Integration of Diverse Geomatics Backgrounds for the Documentation of Cultural Heritage. A Summer School on Pogoni’s Stone Bridges

Andrea Adami [3], Kostantinos Bellos [4], Athanasios Iliodromitis [1], Vassilis Pagounis [1], Dimitrios Anastasiou [2], Georgios Papaioannou [5], Vassilis Tsioukas [4], Daniele Treccani [3]

[1] Research Unit of Geodesy-Surveying & GNSS, Dept. of Surveying & Geoinformatics Engineering, University of West Attica - a.iliodromitis@uniwa.gr, pagounis@uniwa.gr
[2] School of Rural, Surveying and Geoinformatics Engineering, National Technical University of Athens - danastasiou@mail.ntua.gr
[3] Unesco Research Lab, Campus Mantova, Dept. ABC, Politecnico di Milano - andrea.adami@polimi.it, daniele.treccani@polimi.it
[4] School of Rural and Surveying Engineering, Aristotle University of Thessaloniki - Costas.Bellos@hotmail.com, tsioukas@topo.auth.gr
[5] Museology Research Laboratory, Dept of Archives, Library Science and Museology, Ionian University - gpapaioa@ionio.gr

Keywords: Education, Cultural Heritage, Laser scanner, GNSS, Photogrammetry, SLAM.

Abstract

The paper describes the training activity -a summer school- that took place in Pogoni, in the Greek region of Epirus, in the summer of 2024. The school's main objective was to train students from diverse backgrounds on the digitization of historical Cultural Heritage. Specifically, this school, however, tackled very specific features regarding its main subject (heritage) and the knowledge addressed in it. The cultural heritage subject of the digitization was a small number of stone bridges in the Pogoni region of Greece. These bridges, which can be ascribed to a fairly broad historical period, are, however, characterised by strong similarities that configure them as a widespread, albeit punctiform, heritage. These include the materials used, construction techniques, and locations. These characteristics require a comprehensive disciplinary approach. The discipline of Geomatics, characterised by the common goal of measuring, from the Earth down to the small objects, with known precision, has within it several interests related both to the development of tools and technologies used and to their application. The students who participated in Pogoni's summer school had diverse backgrounds (from engineering to architecture) and found themselves among their teaching staff in a group of experts in digitization for cultural heritage, GIS, GNSS, and SLAM, articulated among academic faculties from architecture and engineering schools. This activity was an opportunity for educational growth for the students as well as professional exchange for the faculty. The results reflected the different deliverables of the summer school, not only in the first papers produced during the school, but also in the final products (georeferenced point clouds, drawings, orthophotos, master’s degree thesis), which were collected in a dedicated spatial information system.

1. Introduction

1.1 Pogoni Summer School

There is a long tradition of both academic and non-academic training courses -such as the so-called "summer schools"- in the field of Cultural Heritage documentation. This is due to several factors. On one hand, documentation is a cross-disciplinary activity that does not pertain to a single field of study but rather requires a multidisciplinary approach. It is sometimes assumed to be merely a technical operation, where the application of a technology or method is sufficient for success. However, as in-depth studies on architectural and cultural heritage surveying have shown, the effectiveness of Cultural Heritage documentation relies on the fact that measurement and data processing operations must be guided by a cognitive and interpretative model that determines the results. There is no such thing as the absolute "perfect" survey—only a proper survey concerning a well-defined objective. From this perspective, it becomes evident that Cultural Heritage documentation requires at least an understanding of the value of the asset and the recognition of its material, cultural, and social characteristics. This field, therefore, involves not only Geomatics but also Conservation, Valorization, History, and Construction Technologies, to name a few of the main disciplines.
Moreover, another distinctive aspect of Cultural Heritage is the challenge of establishing universally recognized and -above all-applied standard rules for documentation. Each asset, due to its technological characteristics, geographical location, and historical background, requires a different approach that can only be developed by adapting general principles, techniques, and tools. Furthermore, since Cultural Heritage documentation is multidisciplinary, it involves various specialists, including architects, conservators, and engineers.

The diversity of the disciplines involved, the professionals active in the field, the numerous case studies, and the multiplicity of objectives all justify the need for specialized training programs, including extracurricular educational activities. Additionally, the continuous technological innovation driven by digital advancements provides new methods and approaches, which in turn require constant updates and professional development.

