Innovative Geospatial and Engineering Solutions for Cultural Heritage

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Abstract. Cultural heritage is facing increasing vulnerability due to various threats, including natural disasters, human activities, and the escalating impacts of climate change. This study examines how geospatial technologies and engineering solutions can address these issues, emphasizing their potential to improve monitoring, protection, and preservation practices for cultural heritage sites. Advanced geospatial technologies, such as non-contact geomatics sensors and structural analysis techniques, offer further capabilities for heritage monitoring. These tools enable the development of early warning systems to proactively identify and mitigate risks to monuments before significant damage occurs. Such systems support timely interventions, reducing restoration costs and safeguarding the integrity of heritage assets. By integrating advanced technologies with field-specific requirements, this study provides an overview of effective resource allocation. This paper highlights the objectives of two recently supported European and national ongoing projects of the Cyprus University of Technology (CUT), namely the "Geomatics and Civil Engineering Innovative Research on Heritage", in short ENGINEER and the "Research and Innovation Knowledge Centre for Engineering in Heritage", in short CONNECTING. Both projects' tasks aim to fill research multidisciplinary gaps, push, and extend knowledge into new and innovative fields dealing with the monitoring, digitization, visualization, and preservation of heritage monuments and cultural heritage sites, assisting their protection, promotion, and safeguarding with the contribution research activities through coordination and support actions as well as through targeted research activities with the support of European leading institutions.

Keywords: Cultural Heritage, Documentation, Remote Sensors, UAV, Earth Observation, Underwater Object Detection.

1 Intoduction

Cultural heritage is challenged with several threats, either natural or anthropogenic, including the far-reaching impacts of climate change, as highlighted by studies [1,2]. These challenges need to be addressed several times with significant financial constraints, and therefore the exploration of innovative and interdisciplinary solutions need to be further explored. To effectively address these issues, innovative approaches that can enhance our existing methods of heritage conservation are needed. These approaches can lead to a deeper appreciation for, as well as more robust protection and monitoring of, our invaluable heritage sites that reflect our history and identity.

To achieve this goal, we need to develop standardized methodologies that integrate cutting-edge technologies. For instance, non-contact geomatics sensors can provide detailed data regarding the geometry, shape and status of a site, without physically disturbing the sites. In addition, advanced structural analysis techniques can assess the integrity of these structures under stress. Additionally, conservation engineering can offer insights into best practices for maintaining the stability and longevity of h eritage sites.

By utilizing these advanced tools and technologies, we can establish early warning systems that identify at-risk monuments before damage occurs. This proactive approach not only aids in the preservation of these sites but also fosters a greater understanding of their historical significance and the factors that threaten them. Overall, enhancing our capabilities in heritage research and conservation is crucial for ensuring that future generations can appreciate and learn from these cultural treasures.

2 Addressing Research Gaps and End-User Requirements

Understanding the nature of captured data is of paramount importance when it comes to applying it effectively to specific conservation outcomes. This understanding is also critical for meeting the diverse data posed by end-users, which can be accomplished using suitable and cost-effective geomatic methods [3]. Moreover, several challenges remain regarding the potential for multi-use of (heterogenous) data. Such data must be added here to established standards that ensure reliability and compatibility. This adherence not only facilitates its use across different projects but also promotes collaboration on multidisciplinary initiatives, which are increasingly essential in today's complex environmental landscape. Policymakers and users expect high standards that encompass rigorous specifications for data quality, accuracy, and format, adding another layer of complexity to data management in conservation.

In addition to these challenges, there are ongoing concerns surrounding data integration and fusion. The interdisciplinary application of digital techniques requires a thoughtful selection of workflows that accommodate the varied nature of data sources. Data flexibility options must be considered carefully, as they can significantly impact how well different data types and sources can work together. The integration of data from disparate sources presents both opportunities and obstacles, with each source offering unique pathways for integration into a coherent whole.

Furthermore, while adhering to established data types and standards can enhance the potential for maximum data reuse, it is equally important to understand the associated limitations and benefits that come with specific techniques. Each method and sensor carry its own implications for data accuracy, usability, and interoperability. Therefore, a better understanding of these factors is essential for maximizing the effectiveness of conservation efforts and ensuring that the data can be leveraged to its fullest potential across various applications. This comprehensive approach enables more informed decision-making in conservation.

By fostering a synergy between geomatic techniques—such as surveying, mapping, and data analysis—and civil engineering practices, the projects seek to enhance methodologies in the preservation and management of cultural heritage sites [3]. This comprehensive approach promotes knowledge sharing and encourages the development of new technologies and strategies that could significantly benefit heritage engineering. The authors are coordinating two relevant projects (ENGINEER and CONNECTING) that aim to address and bridge existing gaps between geomatic engineering and civil engineering. This collaboration emphasizes integrating these two disciplines through well-structured training programs and targeted research activities.

