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GEOMATIC TECHNOLOGIES TO VALORIZE HISTORICAL WATERMILLS

F. Di Stefano [1] *, M. Sanità [1], E. S. Malinverni [1], G. Doti [2]

[1] Dipartimento di Ingegneria Civile, Edile e Architettura, Università Politecnica delle Marche, Ancona, Italy – (f.distefano, e.s.malinverni)@staff.univpm.it, m.sanita@pm.univpm.it
[2] Scuola di Ateneo di Architettura e Design, Università di Camerino, Ascoli Piceno, Italy - gerardo.doti@unicam.it

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ABSTRACT:

The watermills, due to their technological innovation, represent a clear example of historical industrial heritage. A census campaign of water-powered grain mills was conducted in the Marche region (Italy). Almost 1,000 of them were counted, distributed throughout the regional territory in several water catchment areas. After a long multidisciplinary activity conducted among the Universities of Marche region, a geodatabase was implemented by GIS to map and register the historical watermills. The geodatabase is used to compose and manage an overall, uniform, homogeneous and expeditious cataloguing of the historical watermills distributed throughout the Marche region. In the second step, to get precise geospatial information, to obtain dimensional data, achieving metric and georeferenced 3D models, and to verify the real condition and state of preservation of them, 3D survey campaigns were conducted. In this phase, for some selected watermills the survey was carried out using geomatic sensors, such as photogrammetry and 3D LiDAR scanner. The final step of this research was to connect the 3D digital models from geomatics surveys in the GIS geodatabase, to enrich the collected historical documentation of the watermills, to improve their knowledge and valorization.

1. INTRODUCTION

Cultural heritage includes not only buildings that represent the highest artistic or architectural expression of a place and its population, but also those structures that bear witness to the rural and industrial activities carried out by a community throughout its history. Built structures that not only have an important historical-testimonial value but also represented a resource for the territory in support of production activities (UNESCO, 1972).
The mills and the technological innovations that, the art of milling has made since the Middle Ages, represent a clear example of historical industrial heritage. In order to harness the flowing power of watercourses, mills were built to be able of converting hydraulic energy into mechanical one. Watermills also represent a complex architectural form due to their location and construction considering the presence of the watercourse or waterfall in its vicinity and the design of the associated hydraulic system.
Watermills are considered as a cultural asset and throughout Italy are the subject of study and valorization also tourism. It is therefore worth recalling their indispensable socio-economic role, the hydraulic, engineering, and technological aspects. The aim is also to make a census of those that are still functioning, those of which vestiges remain, to make them known to the wider public and, in cases where possible, to recover them for cultural and educational purposes.
A census campaign of watermills was conducted in the Marche region (Italy) in 2021: 963 grain mills were geolocalized on the regional territory, close to watercourses in the 13 main water catchment areas of the Marche region.
This work led to the implementation and organization of a geodatabase to catalogue the historical watermills. In this the Geomatics can provide methods and tools for managing information, developing survey projects and it constitutes a valuable and irreplaceable form of knowledge for the built heritage. This attempt to improve the historical documentation by a geomatic surveying was adopted on a selection of case studies of watermills with the aim of defining intervention strategies for the valorization of these historical artefacts.
The main contributions of this work are as follows:

- Implementation of a geodatabase of historical watermills in a GIS;
- 3D survey with geomatics sensor of some historical watermills;
- Development of a 3D GIS by integrating geodatabase data with a 3D model obtained from the geomatic survey;
- Maintenance and usability of the system for the knowledge and valorization of historical watermills.

The paper is structured in this way. Section 2 concerns the state-of-the-art on the use of geomatic technologies to support the documentation and valorization of cultural heritage. Section 3 illustrates the methodology for the cataloguing of the historical watermills of the Marche region, after the census. Section 4 describes the implementation of the geodatabase and the 3D survey of watermills by geomatics technologies Finally, conclusions and future works are outlined in Section 5.

2. STATE-OF-THE-ART

Fear and concern have developed over the loss of existing architectural artefacts and their memory, knowledge, and dissemination in the present and near future, nowadays researchers in the field of geomatics are striving to experiment with increasingly innovative approaches to documenting and surveying data for the valorization of the built heritage.
In order to promote knowledge and safeguard cultural heritage, Italian public authorities in charge of managing cultural assets, from the Ministry to local administrations, have launched census campaigns and cataloguing activities to identify every form of cultural asset present in the Italian territory (ICCD). However, this cataloguing process stops at mere documentation in the form of data records or sheets containing various types of information: descriptive, historical, in the form of text and

* Corresponding author

image. Therefore, there is a necessity to go over this form of technical cataloguing and use a more interactive and user-friendly approach to ensure that these data can be consulted and understood by a wider audience.

