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TOWARDS A 3D DIGITAL MODEL FOR MANAGEMENT AND FRUITION OF DUCAL PALACE AT URBINO. AN INTEGRATED SURVEY WITH MOBILE MAPPING

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Abstract

The digitization is the first feat of safety, knowledge and management of Cultural Heritage. The technological development has produced a complexity increase to manage the big data acquired. This paper shows the best practices for the digitization of a museum (National Gallery of Marche), hosted in a historical and complex building: it's a problem of contents and "container" (the Urbino Ducal Palace = a city in the appearance of a Palace). This is the case study of the first challenging aim of the CIVITAS project. The digitization workflow has combined the several sensors and technology at different scales, such as static and mobile wearable laser scanners systems, the different focals for internal and external cameras, 360 panoramas and HD images. The goal achieved is the new 3D digital model, validated and with high accuracy, containing big 3D data, as starting point of HBIM, Serious Games, VR/AR applications.

Keywords

Cultural Heritage, 3D model, reality-based model, integrated survey.

1. *Introduction*

Digital technologies have transformed the way of thinking of Cultural Heritage (CH) researchers, all industry professionals work by providing new ways to collaborate. For some time now, working on CH means working with a multidisciplinary team. Moreover, digital documentation includes the collection of many different types of data and tools. The importance of Cultural Heritage documentation is well recognized and there is an increasing pressure to document and preserve them also digitally.

The safeguard, the protection and the fruition of CH have gained a powerful tool, thanks to the potentialities of immersive visualization and 3D reconstruction (Bruno et al., 2010).

Those goals require an integrated survey through several tools (sensors and techniques) must be necessarily used. Moreover, methods able to seamlessly combine different models together have to be developed in order to remove overlaps and fill gaps between them to create one model suitable for documentation and visualization (Clini, Quattrini, Frontoni, Nespeca, 2015).

For large areas, the latest technological developments are aimed at the improvement of mobile, wearable or transportable acquisition systems, which greatly reduce working time (Petrie, 2010) (Recchiuto, Scalmato, Sgorbissa, 2017). The traditional scanning systems and the new digital photogrammetry algorithms are combined with the latest Simultaneous Localization and Mapping (SLAM) systems, which consist of the concurrent construction of a model of the environment (the map) and the estimation of the state of the instrument moving within it (Cadena et al., 2016) (Fuentes-Pacheco, Ruiz-Ascencio, Rendón-Mancha, 2012).

Recently, the development of wearable systems based on multiple profilers and cameras opens to new challenging field of applications. The potentialities of such systems in terms of accuracy, productivity and completeness of the final dataset has been tested and described in many papers, such as (Castagnetti et al., 2016) (Andrea Masiero et al., 2018).

Mapping large-scale indoor or underground environments with high surface complexity, detail and possibly low ambient light is still a demanding task and a variety of technological solutions is significantly improved.

The higher acquisition speed allows to survey a larger area, but this often means more data to be managed. For this reason, the data management is a strategic issue, today more than ever, also in the CH field.

Some projects present the implementation of a system for managing data based on the 3D model of the cultural object with a focus on the process for cultural assets management and the interface design for cultural services (Apollonio et al., 2017).

In this way, alongside the parametric modeling on BIM (Building Information Modeling) platform, especially for CH, the information systems capable of manage various data and complex geometric shapes are increasingly being developed (Quattrini, Malinverni, Clini, Nespeca, Orlietti, 2015).

The case study presented in this paper is Palace Ducal at Urbino. The new 3D model is created to become a support for the new museum exhibition project, but also as a complete data collector for all further needs for the Palace or the Gallery.

At the present stage, although the project phases are not completed, the paper wants to describe the work of data acquisition and processing. The methodology used respects the principles of the London Charter: for a CH computer-based visualization to match the rigour of conventional research, its rigour must be visible (www.londoncharter.org) (Brusaporci, Trizio, 2013). Sufficient information, that accurately describes the work done so far, is provided below.

Digitization of such a complex architectural object, very large and important, required the integration of different techniques and was the test field for the use of an innovative wearable instrument. From the first data mining, the chosen settings prove to be sufficiently rich in terms of geometry and colours to allow global and local analyses, the multiscale details and the data quality.