3 The motivation

The ENGINEER project represents a groundbreaking initiative focusing on innovative research in heritage preservation. Alongside it, the CONNECTING project aims to establish a knowledge centre dedicated to engineering in heritage. The thematic priority of both projects is intricately linked to the Smart Specialisation Strategy of Cyprus (S3Cy). This strategy is designed to foster sustainable development throughout the country, tapping into its unique characteristics and robust research eco-system.

The final report of S3Cy underscores the critical role of cultural heritage as a foundational pillar for the future development of Cyprus. It emphasizes that cultural heritage is not only a source of national pride but also a vital resource that can drive economic growth and innovation. The report details how this cultural heritage interacts with various sectors, particularly tourism, which serves as a significant economic engine for Cyprus [4]. By attracting visitors to its rich historical sites and traditions, tourism contributes substantially to the country’s GDP.

Furthermore, the report highlights the potential of integrating information and communication technology (ICT) into cultural heritage initiatives. Utilizing ICT can enhance the preservation, promotion, and accessibility of Cyprus's cultural assets, thereby creating new opportunities for sustainable tourism and economic diversification.

Recent studies conducted across Europe and in various regions around the world have demonstrated that heritage can significantly contribute to the growth of the real economy. This impact is particularly evident through the development of innovative tourism concepts such as cultural tourism, geotourism, and sustainable tourism [1,3]. These forms of tourism not only promote the appreciation and preservation of local culture and natural landscapes but also attract visitors who are eager to engage with and experience unique historical and cultural sites.

Moreover, the construction industry also benefits from heritage initiatives, as the restoration and maintenance of heritage buildings create jobs and stimulate economic activity. The careful preservation of these structures not only protects the architectural and historical significance of communities but also enhances their appeal as tourist destinations. Collectively, these efforts underscore the importance of heritage as an asset that can drive economic growth and sustainability. This collaborative approach between cultural heritage and other disciplines is vital for ensuring the long-term prosperity and resilience of Cyprus in a rapidly changing global landscape.

4 Recent Studies

Developing innovative methodologies for the long-term monitoring of heritage monuments is crucial for ensuring their preservation and resilience. These methodologies should not only account for current conditions but also proactively actively anticipate potential adverse effects such as climate change and geological events like earthquakes. Investing in these preventive measures will be more cost-effective than addressing the consequences that arise once damage has occurred.

The societal impact of losing a heritage monument is profound and irreparable, as these structures embody our history, culture, and identity. Therefore, comprehensive digital documentation of these monuments is essential. This process entails creating detailed records of their condition before potential damage occurs, thus providing a vital baseline for preservation efforts. Digital documentation aids in capturing architectural details, analyzing structural integrity over time identifying early signs of deterioration.

The project's objectives are centred on establishing robust standards and protocols for the ongoing monitoring of built heritage [5]. This includes developing guidelines for data collection, analysis, and reporting and ensuring these standards align with best practices in heritage conservation. By implementing these measures, we can safe-guard our cultural legacy against the growing threats posed by environmental natural disasters, securing the future of these invaluable monuments for generations to come.

4.1 Ground motion data from the EGMS

A recent case study conducted in Cyprus, as part of the multidisciplinary ENGINEER project, showcased the European Ground Motion Service (EGMS) in its ability to deliver consistent and reliable information about ground movement in monuments and heritage sites, achieving millimeter-level accuracy over extensive areas. The EGMS holds significant potential for monitoring cultural heritage sites, acting as an early warning system for local and national authorities tasked with heritage management and protection. Furthermore, the data provided by EGMS is especially beneficial in tracking less accessible regions, which are often challenging to monitor using conventional methods [6].