Geomatics, known as the science of acquiring, processing, and mapping spatial data, makes significant contributions to the documentation and digitization of tangible cultural heritage. Therefore, geomatics technologies can offer useful and suitable tools for improving and customizing the management of cultural heritage data.

A geodatabase, implemented on GIS environment, is a suitable structured geoinformation system for storing data on cultural assets, contained, like attributes, in dedicated tables and geolocalized on maps. GIS is well suited for this type of work (Moya-Muñoz & Pinto-Puerto, 2022), offering the possibility of creating a geospatial mapping of historical artefacts and being able to create a database containing all the information associated with each cultural heritage asset.

In addition, geomatic sensors offer the possibility of acquiring 3D data of historical monuments through survey techniques such as photogrammetry and 3D LiDAR scanners. This makes it possible to obtain 3D digital models of historical artefacts that can be shared through an online or offline visualization software to enrich the knowledge.

The literature at nowadays boasts of several examples in which there is a mixed approach between 3D survey outputs and GIS cataloging through the creation of an enriched geodatabase. This combination is valuable to exploit to ensure enhanced management and dissemination of information about cultural heritage assets.

Examples of geodatabase implemented on GIS to support the documentation and the conservation of cultural heritage asset are found in the case study analyzed by Cernaro and Iglesias (2022) and Malinverni et al. (2019). In the first work a cadastre based on a GIS platform was created for a selection of modern cultural heritage assets in the city of Messina (Italy) previously recorded in the Registers of the Modern Movement (DoCoMoMo). The second example of GIS support for CH conservation concerns on the creation of a geodatabase on Villa Buonaccorsi. These authors also proposed a methodology to support the management and planning of landscape architecture while also considering changes over time. In this way, GIS was used as a tool to preserve the historical identity of the site, as it was ideal for creating data archiving. Moreover, it was possible to guarantee the enhancement and conservation of the cultural heritage through a digital platform.

Thanks to the features and functionalities of GIS, it was able to store heterogeneous data of various types, result of a multidisciplinary approach. In the preliminary phase, experts from different disciplines collected and analyzed information about the state of conservation of cultural heritage asset. Then with the support of the GIS it was possible to catalogue all the information in a geodatabase and relate them to the specific built cultural heritage.

An example of a multidisciplinary approach based on GIS tools, was the one conducted by Indirli et al. (2011). Their goal was to carry out research in the field of hazard, vulnerability, and risk assessment in historic centres. Their methodology included the acquisition and evaluation of cartographic and photogrammetric data as a first step, which served as a skeleton for the construction of the geodatabase in a GIS environment.

In the case of the Mengoni Arch (Bitelli et al., 2019) a cataloging card was created so that the data was merged into a database containing the inventory number, the type of document, etc. This database is useful not only because it is an inventory but also because it is a good example of implementation in a GIS environment.

Another multidisciplinary research, in four consecutive phases, is proposed by Marra et al. (2021) which developed the following methodology: they identified the sites of interest such as churches, museums, castles and archaeological sites, then they performed 3D surveys to collect information through photogrammetry, laser scanning and processing the 3D data by modeling. In the third phase, they implemented procedures devoted to a semantic model, GIS 3D, HBIM, and VR systems.

Furthermore, GIS is exploited to manage knowledge of historical villages or historical monuments in the specific case of emergency and risk management. In these cases, GIS is a useful tool for the planning and management of interventions and restoration strategies for cultural heritage.

In the case study of the HeritageCare project (Masciotta et al., 2021), the authors set out the working methodology for the documentation, conservation, and enhancement of cultural heritage through a multidisciplinary approach. Standard, medium, and high levels of knowledge were defined, based on the quantity and quality of data that are gradually acquired and collected. These knowledge levels are used to identify which types of survey to carry out, identify which conservation intervention strategies must be implemented and then define a project plan for the restoration and valorization of cultural heritage.

Historical villages represent a highly vulnerable cultural heritage; the preservation of vulnerable historical villages can be ensured with the GIS that allow exploiting heterogeneous data for efficient vulnerability assessment, in terms of both time and usability. Geometric attributes of the buildings, which currently are mainly inferred by visual inspections, can be extrapolated from data obtained by 3D survey technologies. Furthermore, the integration with non-metric data ensures a more complete description of the post-seismic risk thematic mapping (Piccinini et al., 2022).

Thanks to technological and IT innovation, which has also affected the techniques and tools of geomatics, there have been further developments in the field of data management through information systems. GIS 3D represents a valuable tool for integrating 2D maps with 3D models that are generated by data acquisition methods through geomatics survey devices.