The uniqueness of the educational activity described in this article lies in the fact that, while still within the field of Geomatics, the training offer is targeted at different sectors of the discipline and an audience with diverse backgrounds. The participants include architects and engineers involved in Cultural Heritage documentation, each with their own technical and cultural expertise. Furthermore, Geomatics itself played a dual role in this context, which could be described as both three-dimensional documentation and geographic documentation. This involved photogrammetry and laser scanning (including SLAM - Simultaneous Localization and Mapping) for the three-dimensional recording of objects, as well as traditional topography, Global Navigation Satellite System (GNSS), and geographic Information System (GIS) for the geographic localization of Cultural Heritage sites and the development of a complete documentation geodatabase.

https://doi.org/10.5194/isprs-archives-XLVIII-M-9-2025-3-2025

1.2 Organization of the School

The summer school, titled SCANNER – Workshop for Documentation and Promotion of Stone Bridges of Greece, took place in Pogoni, in the Epirus region of Greece. It was organized by the University of West Attica - Research Unit of Geodesy – Surveying & GNSS, with the support of the Municipality of Pogoni. In addition to the aforementioned university, the event involved the School of Rural, Surveying and Geoinformatics Engineering of the National Technical University of Athens, Laboratory of Geodesy at the National Technical University of Athens, the UNESCO Research Lab of Politecnico di Milano, Campus Mantova, the School of Rural and Surveying Engineering of the Aristotle University of Thessaloniki, and the Museology Research Laboratory of the Ionian University.

The activities took place from June 16 to June 22, 2024, with the participation of 13 students (figure 1) from 5 different countries (Greece, Cyprus, China, USA, Brazil, Poland).

Figure 1. Students at work

The school's program included field surveying activities in the morning, followed by data processing and technical-scientific discussions in the afternoon, covering not only Geomatic aspects (GNSS, SLAM) but also cultural (Historic Building Information Modelling - HBIM) and social themes (musealisation, Cultural Heritage Valorization). From the very beginning, all activities were strongly characterized by a social approach, enabling students to understand not only the historical and technological value of Cultural Heritage but also the social dynamics of the Pogoni communities where these heritage sites are located today. Particular attention was given to the relationship between local citizens and heritage, with the aim of guiding documentation efforts toward a broader valorization project—not only for the stone bridges themselves but for the entire surrounding context. Students could meet and discuss with citizens, to learn about local traditions and to observe the way of life of the Pogoni region.

2. Pogoni Stone Bridges

2.1 Geographical and Historical Context

Epirus, a mountainous region in northwestern Greece, is defined by the Pindus range and fluvial systems. These topographical conditions required river crossings to support trade, pastoralism, and communication between villages. Built mainly between the 17th and 19th centuries, the stone bridges exemplify a synthesis of functional engineering and cultural symbolism, reflecting the influences of ancient Greek and Roman architectural traditions.

These bridges were built in response to various socio-economic imperatives. While many bridges were commissioned to facilitate regional trade corridors or improve inter-village connectivity, others were essential links to agrarian and religious complexes, such as water mills, monastic estates, and seasonal pastures. Some local villages and wealthy individuals, aware of the necessity to improve infrastructure to facilitate transport and connectivity in the region's mountainous terrain, invested in the construction of stone bridges, an expensive undertaking.

In the Pogoni region, approximately 20 stone bridges remain today, many of which, like other bridges in Epirus, historically served to connect different areas. Some of these bridges are still in use today (figure 2).

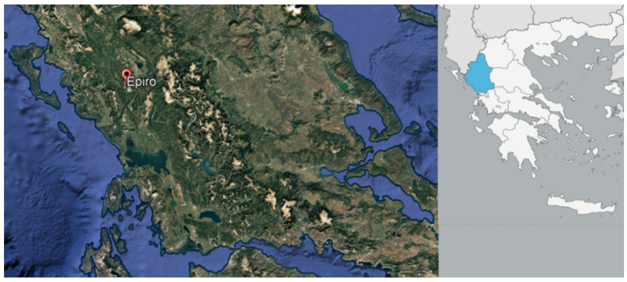

Figure 2. The area of Epirus in Greece

2.2 Construction of Ottoman-Era Stone Bridges

During the period of Ottoman rule, Epirus was the birthplace of many skilled builders from northern Greece. Organized into hierarchical guilds, the builders were led by a Protomastor, a master craftsman responsible for design. They favored narrow stretches of river with stable bedrock to maximize stability and minimize costs. Construction of stone bridges began by diverting watercourses to dig foundations reinforced by wooden and stone pillars. The builders prefer durable local materials, such as limestone and slate, while lime-based kurasani mortar enhanced with organic additives (animal hair or egg whites) offers limited binding strength (Τεχνικό Επιμελητήριο Ελλάδος, 1995), necessitating precise stone fitting.