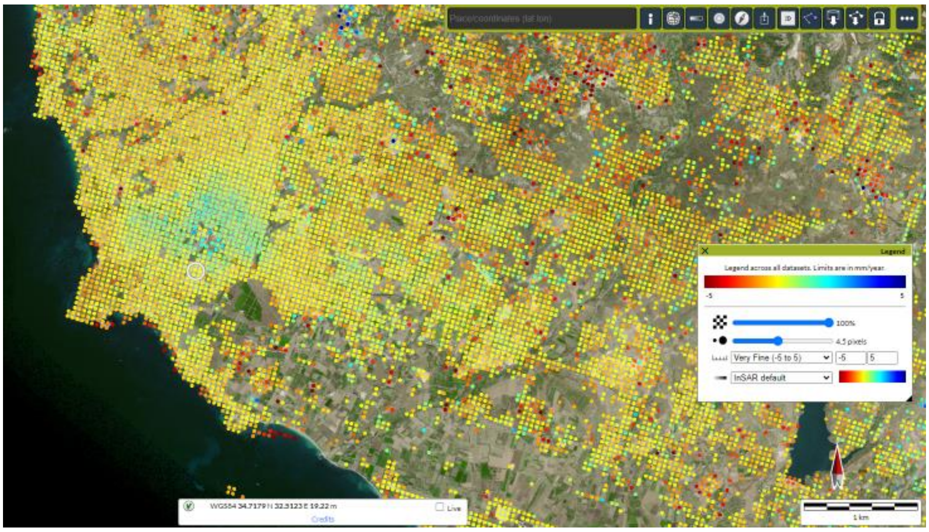

Figure 1. EGMS results over the wider Paphos area [6].

This study was specifically focused on the ground motion data from the EGMS concerning the Paphos district in western Cyprus. Spanning nearly 1,400 square kilometers, the Paphos district accounts for 15.1% of the island's total area (Figure 1). This region houses 147 ancient monuments and archaeological sites that are safeguarded under the Antiq-uities Law of the Republic of Cyprus. Notably, several of these sites, including Ancient Nea Paphos and the Tombs of the Kings, are designated as UNESCO World Heritage Sites. The recorded displacements at the sites of the selected monuments will be applied to the supports of the numerical model, enabling us to calculate the resulting stresses on the monument walls (Figure 2). This methodology takes into account soil-structure interaction and facilitates the mapping of damage patterns on the monuments. Consequently, it will offer valuable insights into the damage caused by ground movement, allowing for a clear distinction between this damage and any damage resulting from prior seismic events.

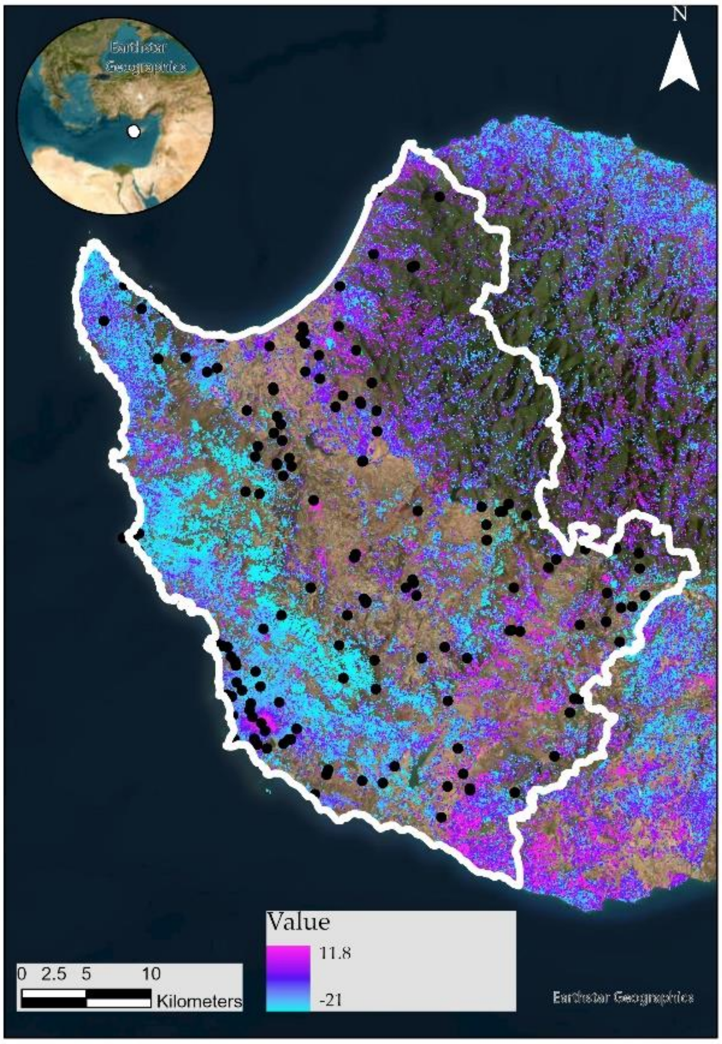

Figure 2. Vertical displacement (expressed in mm) over the Paphos district, using the 2016-2021 EGMS results. Protected archaeological sites are shown with dots [6].