A contribution of how geomatics is a valid support for the conservation and enhancement of cultural heritage has been given by the research work carried out by Gorgoglione et al. (2022). They developed a 3D GIS environment and multi-information model by MMS (Mobile Mapping System) survey. This work turns out to be valid evidence of how the combination of GIS and 3D survey techniques can lead to the exploration of hard-to-reach heritages. This methodology is applicable in all possible fields. In particular, the authors in a first phase collected bibliographic, photographic and cartographic data relating to the evolution of the city of Lisbon and its infrastructures. In the following phase, they dealt with data processing including the development of point clouds for the creation of the 3D model. and the data management in the GIS. As a final phase there is data sharing on a web platform. The web approach was also adopted in the case study of Sánchez-Aparcio et al. (2020) as a method and tool for sharing data to implement a preventive conservation plan for cultural heritage and ensure the information transfer between expert and non-expert users.

A representation of integration between 3D models and GIS data for the enhancement of cultural heritage is offered by the research conducted by Mongelli et al. (2020). The authors recognize the theme of "data fusion" as a trend topic in the ICT sector for Cultural Heritage. They applied their methodology to the Aurelian Walls. They managed the work at different scales of acquisition, passing from territorial scale to building one.

They have developed two classes of hotspots in 2D and 3D. Those in 3D allow the activation of links with other contents including GIS data and georeferenced information. In this way, interoperability between GIS data and 3D data is ensured.
Technological innovation has also involved geomatics surveying tools, to create low-cost, fast and agile solutions, for conducting expeditious data acquisition campaigns by collecting large amounts of data in a short time. Starting from the assumption that the choice of survey method is defined on the basis of built cultural heritage to be investigated, it is clear that the practice of point cloud surveying remains the most common choice as it is transversal and widely applicable. Indeed, it is able to represent every type of object at different scales and at different levels of complexity. So to obtain 3D point cloud, sometimes it is better to use the Mobile Mapping System (MMS) with SLAM (Simultaneously Localization and mapping) technology, which ensures the right balance between costs, time, accuracy and efficiency.
As the authors Di Stefano et al. (2021a) report, the fields of application of this system are many: spacing from the urban environment, built cultural heritage, underground heritage and environment, for monitoring, mapping and modelling. Sometimes the decision to use MMS technology is also due to the difficulty of surveying in environments devoid of light and colour and with a complicated geometry. An example of the application of MMS technology is applied in the Camerano Caves (Di Stefano et al., 2021b). The authors were able to develop an accurate digital 3D model despite the low light and difficulty of pathways. Difficulties also arise in contexts located near water basins such as rivers where the water surface can create a source of interference for the laser sensor. As in the example of watermills located on river banks or near a waterfall, presented in this paper, there are similar examples in the literature such as the surveys described in Smuleac et al. (2020) and in Di Stefano et al. (2019).

3. METHODOLOGY

The Marche region, through the regional law (L.R.) n. 4 of 20/02/2019 - "Valorization of historical watermills in the Marche region before 1900", approved the project "Preparation of a plan for the census/cataloguing of historic watermills in the Marche region" of the inter-university research group coordinated by Prof. Gerardo Doti and formed by the four universities of the Marche region: Camerino (UNICAM, lead partner), Ancona (UNIVPM), Macerata (UNIMC) and Urbino (UNIURB).

The regional universities in order to properly carry out and develop the research project, have chosen to work in synergy, integrating different disciplinary competences, from the history of architecture to restoration, from geology to hydrology, from geomatics to urban planning.
The inter-university working group has developed a methodology and identified the set of tools useful for the acquisition of a correct knowledge of the number, location, current status and positional characteristics of historical watermills in the Marche region. This is an essential condition to be able to subsequently proceed with any concrete action to support and valorize the ancient mills.
The census was based on a multi-level documentation of watermills, based on degrees of knowledge referring to the quantity of data referred to each artefact. Attributes are related to various cartographic, documentary, and temporal sources and their geolocation which made it possible to define evaluation parameters of knowledge on the artefacts involved.
One of the main contributions of UNIVPM researchers has come from the geomatics team for the surveying and archiving geodata of the historic watermills (Figure 1).
First, a dedicated geodatabase in a GIS, was created, organizing, and implementing some data of the investigation conducted by different experts involved and in several stages of analysis.
Secondly, to get precise geospatial information, obtain metric dimensional data, and verify the state of preservation of the historic watermills, some direct inspections and geomatics survey campaigns were conducted.
The final objective of this research was to connect the 3D digital models from geomatics surveys in the GIS geodatabase, to enrich the collected historical documentation of the watermills, to improve their knowledge and valorization.

3.1 Geodatabase implementation

The first phase of the work consisted in drawing up a census of historical mills in the Marche region: 963 water-powered grain mills were counted (Mauro, 1998). Experts from the various universities in the Marche region worked together to create a geodatabase of all the mills in the Marche region, divided by province. The purpose of the geodatabase was to gather information on the geographical location of the mills, the identification attributes to each mill, historical and architectural descriptions, existing documentation (Figure 2), and a starting analysis of the actual condition. The ID code is the identifying number registered in the S.I.R.Pa.C. (Sistema Informativo Regionale del Patrimonio Culturale) according to ICCD catalogue.