The structural system used temporary wooden supports to hold up semicircular arches constructed from wedge-shaped voussoirs. A central keystone (historically termed the holy stone) provided critical stabilization by transferring the lateral forces down to the bases. Following the completion of arches, irregularly spandrel stones were fitted into interstitial spaces to form a cohesive façade (Υπουργείο Εθνικής Παιδείας και Θρησκευμάτων, 2007).

Once the construction was complete, the carpenters removed the formwork using pry bars. The formwork removal phase was inherently hazardous, as evidenced by the collapse of many unstable structures during this stage. These bridges use locally sourced materials and adaptive techniques that underline the balance between engineering and ecology.

2.3 Cultural Synthesis and Symbolic Legacy

Stone bridges have played a crucial role in facilitating trade, migration and cultural exchange. Structures such as the Kalogeriko Bridge and the Tzoumerka-Fanari span (Δημητράκης, 1999; Jimás, 2022) have proven to be essential economic lifelines, fostering regional prosperity and embedding narratives of communal cooperation. Furthermore, these bridges have served as anchors for community rituals, from weekly bazaars to seasonal livestock migrations (Υφαντής, 2005; Grigoropoulou, 2009).

Folklore has given these bridges a mythical significance: legends such as *The Devil's Bridge* and Kostas Krystallis's reinterpretation describe the construction as contests between human ambition and natural forces (Politou, 1904). These stories often invoke sacrificial motifs, reflecting a reverence of rivers as divine entities. The cultural ubiquity is evident in the Bridge of Arta, which has inspired over 333 songs variations in Greece, with adaptations spreading across Southeastern Europe (Μαντάς, 1984). The deeper symbolic meanings of bridges encompass religious, economic, and social dimensions, thereby transcending their functional purpose.

3. Survey Activities

The summer school included numerous activities related to the Cultural Heritage documentation process, many of which, as previously mentioned, were linked to Geomatics, particularly focusing on 3D digitization and documentation.

The first phase, which was preparatory for all subsequent activities, involved the development of a list of various bridges to select those to be digitized. This selection was based on parameters such as geographical location, technical and construction characteristics, and accessibility (considering the available equipment). During this phase, the purpose of the survey was further defined—namely, the documentation and promotion of the bridges through a structured knowledge approach, which could be represented at an architectural scale of 1:100. This also allowed for the selection of appropriate tools and the definition of accuracy requirements. Furthermore, multidisciplinary teams were formed, comprising both faculty members (from different universities and Geomatics-related disciplines) and students (architects and engineers). This approach was also aimed at developing a general communication strategy for the results, which, from the outset, was designed to manage data within a WebGIS.

The technologies employed for geographic localization included classical topographic methods (total station) and GNSS for bridge positioning. In the Epirus region, characterized by rugged terrain with mountains and deep valleys, often accessible only by local, unpaved roads, geolocation played a crucial role in supporting the information system in which all collected data was integrated. Additionally, GNSS data was used not only for the precise positioning of case studies but also for the alignment and georeferencing of photogrammetric models and laser scanner point clouds. The use of GNSS receivers and data processing also provided architecture students with an opportunity to explore a technology that is rarely covered in their academic curricula.

The technologies used for 3D digitization included photogrammetry (both terrestrial and drone-based), terrestrial laser scanning, and SLAM. In photogrammetric surveying, students worked on image acquisition planning (determining object distance/flight height, markers placement and their optimised distribution) to ensure the required accuracy for the overall project. They also actively participated in photographic data collection and assisted UAS pilots (since they didn’t have a valid flight license) throughout the acquisition process. The drones used included Mavic 2 Pro, Mavic 3 Cine, and Mavic Mini, the latter primarily for documenting fieldwork activities.

The students also had the opportunity to see other instruments/methods, in addition to those they had experienced. And so, they were able to see the acquisition stages and test data of a flight made with Leica Fly2go, for the documentation of the Kalnterimi Bridge.