4.2 Monitoring underground heritage sites

The authors have also conducted int the past a detailed case study to investigate the monitoring of underground heritage sites, with a particular emphasis on understanding the relationship between damage conditions and historical seismic activity for tomb T4, located within the Tombs of the Kings Necropolis, which is recognized as a UNESCO World Heritage site (Kyriakides et al., 2017) [7]. This study aimed to assess how past seismic events may have impacted the structural integrity and preservation of the tomb. In addition to the case study, the authors carried out a comprehensive simulation study that utilized data derived from a comparable seismotectonic environment. This simulation was carefully scaled to reflect the anticipated seismic hazards specific to the region of the Tombs of the Kings. The findings aimed to enhance the understanding of risk factors affecting the site and to develop potential strategies for safeguarding these invaluable heritage assets against future seismic threats [3]. Similar work is currently replicated as part of the ENGINEER project for Tomb 7 (see Figure 3) where close range and other photogrammetric data are been used to model the site.

Figure 3. Point cloud using drone data from Tomb 7, "Tombs of the Kings archaeological site" [6].

4.3 The case of the Roman Baths of Amathus in Limassol, Cyprus

In recent years, the integration of geomatic techniques with varying levels of accuracy and resolution has been applied to the geometric documentation of numerous archaeological sites. A case study was conducted on the Roman Baths of Amathus in Limassol, utilizing both aerial photogrammetry and Terrestrial Laser Scanning (TLS) methods to achieve the final results. The archaeological site of Amathus, recognized as a UNESCO World Heritage site, is located 10 km east of Limassol's center. It stands as one of the most important historical sites in Cyprus. This case study examines the Roman Baths and the Doric columns (Figure 4), positioned beyond the Roman market (Agora), which together encompass an area of approximately 625 m² (around 25 m x 25 m) [8].

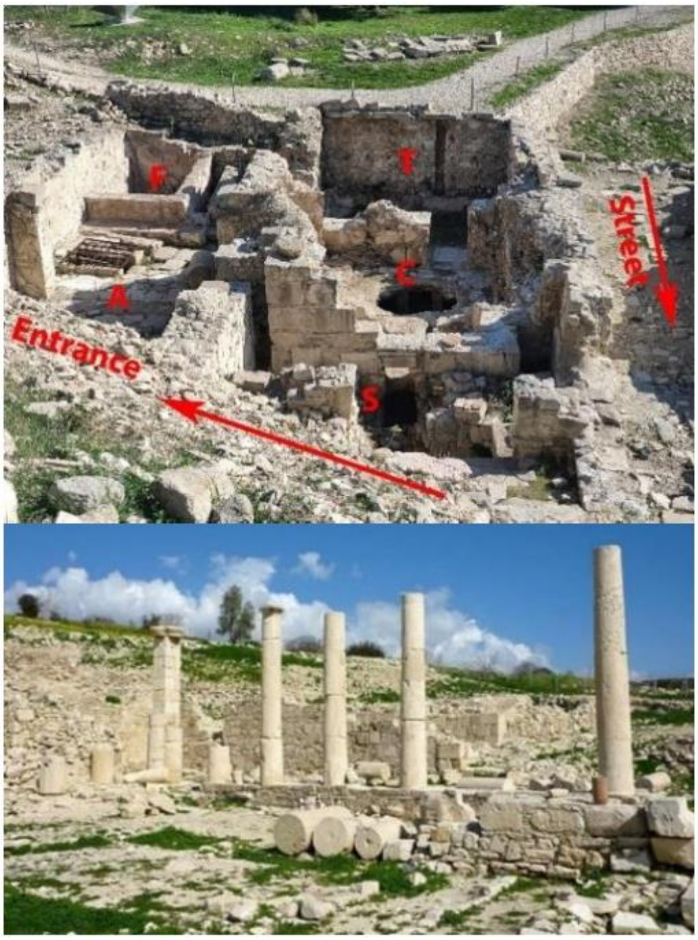

Figure 4. The Roman Baths (above) and the columns (below) [8].

The photogrammetric data were collected using Post-Processed Kinematic (PPK) imagery, while the TLS georeferencing relied on specific targets. The primary aim of this study was to evaluate the reliability of PPK photogrammetric data without the use of Ground Control Points (GCPs) and to assess how effectively these data could be integrated with TLS data. Additionally, the two acquisition techniques were compared, demonstrating that aerial images with a Ground Sampling Distance (GSD) resolution of 0.005 m can be qualitatively fused with TLS scans at a resolution of 0.0061 m per 10 m [8]. This research provides a comprehensive overview of the methodology leading to the development of the final 3D photorealistic product (Figure 5).

Figure 5: Photogrammetric 3D mesh of Roman bath, Amathus [8]

5 Proposed Research Infrastructure Gains

The CONNECTING consortium aims to provide equipment with cutting-edge ground-based terrestrial laser scanners and sensors, known for their versatility in monitoring the stability of monuments and sites [9].