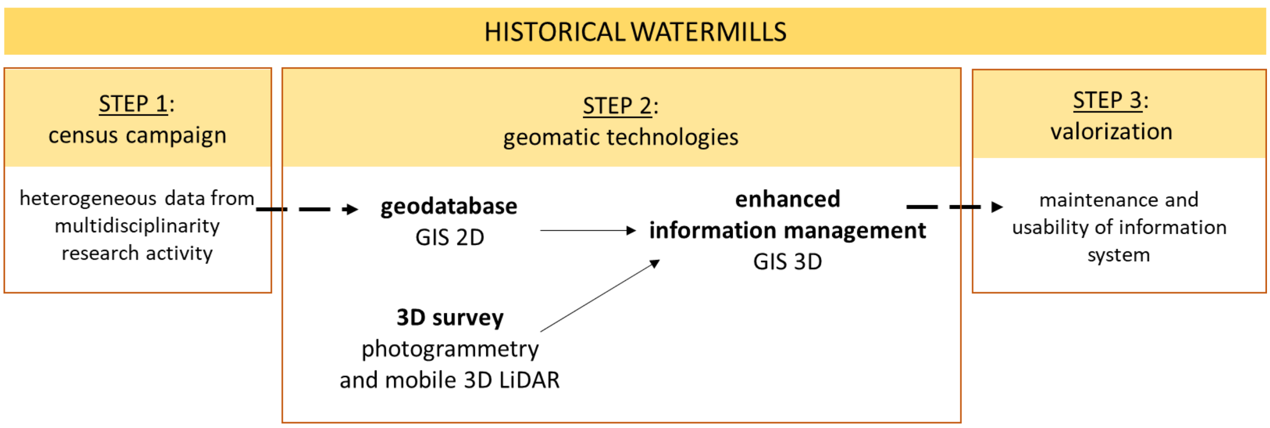


Figure 1. Methodology workflow

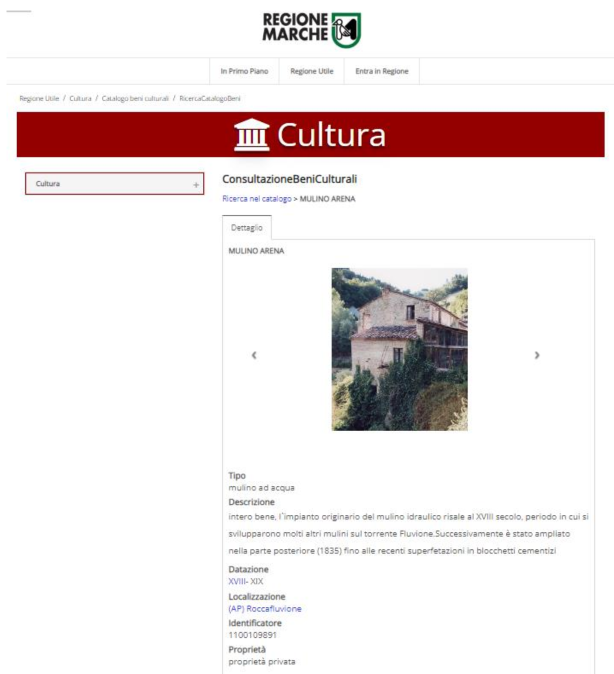


Figure 2. Example of a data sheet of a watermill

After this multidisciplinary activity, a geodatabase was organized in the GIS. The geodatabase, was developed in some steps, as specified below:

- organization of basic and thematic cartography (raster and vectorial, online and offline);
- identification of historic watermills throughout the Marche region, with the specifications referring to various cartographic, documentary and temporal sources;
- mapping/geolocation (Gauss Boaga - EPSG 3004 reference system) of the individual assets/architectural complexes, on regional cartographic map and on the hydrographic network;
- summary recording of each individual asset, with priority given to assets that have survived to date.

3.2 3D survey

In the second phase, a geomatics survey campaign was carried out achieving metric and georeferenced 3D models of the watermills. For this phase, some mills were selected, and the survey was carried out using geomatic sensors.
The survey campaign was conducted by means of innovative geomatics instruments to perform an expeditious just complete acquisition of historical artefacts. The choosing of the sensors' type suitable (Figure 3) in according to the recording methods, was based on the capabilities for the digitalization of the selected cultural heritage assets. The following aspects of the devices adopted have been considered and balanced: resolution, accuracy, range, environmental conditions (e.g., presence of water, dense vegetation, disturbing electromagnetic sources), data provide to obtain a complete geometric model.
Through the use of topographical instrumentation, the integration of data, aerial and terrestrial, photogrammetry and mobile mapping system (MMS), metric and georeferenced 3D digital models of some selected watermills were achieved.