For terrestrial laser scanning, students not only observed but also had hands-on experience using the Leica RTC360 and BLK360 scanners, allowing them to compare their features and operational methodologies, even in challenging logistical conditions. Different approaches were applied to the projects—sometimes using a classical topographic method (working in local coordinates and just a final transformation into the national Reference System) and, in other cases, a GNSS-based approach, which enabled work to be conducted directly within the global reference system.

Finally, the students had the opportunity to test SLAM technology using the GeoSLAM Zeb Revo model, comparing it with laser scanning in both the data acquisition phase (in terms of operational and logistical aspects) and the evaluation of results.

In the afternoons, to avoid extreme climatic conditions and high temperatures during the central hours of the day, students engaged in data processing activities in collaboration with tutors. This allowed them to explore and use professional software, rather than relying solely on educational solutions.

3.1 Other Activities

In parallel with the surveying and measuring activities, which were closely related to Geomatics, the summer school planned two other in-depth efforts.
A first in-depth study was social in nature. In fact, an attempt was made to let students better understand the local culture and traditions by visiting the *Pogoniani Folklore Museum* and by interviewing some citizens.
The second activity was towards this very direction -the preservation and enhancement of heritage-, in fact the students worked in groups to analyse different solutions to enhance the awareness, attractiveness, and potential for repopulation of the entire region. Following a number of evening lectures that framed the theme with different viewpoints, examples, and possible solutions, heterogeneous groups of students tried to propose alternative solutions to revitalize the area, spread its knowledge, yet preserving all the traditional features.

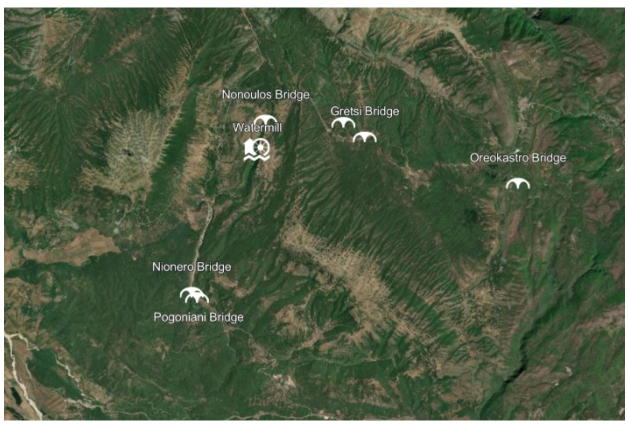

Figure 3. Map with the location of the six bridges (and the watermills).

This contribution has been peer-reviewed.
https://doi.org/10.5194/isprs-archives-XLVIII-M-9-2025-3-2025

4. Results

During the data acquisition days, students successfully documented six bridges (as well as two watermills near the bridges) using the various techniques and tools described (Figure 3). They are:

- Oreokatro Bridge
- Nonoulli Bridge and the Watermill,
- Gretzi Bridge and the Watermill
- Meropi Bridge
- Nionero Bridge
- Kalnterimi Bridge

In line with the overall project objectives, the documentation for each bridge included a georeferenced point cloud, a textured mesh model, and orthophotos (both façade and nadir views) for detailed and precise documentation. Additionally, bridge survey drawings were produced (Figure 4). Alongside these geometric data, descriptive documentation was also created to illustrate the historical and cultural value of the bridges and their surroundings, such as videos and 360-degree images for interactive exploration.