These tools, along with low-altitude active and passive sensors such as LiDAR, RGB, and multi- and hyperspectral drone sensors, are designed for quick and precise assessments. They generate high-resolution thematic maps and create 3D representations of landscapes and urban areas, bridging the observation gap between satellite and ground-based data. Their versatility also extends to underwater applications, offering a wide range of potential uses. The CONNECTING project is designed to support the European Commission's vision of creating a collaborative cloud platform dedicated to cultural heritage by the year 2025. This ambitious initiative seeks to foster meaningful partnerships among cultural heritage professionals throughout the European Union. By leveraging cutting-edge digital tools and technologies, the project aims to enhance the preservation and accessibility of European cultural treasures. The goal is to establish a comprehensive digital infrastructure that allows for effective sharing, collaboration, and innovation within the cultural heritage sector, ensuring that these invaluable resources are safeguarded for future generations [10]. An overview of the proposed infrastructure to be acquired is depicted in Figure 6.

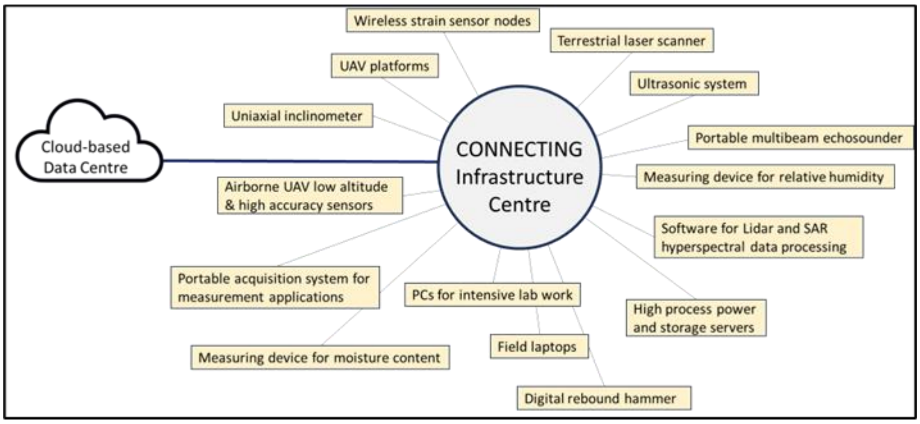

Figure 6: Proposed research infrastructure of the CONNECTING project [8].

The following section, provides a brief overview of the sensors and methodologies currently used for cultural heritage documentation and monitoring, categorized by the platform or environment where they are most used, based on published papers. Indeed, this meta-analysis of the literature review [11] was based on the available literature and published documents accessible from the Scopus engine (accessed on 8 August 2023). A comprehensive series of analyses was conducted, revealing a significant finding regarding the nature of review papers in the field. It was observed that these papers, whether they are published in peer-reviewed scientific journals or presented as part of conference proceedings, concentrate on applications associated with remote sensing and photogrammetry. An overview of the research landscape of heritage based on keywords from several published papers found in Scopus Engine [see more in 9] is depicted in Figure 7.

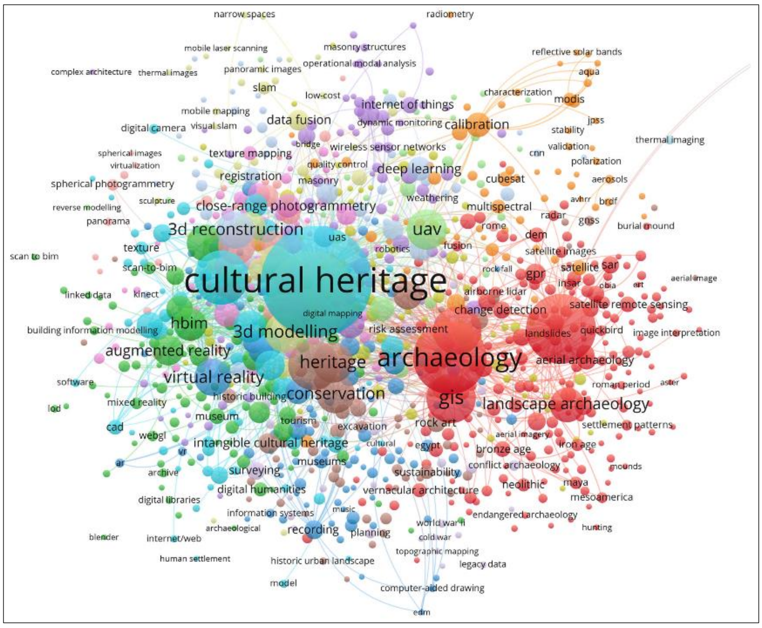

Figure 7: Co-occurrence analysis based on keywords from published papers found in Scopus engine [11].