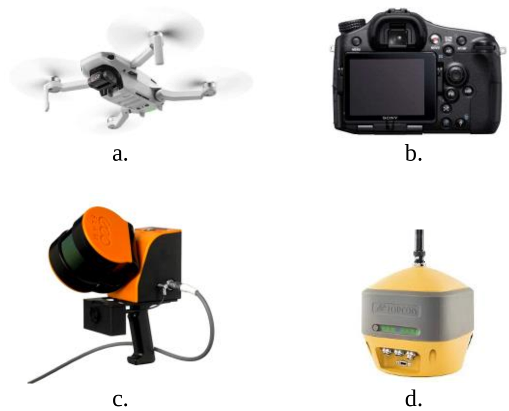


Figure 3. Sensors used for geomatic survey: **a.** DJI Mavic Mini as drone aerial photogrammetric system; **b.** Sony Alpha 77 as close-range photogrammetric camera; **c.** GeoSLAM Zeb Horizon with GoPro camera as MMS; **d.** TopCon Hiper HR as GNSS receiver.

The following tables (Table 1, Table 2) resume information on the main technical specifications of the sensors used.

Table 1. Technical specifications of GeoSLAM Zeb Horizon

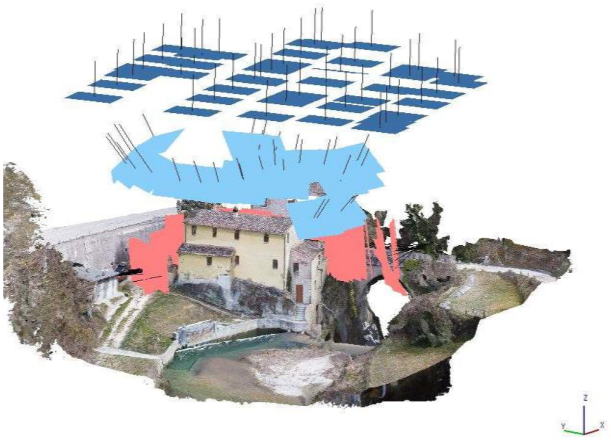
Range	100 m
FOV	360° x 270°
No. of sensors	16
Scan rate	300,000 points/s
Scan range noise	± 30 mm
Colourised point cloud	yes
Intensity	yes
Processing	Post

Table 2. Techical specification of photogrammetry sensors

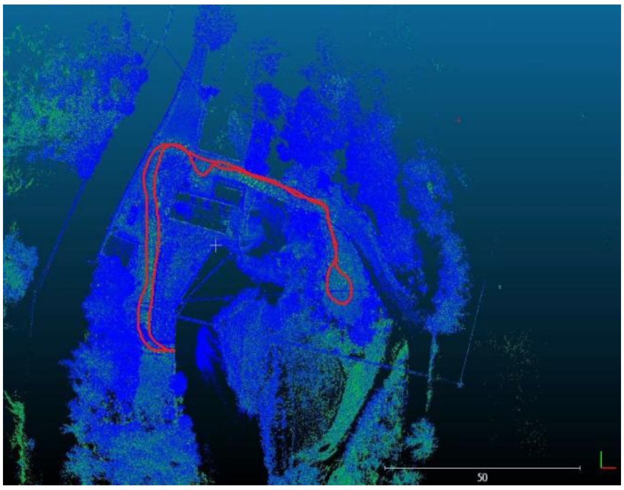
DJI Mavic Mini	
Focal lenght	23-69mm
Aperture	f/2.4
Photo resolution	21 MP (5344x4016)
Sony Alpha 77	
Focal lenght	135 mm
Aperture	f/2.8
Photo resolution	24 MP (6000x4000)

3.2.1 Environmental constrains performing the survey.

Devices such as UAV (Unmanned Aerial Vehicle) for aerial photogrammetry and MMS (Mobile Mapping System) equipped with SLAM (Simultaneously Localization and Mapping) technology, thanks to their portability and flexibility, were suitable to survey the exterior parts of the historical assets, overcoming the environmental constrains due to the presence of the watercourse or waterfall, which limited the proximity or the complete route around them (Figure 4).
In other cases, the mills were located in critical contexts to make the survey. In some environmental contexts, where drone take-off, it was impossible or prohibited, due to the presence of dense vegetation or disturbing electromagnetic sources (e.g., power station near the mill itself in function), to make aerial photogrammetry, that was replaced by close-range photogrammetry, always guaranteeing a good level of detail in the output. The same happen using the total station instead of the GNSS receiver, when the contexts didn't guarantee a good connection to the satellites.



a.



b.

c.

Figure 4. Geomatic survey campaign conducted in a watermill. **a.** UAV and close-range photogrammetry; **b.** MMS point cloud with trajectory shown; **c.** operator using the MMS to carry out the survey over the waterfall.