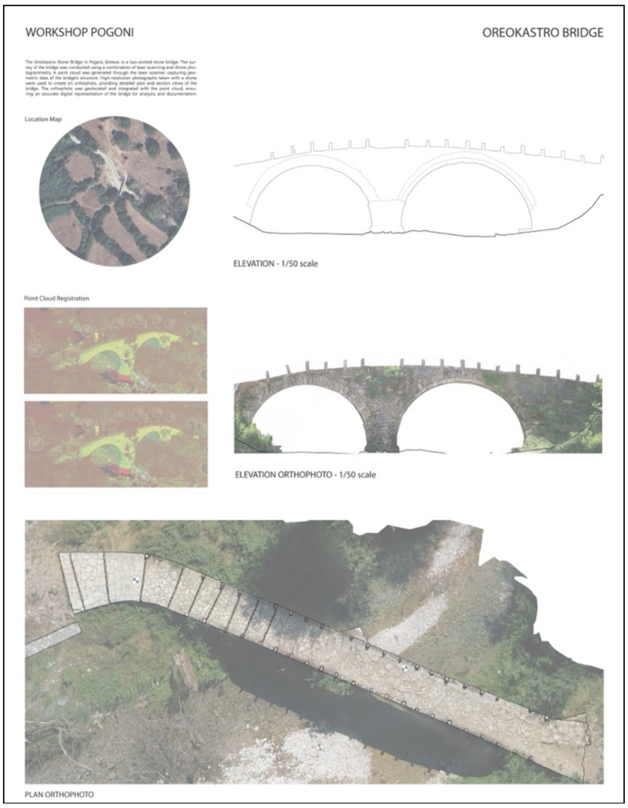

Figure 4. An example of documentation. The bridge of Oreokastro with localisation, point cloud images, drawings and orthophoto.

All data were then integrated in a Geographic Information System where it is archived and made available to the public. The information system is developed on a PostgreSQL database, where all new data are stored. Through a GeoServer, all data are provided using the Web Map Service (WMS) protocol version 1.3.0 and made accessible to all users via a web-based mapping platform available at http://195.130.106.60/StoneBridges/.

In this web application, users can navigate the map and retrieve all necessary information and metadata for each documented bridge. Additionally, for each bridge, a corresponding page has been created, providing access to documentation sections of the monument, such as historical information, a 360-degree panoramic tour, and geometric diagrams for each bridge (Figure 5). A case study of Gretsi Bridge is online on http://195.130.106.60/Gretsi/.

Figure 5. From top to bottom: a) screenshot of the geographic information system GIS with the identification of the surveyed area; b) 360-degree image exploration of Gretzi bridge; 3) Laser scanner data, explorable by the TrueView platform (Leica); virtual exploration of a single pointcloud.

Beyond the aforementioned systematic measurements and topographical approaches, heritage-related activities on the bridges of the borderland region of Pogoni in Epirus (northwestern Greece), produced particularly meaningful outcomes through an applied, participatory framework. Students and researchers collaborated in interdisciplinary working groups, adopting methodologies aligned with Participatory Action Research (Cornish et al., 2023) and the co-creation of heritage narratives (Papaioannou & Stergiaki 2012), both of which emphasize collective agency and situated knowledge in heritage work. Through structured brainstorming sessions and facilitated dialogue, participants developed proposals aimed at revitalizing

the area, enhancing its cultural visibility, and promoting broader awareness of its historical and environmental significance.
These discussions were not only creative but also politically charged, often revealing tensions around spatial justice, cultural access, and decision-making authority—issues central to Critical Heritage Studies (Harrison et al. 2023). The process exemplified the potential of Applied Heritage Research to function as a conduit between academic fieldwork and real-world policymaking. The resulting proposals, to be submitted to the local Municipality, were shaped by this collaborative ethos and civic engagement. Suggestions included both digital initiatives—such as virtual museums and heritage dissemination platforms—and site-specific interventions, such as the installation of informational totems near the iconic stone bridges and elevated structures reminiscent of watchtowers. These would act as visual landmarks and observation points, strengthening orientation and experiential engagement with the layered cultural landscape of Pogoni.

The work to achieve the above results was also handled in an unusual way for a summer school, including taking into account the different time requirements for each activity. Thus post-processing activities were divided into activities carried out "during school" and "after school." The former involved verification of acquired data, adjustment of topographic observations and general registration of laserscanner data and orientation of acquired photos. The operations devolved to the second phase, and left to the students' management, are those that take longer (often dictated by the amount of data and computation time). These include final point cloud processing, orthophoto development, and especially the graphic editing phases. Drafting designs from point clouds and orthophotos, in fact, require time that is difficult to find during intensive summer school sessions.

However, this approach made it possible to keep the collaboration with the students alive even after the summer school was over through continuous work review activities. This collaboration also led to the completion of at least two master's theses, defended at the Politecnico di Milano during the summer session, and an additional couple of diploma theses that will be defended in the near future in the School of Rural and Surveying Engineering of the Aristotle University of Thessaloniki, exploring topics related to the summer school – but not only - starting from the data collected.