Emerging fields can be also identified from such literature review analysis. Table 1 generates a summary list of keywords (top 25) associated with citation bursts. The visualization highlights the keywords with the most significant citation bursts and identifies the time periods during which these bursts occurred, marked in red to indicate their start and end. For example, in early 2010, terms like three-dimensional, sensors, calibration, image processing, and satellite were prominent in the literature. Of particular interest are the final rows in Table 1, which reveal emerging trends in research domains, such as the adoption of UAVs, antennas, monitoring, and deep learning. Details regarding the sensors are found in the following subsections.

Table 1. List of keywords (top 25) that are associated with citation bursts (red color indicates the period where the specific keyword is substantial refer to the literature).

Keywords	Year	Strength	Begin	End	2010–2022
three dimensional	2010	83.76	2010	2013	
sensors	2010	32.9	2010	2013	
calibration	2010	25.88	2010	2016	
image processing	2010	23.25	2010	2016	
satellites	2010	20.22	2010	2016	
design	2010	19.42	2010	2012	
research	2010	17.87	2010	2013	

nasa	2010	16.64	2010	2012
photography	2011	26.98	2011	2015
laser scanner	2011	19.09	2011	2013
terrestrial laser scanning	2012	13.76	2012	2017
surface analysis	2010	33.21	2013	2017
system program documentation	2013	19.44	2013	2015
spectroscopy	2013	15.4	2013	2014
information management	2012	16.69	2015	2019
3 d modeling	2012	16.24	2015	2017
close-range photogrammetry	2010	18.41	2016	2017
structure from motion	2013	25.45	2017	2019
uav	2014	19.27	2017	2022
antennas	2017	36.93	2018	2022
heritage	2016	16.03	2018	2022
landscape archaeology	2019	16.18	2019	2020
textures	2012	15.8	2019	2020
monitoring	2010	14.93	2019	2022
deep learning	2020	31.28	2020	2022

5.1 Close-Range Sensors

RGB Sensors

RGB sensors are passive sensors, commonly used for closed-range photogrammetric applications. These sensors operate in the visible part of the spectrum, between 380–750 nm. While CMOS sensors are sensitive to approximately 350–1050 nm, an infrared filter (750–1000 nm) is applied to reproduce natural colors visible to humans. By replacing the infrared filter with a red one, some cameras can be easily customized to near infrared, hence CMOS records infrared wavelengths into the red channel of the RGB image file [11].

This cutting-edge platform is engineered for extended endurance, offering impressive flight times that enable lengthy operational missions in various environments. Its robust design incorporates weatherproof capabilities, making it suitable for a wide range of weather conditions. The variety of RGB cameras available in the cultural heritage sector is unmatched. These cameras are categorized by their sensors and lenses. CMOS sensors are classified by physical size and resolution, while lens characteristics include focal length and ma-terial, with glass preferred over plastic.

Manufacturers prioritize different features based on the camera's intended use and cost. For instance, rigidity is important for 3D reconstruction but may increase weight, complicating drone mounting. Interchangeable lenses offer versatility but add size and weight, and features like LCD screens may be unnecessary for drones. Key features for specific applications include recording in raw format, remote control connections, and synchronization for precise triggering. While primarily used for documentation, these cameras are also employed in 3D reconstruction through techniques like Structure from Motion (SfM) and Multi-View Stereo (MVS). Calibration is essential to achieve color accuracy and geometric precision, often requiring ground control points measured with a total station. 360° cameras are gaining popularity for quickly capturing comprehensive data, with applications in virtual tours and 3D reconstruction. Affordable cameras can create virtual tours, but high-quality 3D reconstruction needs specialized cameras with arrays of sensors. The most common setup features are two back-to-back image sensors with 180° lenses, while advanced models use 3 to 25 sensors to minimize distortion and enhance resolution, crucial for effective 3D reconstruction.

Terrestrial Laser Scanners

LiDAR technology in Terrestrial Laser Scanners (TLS) uses active sensors that emit laser beams in the 900–1064 nm wavelength range. These beams reflect off nearby objects, allowing the scanner to measure the distance through time of flight (TOF) or phase shift. Modern TLS devices can capture a 360° × 270° field of view and acquire points at rates from 30,000 to 2 million points per second. Key TLS characteristics include angular resolution, distance accuracy, signal-to-noise ratio, and the presence of a coaxial RGB camera. The final point accuracy typically ranges from 5 to 15 mm at 100 meters. During post-processing, point clouds undergo co-registration or geo-registration, often using spherical targets and combining total stations with Global Navigation Satellite Systems (GNSS). Iterative Closest Point (ICP) algorithms are employed for alignment. Many TLS units also incorporate complementary sensors like GNSS and barometers to improve initial positioning. Some modern systems use LiDAR or visual Simultaneous Localization and Mapping (SLAM) techniques for co-registration, allowing for mobility during data acquisition. Scanners can be handheld, vehicle-mounted, or drone-mounted, enabling faster data collection, although this may result in lower accuracy, typically between 30 mm and 50 mm at 100 meters. Regular professional calibration and servicing are crucial for maintaining the performance of these complex instruments.