Summarizing, the features of the work presented here are: an important historical building; a main museum with a large collection; a big surface to digitally document; an integrated survey; a large amount of data to process; the information system for management; scalability of data; multilevel details.

2. *The CIVITAS project*

The work described in this paper is part of CIVITAS (ChaIn for excellence of reflectiVe Societies to exploit dIgital culTural heritAge and museumS), an interdisciplinary research project founded by UNIVPM and aimed for digitization and fruition of Ducal Palace at Urbino.

According to the introduction, CIVITAS proposes 5 strong challenges (ch) that respectively regard the following topics:

1. Digitization of Cultural Heritage at different scales (ch1),
2. Digital Content Management for 3D/4D semantic-aware models (ch2),
3. Enhancement of Visitor Experience and Social Inclusion (ch3),
4. Fruition by multisensory (visual, haptic, sound) Interaction paradigms (ch4),
5. Business models based on Digital Heritage for Culture, Research, Tourism, Reflective Society promotion (ch5).

They open up a large variability of chances in sustainable exploitation and conservation of CH. These challenges require a chain of interdisciplinary competences able to face the main issues, both methodological and technological, from different and interlinked perspectives.

The first challenging aim of CIVITAS (ch1) regards the digitalization workflow and the combination of the related 3D sensor technologies to acquire and merge shapes at different scales (geospatial, architectural, sculptural, pictorial, and archaeological) and with different levels of accuracy.

The techniques and the methodology used are based on the combination and matching of the various datasets with different levels of detail (LOD), captured by photogrammetry (SfM) and 3D laser scanning.

The 3D models include HD pictures to obtain a high-quality realistic representation.

In this research, an innovation is represented by the study and the application of non-invasive acquisition systems to digitize paintings, frames, frescos, tapestries, etc.

The aim is to obtain a 3D model of the artwork characterized by high resolution and accuracy and to match it with the captured HD images in order to use the model both for digital collections and fruition, and for conservation and restoration, as stated in the following challenges.

The second challenge regards the DH collection archiving and management with a particular focus on BIM representation of the digital cultural heritage collections. In this context the application of Linked Data and Semantic Web technologies will be investigated, and a methodology will be implemented to provide accurate and semantically rich representations of the BIM models.

CIVITAS will design, build and validate workflows from reality-based models to deliver 3D and metadata with different purposes/Level of Details/users/enrichments (crossing of disciplinary boundaries).

In an interdisciplinary perspective, the previous key activity is one of the major focuses of Challenge 3 answering to the following question: "How can research provide tools and methods to enhance the visitor experience, improve cultural contents' learning and create enjoyment into the museum?"

Finding a structured answer implies the application of Customer Experience-oriented methodologies to define visitor journeys' requirements and the specifications of interactions with the digital contents and virtual facsimiles.

Moreover, CIVITAS project will be a hive of challenging ideas to develop innovative human-machine interfaces to enhance the visitor experience and finally to facilitate the use of Digital CH (Challenge 4).

Experimentations will focus on the interaction with both virtual and physical facsimiles. Advanced visualization displays (e.g. adaptive AR-glasses, Head-Mounted Displays), tactile stimulation technologies (e.g. force feedback displays) integrated with volumetric sound displays. In parallel, Rapid Prototyping techniques will be exploited to create a physical reproduction of the digitized. To serve these purposes, advanced Virtual/Augmented/Mixed Reality technologies can be combined and adopted, suited and adapted to different user profiles e.g., children, average users, professional users, etc...

Although these technologies are mature enough, they do not represent a mass phenomenon, especially in DCH. This is due to several factors (costs of equipment, systems accessibility and usability, IT acceptance, quality of the sensorial experience); therefore, provide effective solutions enhancing visitor's experience with artworks remains a challenge for research.

In this context, CIVITAS aims at studying new pervasive and effective solutions which enable the development of a virtual/augmented environment, through the multisensorial interaction with virtual artworks.