The first thesis (figure 6) developed by the student Ziyu Hu, focused on the stone bridges of Pogoni, to highlight the strong connection between human intervention and the natural environment. The thesis was structured in two main phases. The first phase involved data collection and processing, including the GIS-based representation of the territory, historical studies and analyses on ancient travel routes, population movements, and the distribution of major settlements.
At the architectural scale, point clouds were used for the three-dimensional reconstruction of the Oreokastro bridge, offering an opportunity to explore and narrate its construction techniques. The second phase consisted in the development of a story map using the ArcGIS platform. The student created a dissemination-oriented digital platform—conceived, for example, for display on a digital totem—designed to communicate the findings and insights gained during the first phase.

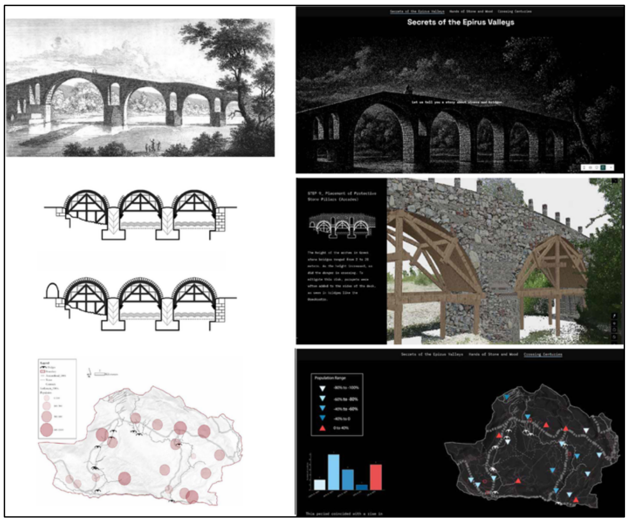

Figure 6. screenshots of the thesis about Pogoni Bridges and their link with nature. On the left, some studies and sources, on the right the graphical dissemination interface of the Story map. Courtesy of Ziyu Hu, image from the thesis.

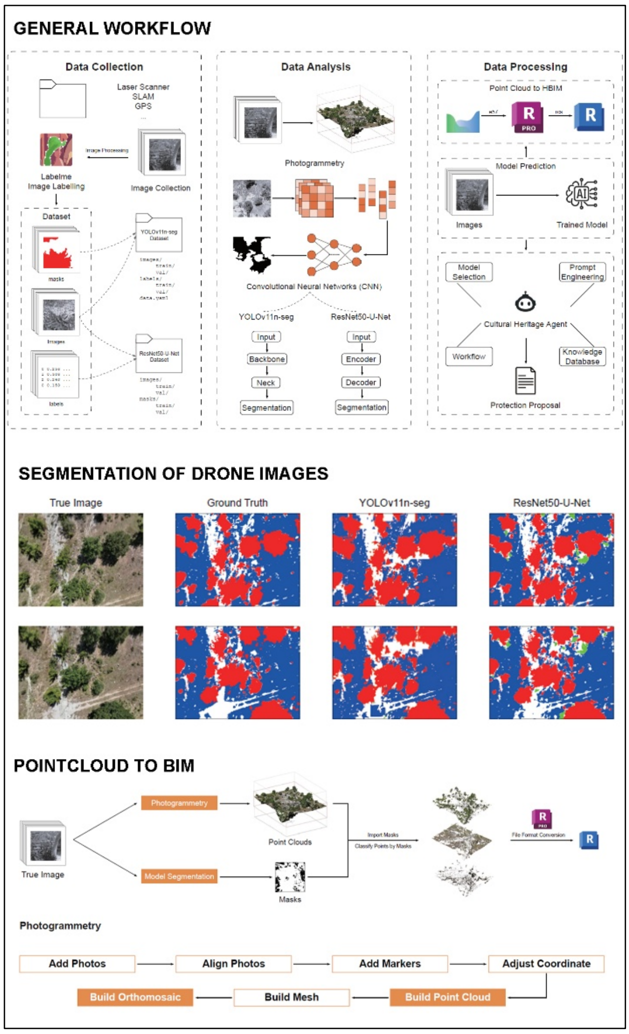

Figure 7. screenshots of the thesis about automatic recognition of vegetation in images, by Artificial Intelligence approach. Courtesy of Diqi Huang, image from the thesis.