5.2 Low-Altitude Sensors

Drones use similar sensors for low-altitude applications, with onboard RGB sensors that enable better photography positions and angles. The introduction of location-aware drones with single-frequency GNSS in the early 2010s led to autonomous flights for large-scale mapping. Subsequently, multicopter drones captured oblique photographs for detailed 3D reconstructions of cultural heritage sites.

Onboard cameras are optimized for weight and space but resemble standard cameras. The adjustable flying height allows for control over image scale without needing interchangeable lenses, with wide-angle lenses preferred for their favorable base-to-height ratio and height precision.

Manufacturers prioritize small, lightweight cameras, often custom-made without extra accessories. While cameras and drones are technically separate, many vendors have created combined solutions that limit user choices. Some drones offer various payload options, including RGB, thermal, multispectral, hyperspectral, and LiDAR sensors, but these cater to specialized applications.

5.3 Underwater Sensors

Underwater RGB sensors function passively but become active with flash or artificial lighting. Natural sunlight decreases with depth, making it difficult to capture clear photos without external light. Additionally, water absorbs infrared, red, and green wavelengths, resulting in a predominant blue hue, which complicates color accuracy despite using color checkers. This variability in light attenuation depends on environmental factors and the distance from the light source to the subject.

This leads to significant color differences in underwater images, prompting ongoing research into haze removal and color restoration techniques, although no universal solution exists. When a camera is in a watertight enclosure, light passes through multiple media, invalidating the principle of straight light transmission. If the camera is properly aligned, geometric image deformations can be corrected with existing lens distortion models and through self-calibration.

Dome ports are more effective than flat ports, which can introduce additional deformation, such as color aberration. The advent of Structure from Motion (SfM) and Multi-View Stereo (MVS) techniques has led to the development of various applications for documenting underwater heritage. Recently, efforts have been undertaken to address the challenge of color degradation in deep waters under artificial lighting conditions [12]. The authors introduced an initial solution to the significant loss of color in these environments using a self-adaptive color calibration method. This approach is independent of physical and environmental parameters and incorporates Structure from Motion (SfM), Multi-View Stereo (MVS), and Fast Nearest Neighbor (FNN) techniques.

5.4 Aerial and Satellite Sensors

Aerial and satellite sensors have become essential tools for studying cultural heritage. Aerial photogrammetry, one of the oldest methods for surveying extensive archaeological sites and heritage objects, has proven valuable in this field. Archived aerial images are particularly significant, as they provide important information about landscapes that have changed due to modern construction.

In recent years, the use of sensors on satellite platforms has also increased significantly. This growth is primarily due to advancements in the space sector, which have enhanced the capabilities of these satellites to deliver improved spatial and spectral imagery. Contemporary satellites can capture multispectral and hyperspectral data across a range of approximately 380 nm to 2500 nm, and thermal sensors with resolutions as high as 5 meters are now available.

6 Discussion

This paper envisions to promote research potentials towards the better protection, management, and documentation of cultural heritage sites of Cyprus. CUT's projects pathways to impact involve supporting emerging multidisciplinary needs for monitoring, documenting, analyzing, and preserving cultural heritage sites on land and underwater. The project's expected results include:

- knowledge in data collection and integration in cultural heritage,
- implementing a cloud Data Centre,
- developing geospatial fusion techniques and creating databases and datasets of cultural heritage sites.

Additionally, the project aims to implement security measures, establish guidelines for standards, and train researchers. A Communication, Dissemination, and Exploitation plan will support the project outcomes. These projects focus on reaching academia, the research community, professionals, private industry, stakeholders, public authorities, and the public interested in innovative technologies, research, cultural heritage, and schools. The preliminary outcomes highlight the potential of the infrastructure, making it open to external users and potential collaborators. Innovative technologies for heritage documentation can impact a range of economic, social, and technological developments.

By utilizing these innovative technologies for heritage documentation, we will enhance public awareness and appreciation of cultural heritage while facilitating knowledge sharing and cultural exchange. Technological advancements will include linking cloud data centers and showcasing innovative methods for documenting cultural heritage. This is expected to lead to breakthroughs in computer vision, machine learning, and robotics, resulting in the development of new tools and software. These technologies can also create new applications in urban planning, architecture, and geospatial analysis.