Table 3 summarises the data acquisition and processing techniques used.

Table 3. Data acquisition and processing techniques

data acquisition		data processing	
sensors	**data**	**products and operation**	**software**
Close-range photogrammetry UAV photogrammetry	Images	Photogrammetric point cloud generated with SfM approach	Metashape
MMS (LiDAR + camera)	Scans	Laser scanner point clouds: registration, processing, alignment, filtering	GeoSLAM Hub, Cloud Compare
GNSS receiver (or Total station)	Topographic data	Coordinates for correct geolocalization of CH assets and georeferencing point clouds	Meridiana

4. RESULTS

4.1 GIS 2D

The first and most challenging result of the research activity consisted in the implementation of the geodatabase on an open source GIS platform (QGIS). The feature points, represented the historical mills (Figure 5), have attribute tables containing all the information collected during the census phase (Figure 6).
In this way the tables, which can be translated into descriptive sheets, have been organised according to a structure of attributes that complement and refer to the individual artefact uniquely identified with its own code. The outcome is an easily queryable relational structure, where semantic information is linked to the geometric feature that provides for each asset surveyed the geolocation with which can be traced back to the position on suitable cartographic bases, selected and interrogated for the most diverse purposes.

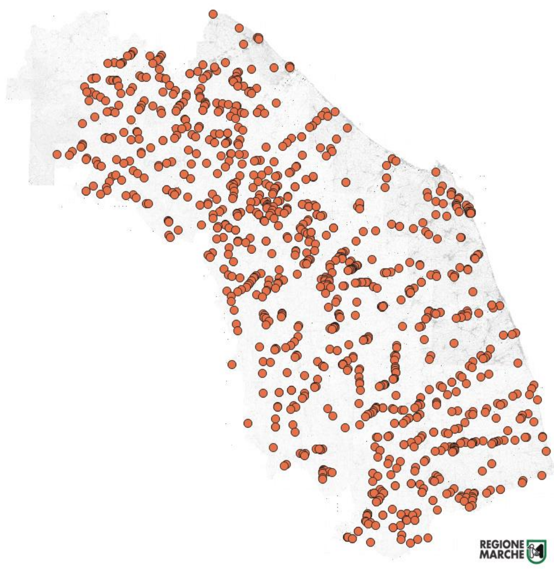


Figure 5. GIS map of all localized watermills of the Marche region

1	Codice	Nome	Tipo	Provincia	Comune	Bacino	X_GB_Est	Y_GB_Est
2	MC 056	Molino Natalini	Macinazione	Macerata	Pollenza	NULL	2384950	4793581
3	PS 096	Taullo	Macinazione	Pesaro-Urbino	Gabicce Mare	Marecchia - Con...	2339967	4870412
4	PS 095	Ranocchia	Macinazione	Pesaro-Urbino	Pesaro	Foglia	2346846	4866842
5	PS 147	Valle Sant'Anast...	Macinazione	Pesaro-Urbino	Sassofeltrio	Marecchia - Con...	2313825	4863781
6	PS 113	Collina	Macinazione	Pesaro-Urbino	Pesaro	Foglia	2351690	4864291
7	PS 112	Canonici	Macinazione	Pesaro-Urbino	Pesaro	Foglia	2352049	4863940
8	PS 114	San Cassiano	Macinazione	Pesaro-Urbino	Pesaro	Foglia	2352063	4864293

Show All Features

Figure 6. Extract of an attribute table

4.2 3D digital models

In order to carry out the 3D survey on field by the geomatic sensors, a selection of watermills was made, processing and combining the data with those already stored in the GIS.
One of some surveyed watermills is presented here, as a test, to show the acquisition methods and operations that were carried out for the 3D survey: Mulino Arena, located in the province of Ascoli Piceno (Marche, Italy) (Figure 4c).
As the mill is privately owned, only the external part was surveyed. It was not possible to access the milling machine room as it was a forbidden area following the earthquake that struck the area in 2016.
For this watermill, the sensors shown in Figure 3 were used. Since the mill is still in activity and for the distribution electricity pylons in the proximity, the UAV was used in manual mode due to the presence of the disturbing electromagnetic field and for the presence of the electricity cables. Close range photogrammetry was used to complete the survey in order to have a greater detail of the 3D model mapping (Figure 4a).
As the mill is located adjacent to the river and a waterfall, the surveying, carried out with the portable MMS device in hand-held mode, attempted to make a closed path back and forth in the neighborhood of the mill; using also a bridge across the river, in order to be able to survey parts of the building from the other side of the river. The river is not very wide and the operating range of the MMS above this size ensured that the part of the building above the waterfall could be detected (Figure 4b).
In order to georeference the point clouds obtained from the photogrammetric and laser scanner surveys, five targets were placed, around the mill, and detected by a GNSS receiver.
The survey was carried out in a few hours and thanks to the easy and fast solutions, a large amount of data was collected. Table 4 shows the data acquired from the 3D survey to reach the 3D model of the mill.