A final challenging issue of the project consists in the business and social innovation in DCH (Challenge 5). This is an international matter, but this problem can be divided in several bottom-up processes. Emerging technologies in the public sector will require further researches, starting with identifying the specific challenges in the sector. These necessary improvements will be assessed in cooperation with director of National Gallery of Marche region and other experts in its management and fruition. Under this perspective, CIVITAS aims at investigating the adoption, conversion and use process of a new technology both at an organizational and at an individual level, finally coming to the final organizational performance.

Then, in this project, the first of these five challenges it must necessarily be that of digitizing the building, its architecture, its decorations and the masterpieces it contains.

3. Ducal Palace and National Gallery

Federico from Montefeltro, lord of the Duchy from 1444 to 1482, wanted the realization of one of the most beautiful works of the Renaissance: The Ducal Palace of Urbino. Despite the lack of documents that attest to the birth and development, the major scholars have recognized that some of the greatest artists of the period have collaborated in the construction of this majestic building.

The Ducal Palace had several stages of development and it was essentially contributed to the Dalmatian architect Luciano Laurana who is responsible for the twins turrets (called *torricini*). In 1459 Federico had already started the enlargement and the new decoration of the modest existing residence of the counts of Montefeltro.

The oldest nucleus, (known as the apartment of the Jole) was built by the will of Count Guidantonio, Federico's father. It faces with its long side on Renaissance square and was the starting point for the extension and the subsequent planning of the building. Luciano Laurana owes the façade with its evocative twin turrets, the study and numerous rooms on the main floor.

Around 1474, the Sienese architect Francesco Di Giorgio Martini replaced Laurana in the completion of the unfinished parts and designed the complex water system, avant-garde for the time. The "technical" aspect of the building and the modernity of the residence can be particularly appreciated with the visit to the underground, the kitchens, the *neviera* (icebox) and services, which show the organization of a structure that could host an army of pets and a very rich court. Next to his rooms, in the central nucleus of the palace, between the two turrets, the duke had created the splendid inlaid study (called *Studiolo*), a Manifesto of his culture. With the Sienese architect, the Palace experienced its maximum splendour.

During the 16th century, with the succession of the Della Rovere family to the Montefeltro family, the palace underwent further expansions with the addition of the second noble floor.

Directly accessible from its rooms were also the chapel of the Forgiveness, already attributed to Bramante, as well as a small temple dedicated to the Muses, painted by the court painter Giovanni Santi, father of Raphael.

In this part - collection and refined summa of the qualities and interests of the Renaissance man (the studio, the weapons) - is opposed the grandiose refinement of the apartments and the immense *Salone delle feste*, then called the *Sala del Trono* at the time of the papal legates.

The extraordinary renaissance balance of the building is expressed in the most perfect way in the wonderful Courtyard of Honour, in which the chromatic agreements of light stone and brick mark the calculated harmony in the distribution of the compositional elements of the work. The inscription that runs in the band above the arches recalls the glory of Federico.

One of the greatest ornaments of the palace was the rich library of illuminated manuscripts, the most splendid of the period, for which Federico committed a large part of his revenue as warlord. At the death of Federico, 900 codices were stored in the library; the collection was purchased by Alexander VII in 1657 for the Vatican library.

In 1474 Federico had a coveted Duke IV of Rovere, and the proud FE-DUX inscription camps after that date on many parts of the palace. At the death of the duke, in 1482, the culture and refinement of the court of Urbino became the prerogative of his son Guidubaldo and his consort Elisabetta Gonzaga. With them, the Montefeltro dynasty ends moving in the women's line to the Della Rovere branch.

The second floor of the building, which was renovated and raised up in the mid-sixteenth century at the behest of Guidubaldo II Della Rovere, currently houses collections of paintings of the seventeenth century, graphics and collections of ceramics. The duchy flourished until 1631, when it passed to the dominions of the Church. Vittoria Della Rovere, the last of the dynasty, will bring all the ducal assets to Florence, where she goes to cousin Ferdinando de 'Medici.

In 1912, the Ducal Palace became the headquarters of the National Gallery of Marche region. The museum houses many masterpieces: the Muta of Raffaello, the Flagellation of Piero della Francesca, the Ideal City, works by Barocci, Tiziano, Berruguete, Gentileschi (Fig. 1).