The second thesis, elaborated by the student Diqi Huang, concerned the topic of automatic recognition of vegetation using an Artificial Intelligence approach. The presence of infestation of vegetation has in fact emerged, in a preponderant way, already during the acquisition phases and so the student, interested into Artificial Intelligence, tried to develop an approach for automatic recognition in drone and ground images. He also imagined a workflow to allow the recognition and segmentation of vegetation, directly in HBIM environment (Figure 7)

5. Conclusions

The experience described in this article seeks to underscore, once again, the significance of educational activities that complement formal academic curricula. More broadly, workshops, seminars, and summer schools represent valuable opportunities for the scientific and cultural development of younger generations engaged in the field of Cultural Heritage.

This particular summer school offered an integrated approach to various domains of Geomatics—ranging from 3D digitization to georeferencing—applied to a concrete case study: the stone bridges of Pogoni. Beyond the acquisition of technical skills, the program encouraged, and indeed required, critical reflection on strategies for the enhancement of heritage assets. This involved expanding the scope of inquiry to encompass social, touristic, economic, and cultural dimensions. Such an approach not only contributed to a more precise definition of the survey objectives but, more importantly, fostered a broader awareness of the fact that the preservation and valorization of Cultural Heritage rely on a network of complex and interrelated activities.
Like any educational activity involving people from different countries and with different backgrounds (figure 8), the summer school was also a very important social event, providing an opportunity to meet and interact with new people, learn about local traditions, and discover areas that may not be well known beyond their borders. It is therefore a very effective way of disseminating not only technical knowledge, but also the value of the territory and its historical, cultural, and architectural heritage.

Figure 8: Group photo of the school with students and tutors.

Acknowledgements

A special thanks goes to the Municipality of Pogoni for the support given to the whole activity. The authors want to thank all the students and young tutors for their cooperation. We also thank the students Ziyu Hu and Diqi Huang who agreed to publish some images of their thesis (Figures 6 and 7)

References

Τεχνικό Επιμελητήριο Ελλάδος, Τμήμα Κεντρικής και Δυτικής Θεσσαλίας & Γαλερίδης, Α., 1995. *Τα πέτρινα γεφύρια της Θεσσαλίας.* Αθήνα, p. 37.

Υπουργείο Εθνικής Παιδείας και Θρησκευμάτων, Κέντρο Περιβαλλοντικής Εκπαίδευσης Μακρινίτσας, 2007. *Τα πέτρινα τοξωτά γεφύρια της Ελλάδας.* Μακρινίτσα Πηλίου. ISBN: 978-960-98043-9-4, pp. 27-42.

Δημητράκης, Α.Δ., 1999. *Τα πέτρινα γεφύρια της Ελλάδας: Ήπειρος, Μακεδονία, Θράκη, Θεσσαλία, Στερεά Ελλάδα, Πελοπόννησος.* Αθήνα: Αδάμ, p. 33.

Jimás, K., 2022. *Emportikí dromoi - Pétrina gefýria kai diakínisi idéon stin Ípiro: Katá ton 18o kai 19o aióna.* Êdyepeia. ISBN: 978-618-5471-39-2, pp. 84-110.

Υφαντής, Ν., 2005. *Η Πωγωνιανή – Παλιά Βοστίνα και τα Κοινοτικά Διαμερίσματα.* Διευρυμένη Κοινότητα Πωγωνιανής, pp. 175-180.

Cornish, F., Breton, N., Moreno-Tabarez, U., Delgado, J., Rua, M., Aikins de-Graft, A. & Hodgetts, D. , 2023: Participatory action research. Nature Reviews Methods Primers 3, 34. https://doi.org/10.1038/s43586-023-00214-1

Grigoropoulou, S., Moize, M. and Ntova, A., 2009. Τα πέτρινα γεφύρια της Ελλάδας. Undergraduate thesis, Technological Educational Institute of Patras, School of Technological Applications, Department of Civil Infrastructure Projects.

Harrison, R., Dias, N., & Kristiansen, K. (Eds.), 2023): Critical Heritage Studies and the Futures of Europe. UCL Press.

Papaioannou, G., & Stergiaki, A., 2012): Students as Co-Curators in the Virtual Museum of Folk Musical Instruments for Children: Roles, Rules and Realities. International Journal of Heritage in the Digital Era, 1(4), 631-645.

Politou, N., 1904: Study of the life and language of the Greek people: Traditions I (in Greek). Athens: Self-published, p. 520.

Μαντάς, Σ.Ι., 1984: Τα ηπειρωτικά γεφύρια για να καλύψουν μια ανάγκη προέκτειναν τη φύση. Αθήνα: Λαϊκό Πολύπτυχο, pp. 47-50.