Table 4. Mulino Arena 3D survey

geomatic sensors	n. photos	time	point cloud
UAV photogrammetry	74	15 mins	56,1 million pts
Terrestrial photogrammetry	66	25 mins	
MMS	-	6 mins	40,9 million pts

The data processing phase was performed in the laboratory for two days. The photos of the photogrammetric survey were processed using the Metashape software. First the images obtained from UAV photogrammetry and close-range photogrammetry were processed separately, then the cloud points were merged into a single one.

The point cloud acquired by MMS GeoSLAM Zeb Horizon was processed using the GeoSLAM Hub processing software which allows to export the 3D model in .las format. Subsequently, the management, filtering and georeferencing of the point cloud were carried out using the open-source software Cloud Compare. The images that can be extracted from the recorded video, acquired during the walking survey phase, using the integrated GoPro, were not used as they did not guarantee good detail and quality of the final point cloud.
The following figures (Figures 7, 8) show the point clouds obtained from the 3D survey.

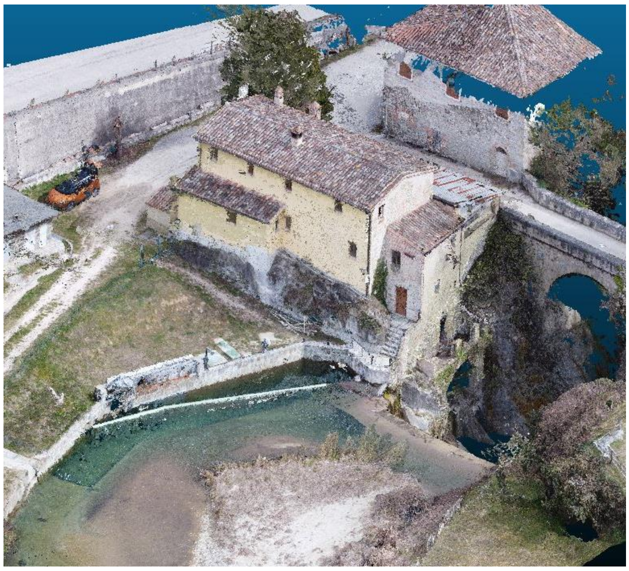


Figure 7. Mulino Arena 3D point cloud from photogrammetric integrated methods of

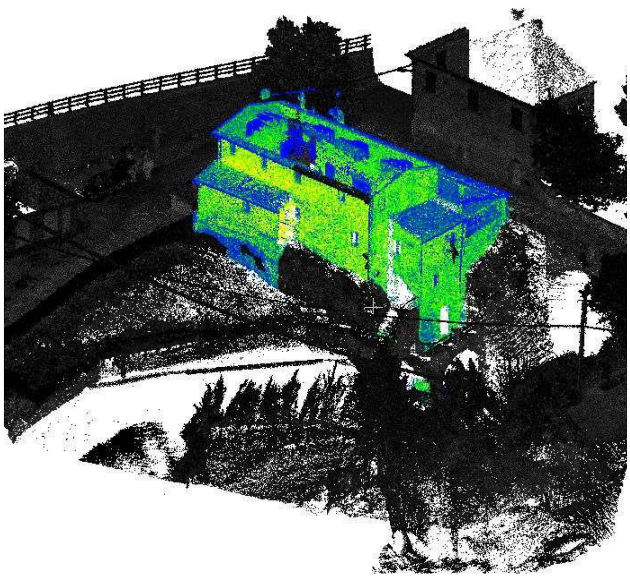


Figure 8. Mulino Arena 3D point cloud from MMS (intensity scale).

The georeferenced of the point clouds (by photogrammetry and by MMS) was performed applying a Cloud to Cloud (C2C) analysis, in Cloud Compare software, to verify their correct overlapping. The RMSE value obtained is 0.02 cm (Figure 9).

This contribution has been peer-reviewed.

