the ageing process. Authors state that "commercial iron gall ink was used for this experiment, making the study more

applicable. In particular, several iron gall ink-stained paper specimens were subjected to an intense analytical program to investigate their chemical and physical modifications after ageing (temperature/humidity, temperature, and ultraviolet light aging)". X-ray photoelectron spectroscopy (XPS), colour variation, colour density, and absorbance were used to assess the changes in iron gall inks. Physical degradation primarily takes the form of ink aging, colour lightening, and decreased colour density. The samples that are exposed to damp heat for 30 days showed the biggest changes in colour. As an important outcome, the study shows that iron gall ink handwriting is significantly impacted by temperature, humidity, and ultraviolet light; therefore, iron gall ink documents in written archives require an appropriate storage environment to guarantee the preservation of important documents and data.

The "use of non-invasive, digital and cost-effective instruments for systematic inventory, monitoring and promotion" is also encouraged by authors in Santos et al. [7] which is mainly focused on the use of Geographic Information Systems (GIS) as a tool allowing "a powerful and effective inventory and analysis to support central and local entities responsible for cultural heritage management". The work focuses on "inventorying, safeguarding, tourism, and cultural promotion of the traditional Portuguese glazed tile ('azulejo', in Portuguese). The suggested GIS tool was tested using data from 70 tile works in the Portuguese city of Covilhã". The results included three pedestrian paths for the promotion of tourism and cultural heritage as well as a georeferenced inventory of images, drawings, and graphics. The findings, which predicted its growth and everyday application in the preservation of the legacy of the traditional Portuguese glazed tile, were confirmed by the research team and the municipality of Covilhã. Municipalities or organizations in charge of cultural heritage conservation can easily implement and oversee the suggested instrument, which can be duplicated in other places.

The authors in Salvatici et al. [8] emphasize the adoption of non-destructive methods, especially for in situ diagnosis of Cultural Heritage. Since the Uniaxial Compressive Strength (UCS) is a crucial measure of a rock's mechanical characteristics, especially during the diagnostic and restoration stages when stones are used as building materials, the main focus of their work is on using no-contact techniques to estimate UCS. Regression approaches were used to build three distinct UCS prediction models, one based on ultrasonic pulse velocity (Vp), one on Schmidt hammer tests (R), and one combining both. The dataset "included 45 Pietra Serena sandstone samples with different degrees of decay". After applying the models to a dataset of Vp and R values measured "in situ on Pietra Serena corbels of balconies belonging to historical buildings in Florence, Italy", Cross-Validation techniques were used to test the models' performance.

The focus of paper [9] is transferred to the realm of architectural heritage, where "a thorough understanding of the assets is essential for any restoration and conservation plan." To gather, arrange, and integrate data from various sources, inspections, and diagnoses, the Historical Building Information Modelling (HBIM) technique is used in this situation. In detail, "a novel procedure involving a fit-for-purpose inventory form and a scan-to-BIM approach is proposed". Multiple surveying approaches are used to expedite the data collecting process, and the modelling and information phases gain from the interoperability of many tools that are already familiar to experts in the field. Therefore, the primary innovation is the capability to manage the complete procedure with a single piece of software, guaranteeing effective and centralized control. This novel approach has been used to examine a sizable section of Pisa's city walls (Italy), demonstrating its capacity to assist in the decision-making stage of planned large-scale architectural heritage conservation.

Moving from research related to Museums and/or heritage artifacts, "the problem of aesthetic value protection and tourism development of the World Natural Heritage Sites (WNHSs)" is critically discussed in Zhang et al. [10]. The authors propose a comprehensive literature review of research in such a field by analysing several works collected in Web of Science and China National Knowledge Infrastructure databases. From the study it emerges that "the research in this field is progressively expanding", being China, Italy, and Australia, the primary regions studied in the literature. The notable research accomplishments are mostly based on the theoretical underpinnings, model building, monitoring and assessment, technical measures, and other aspects, as well as the implications for World Heritage Karst Sites (WHKSs), where "the majority of the research is mostly theoretical. There is relatively little research on model building, monitoring and assessment, and technical measures".

Finally, paper [11] addresses the digital organization of knowledge in the context of cultural heritage, with a focus on the Italian landscape. The paper deals with the construction and sharing of catalogues and ontologies, the use of audio descriptions for accessibility, and the role of guides in narrating cultural heritage. The work also delves into the potential of digital tools and technologies, such as Semantic Web, to enhance the accessibility and enjoyment of cultural heritage. Additionally, it highlights the need for adaptive and inclusive narratives to engage a diverse audience. Finally, the work emphasizes the importance of digitization, interoperability,

and long-term preservation in making cultural heritage accessible and sustainable.

In conclusion, the papers presented in this collection demonstrate how the diverse applications of cutting-edge technologies support developments in the field of cultural heritage and emphasize the importance of ICT-based methods for diagnosing and preserving cultural heritage. The research demonstrates how it is possible to expand the knowledge and skills of experienced practitioners and how to enable the development of new strategies to foster stakeholder involvement in a more fruitful development and improvement of the enormous world cultural heritage. Overall, the collection highlights the significant impact of technology on the research, preservation, and promotion of cultural heritage, providing valuable insights and seeds for future studies in the field.

Author contributions

RF wrote the first release of the manuscript and carried out the analysis of scientific literature, MPC, KS and AP revised the manuscript, FG made the final corrections. RF coordinated the literature research.

Declarations

Competing interests

Maria Perla Colombini and Francesco Gherardini are editorial board members of Heritage Science. The authors have no further conflicts of interest to declare.

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