Also, the project seeks to promote innovative technologies for heritage documentation, offering businesses opportunities to develop and market innovative products and services, such as virtual tours and online education programs. Finally, the ongoing projects can have a positive environmental impact by reducing the need for on-site visits and traditional surveying methods, which generate carbon emissions.

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References

1. Agapiou, A., Lysandrou, V., Hadjimitsis, D.G., 2020. Earth observation contribution to cultural heritage disaster risk management: Case study of eastern mediterranean open air archaeological monuments and sites. Remote Sens. 12. https://doi.org/10.3390/RS12081330
2. Sesana, E., Gagnon, A.S., Ciantelli, C., Cassar, J.A., Hughes, J.J., 2021. Climate change impacts on cultural heritage: A literature review. Wiley Interdiscip. Rev. Clim. Chang. 12, 1–29. https://doi.org/10.1002/wcc.710
3. Agapiou A., Aktas Y. D., Barazzetti L., Costa A., Cuca B., D.' Ayala D., Kyriakides N., Kyriakidis P., Lysandrou V., Oreni D., Previtali M., Skarlatos D., Tavares A., Vlachos M., Geomatics and civil engineering innovative research on heritage: introducing the "ENGINEER" project, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLVIII-M-2-2023, 27–32, https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-27-2023, 2023.
4. ENGINEER project, www. https://engineer-twinning.eu (accessed 24th of Oct. 2023)
5. Argyrou A., Aktas Y., Barazzetti L., Costa A., Cuca B., D'Ayala D., Gravanis E., Hadjipetrou S., Kafataris G., Kyriakides N., Kyriakidis P., Lysandrou V., Michaelides K., Nisantzi A., Oreni D., Previtali M., Skarlatos D., Tavares A., Vlachos M., Votsis R., Agapiou A., Synopsis of activities of the ENGINEER project, 5th CAA-GR Conference 2024, 16-17 April, Serres, Greece.
6. Agapiou A., Lysandrou V., Kyriakidis P., Hadjipetrou S., Kyriakides N., Votsis R., European Ground Motion Service for built heritage: a case study from Cyprus, 13th International Symposium on Digital Earth, 11-14 July 2023, Athens Greece.
7. Kyriakides, N., Lysandrou, V., Agapiou, A., Illampas, R., Charalambous, E., 2017. Correlating damage condition with historical seismic activity in underground sepulchral monuments of Cyprus. J. Archaeol. Sci. Reports 14, 734–741. https://doi.org/10.1016/j.jasrep.2016.07.007
8. Kafataris, G., Skarlatos, D., and Vlachos, M.: FUSION OF DIRECT GEOREFERENCED AERIAL DRONE WITH TERRESTRIAL LASER SCANNER DATA THE CASE OF THE ROMAN BATHS OF AMATHUS, CYPRUS, ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., X-1/W1-2023, 1057–1064, https://doi.org/10.5194/isprs-annals-X-1-W1-2023-1057-2023, 2023.
9. Connecting Project, https://connecting-infra.eu (accessed 12th of Dec. 2023)
10. Argyrou, A., Chamberlain,M., Demesticha, S., Demetriou, D., Filippopoulos, I., Frangoudi, G., Gravanis, E., Hadjipetrou, S., Kafataris, G., Kounnou, C., Kyriakides, N., Kyriakidis, P., Lysandrou, V., Michaelides, K., Nisantzi, A., Noussi, E., Papakonstantinou, A., Sarris, A., Skarlatos, D., Vlachos, M., Votsis, R. and Agapiou, A., Introducing the CONNECTING Alliance: A Small-Scale Infrastructure Project for Supporting Research and Innovation for Heritage, 5th CAA-GR Conference 2024, "Transforming heritage research in a transforming world",16-17 April 2024, Serres, Greece
11. Agapiou, A.; Skarlatos, D. Geomatic Sensors for Heritage Documentation: A Meta-Analysis of the Scientific Literature. Heritage 2023, 6, 6843-6861. https://doi.org/10.3390/heritage6100357

12. Vlachos, M.; Skarlatos, D. Self-Adaptive Colour Calibration of Deep Underwater Images Using FNN and SfM-MVS-Generated Depth Maps. Remote Sens. 2024, 16, 1279.
13. Gallwey, J.; Eyre, M.; Tonkins, M.; Coggan, J. Bringing lunar LiDAR back down to earth: Mapping our industrial heritage through deep transfer learning. Remote Sens. 2019, 11, 1994.