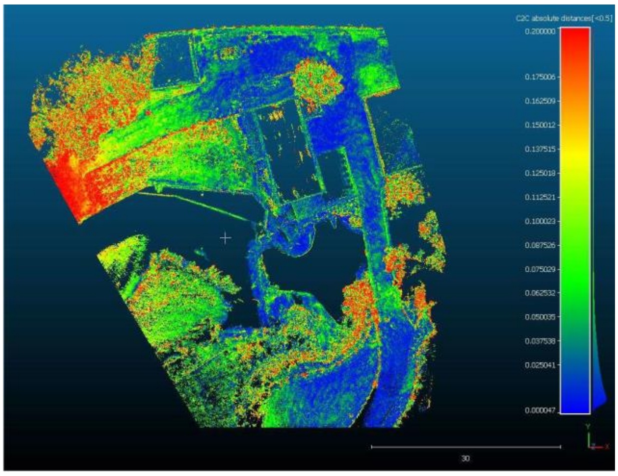


Figure 9. C2C distance computation between point clouds processed from photogrammetry and MMS, related to Mulino Arena

4.3 Enhanced Information Management System

With the intention of creating an enhanced information management system, it was decided to integrate the 3D models obtained from geomatic survey with the data already archived in GIS 2D. It can be selected two modalities, on the base of the future use that will be attributed to the platform. One method can save the 3D models in a shared folder external to the GIS and link them to the respective mill by creating a specific cell in the attribute table. The point clouds could be explored using a 3D viewer in offline mode, such as Potree Viewer.
The other solution could import the point cloud directly into the GIS, if it supported both a 2D map view that any 3D model, in overlap on the 2D map. This is just possible using a professional version of GIS software (Esri) that guarantees both online and offline modes. Like an example we have choiced this second solution (Figure 10).

Figure 10. 3D point cloud imported in GIS, overlapping the 2D map.

As known, GIS is widely used by public administration for a variety of purposes. By this solution we have a geodatabase that relates many attributes of the historical sites and at the same time can be used to create interactive maps and virtual tours, which can enhance public awareness and engagement with built heritage. Furthermore, GIS can be used to analyze the economic impact of historic preservation and heritage tourism, which can inform decision-making related to the valorization of built heritage. GIS can also be used to identify potential funding sources for preservation and restoration efforts, which can encourage private investment in historic sites. Overall, the use of GIS for built heritage valorization is a valuable tool for public administration agencies that seek to promote the cultural and economic value of their community's historic assets.

5. CONCLUSION

The paper discusses the historical significance of watermills, which represent a complex architectural form due to their location and construction, as well as their socio-economic and technological roles. Watermills in Italy are considered cultural assets and are the subject of study and valorization, including for tourism purposes. A census campaign of watermills was conducted in the Marche region of Italy, leading to the creation of a geodatabase to catalogue historic watermills. Geomatics was used to survey and digitally document the built heritage of watermills, with the aim of creating a more comprehensive information database in 3D form and defining intervention strategies for their valorization. Overall, the use of GIS and geomatics in documenting and promoting the cultural heritage of watermills is an important tool for preserving and promoting these historical artifacts.
The implementation of a geodatabase on a GIS environment is a suitable tool for storing data on cultural assets and for creating a geospatial mapping of historical artifacts. Geomatic sensors such as photogrammetry and 3D LiDAR scanners can be used to acquire 3D data of historical monuments and create 3D digital models that can be shared through online visualization software to enrich knowledge. A mixed approach between 3D survey outputs and GIS cataloging through the creation of an enriched geodatabase is valuable for enhanced management and dissemination of information about cultural heritage assets.
The research activity focused on the construction of a Geodatabase on an open-source GIS platform (QGIS, Esri) for the spatial distribution of historical watermills in the Marche region. The feature points which map the historical mills are connected with attribute tables containing all the information collected during the census phase, organized according to a structure of attributes that complement and refer to the individual artifact uniquely identified with its own code. The outcome is a relational structure that is easily queryable, where semantic information is linked to the geometric feature.
The geomatics survey campaign was carried out in the second phase, to achieve metric and georeferenced 3D data. The survey campaign was conducted using innovative geomatics instruments, including topographical instrumentation, aerial and terrestrial photogrammetry, and a mobile mapping system. The devices were chosen taking into account their recording capabilities in relation to the accessibility of the cultural heritage assets and considering aspects such as resolution, accuracy, range, environmental conditions, and data product. The use of these flexible devices enabled the surveying of exterior parts of historical assets, overcoming constraints posed by the presence of water courses or waterfalls. In some cases, close-range photogrammetry and total station were used instead of aerial photogrammetry and GNSS receiver, respectively, due to environmental constraints.
The 3D survey, for testing operations and data processing, was made on Mulino Arena, located in the province of Ascoli Piceno, Italy. The resulting point clouds enabled to produce the 3D model of the mill.
The integration of 3D models, obtained from geomatic survey, with the data, already archived in GIS 2D, has used either a shared folder or a direct import of the point cloud into the GIS. The chosen option, using a professional version of the GIS software, has been guaranteed both online and offline modes.

The use of GIS is highlighted as a widely used tool by public administration for various purposes, such as creating interactive maps and virtual tours of historic sites, analyzing the economic impact of historic preservation and heritage tourism, and identifying potential funding sources for preservation and restoration efforts. The use of GIS for built heritage valorization is a valuable tool for public administration agencies seeking to promote the cultural and economic value of their community's historic assets.

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