Fig. 1: New point cloud of Laurana’s façade with twin turrets.

The type of objects consists of paintings, sculptures, tapestries, drawings, prints, furnishings, ceramics and coins. Instead, the amazing collections of the Ducal Palace are now largely preserved in the Uffizi Gallery at Firenze and the Distinguished Men of the *Studiolo* are collected in the Barberini collection and partly in the Louvre Museum. (Baldi, 1724) (Curuni S.A., 1985)

4. The integrated survey

Digital technologies are transforming the way of thinking of CH researchers. The technologies for creating digital reality-based models have felt a noteworthy improvement. 3D models have to be constructed from accurate acquisition processes, semantically organized, low-cost and simple management systems (Nespeca, 2018) (Attenni, Bartolomei, Hess, Ippolito, 2017).

For the acquisition phase, many sensors and other techniques such as laser scanning and photogrammetry must be used. This aim requires to develop methods able to seamlessly combine different models together in order to remove overlaps and fill gaps between them to create one model suitable for documentation and visualization. We carried out several acquisitions dealing with architecture, but we are currently planning also acquisition for paintings and sculptures (reliefs of Laurana and several kinds of moldings such as fireplaces, doors and *peducci* on which stand the vaults of the Palace).

4.1 The wearable system

In addition to the standard acquisition, a day with the Pegasus backpack was performed in the framework of the CIVITAS project.

This tool is a terrestrial mobile mapping system recently developed by Leica Geosystems: it features two laser profilers, five cameras, a GNSS receiver and a 200-Hz INS.

The main advantage of this system is to allow an accurate and fast surveys of areas accessible by a human carrying a backpack (Fig. 2).

It is very useful especially in the case of places where it is difficult to carry other instruments.

The weight of the Pegasus backpack, specifically 11.9 kg, is surely reasonable for a backpack carried by an average person. The SLAM technique using the two laser profilers, which acquires 600k points per second at a maximum range of 50 m, and with a high precision IMU, nominally ensures position accuracy in indoor environments from 5 cm to 50 cm walking for 10 min. However, as stated in the backpack specifications, several factors can affect this value. Each camera acquires 4 Mpx images at 2 Hz. Battery life nominally ensures 4 h of operating time, which should be enough for most use cases. (Andrea Masiero et al., 2018).


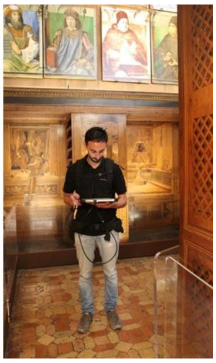

Fig. 2: Pictures of outdoor and indoor acquisition, architectural space, decoration and details capture, by Back Pack system.

The Leica Pegasus backpack survey was done on 21 May 2018 and it was structured according to the following phases:

- Positioning of the Backpack on the ground for the static system initialization.
  This phase requires the instrument to be open to collect as many satellites as possible (GPS, GLONASS and BEIDOU).
- The dynamics system initialization.
  After the first phase, it is needed to walk (always in the open air) to synchronize the IMU with the GNSS system, in order to synchronize them.
- During the survey phase it is possible to vary the light intensity of the cameras, but there are not scanning variables (density or quality) because the instrument associates each section of the profiler with a second of the trajectory.
- For the final tasks, the survey is completely indoor, where the satellite acquisition phase is not required. In this case, the instrument is equipped with a base to fix the starting/ending position of the mission.

The resulting point clouds combined with photogrammetric data requires a post-processing workflow of the data acquired by the individual sensors based on the use of different specific software. In a day of work, in just 4 hours, three different tracks were acquired. In order to have a data redundancy and a good overlap between the paths and between the other acquisitions, many areas have been acquired by several paths. In particular, the exterior, thanks to the GNSS signal, has given excellent results and is a valid link for the other scans registration.

The first track, visible in Figure 3, returned 280 million points. After processing in software dedicated to mobile data, the point cloud, imported into the Cyclone software, consists of 30 parts and its dimension is 2.61 GB. The data processing and the loop closure of the track allows to fine-tune the registration, minimizing the error propagation (Fig. 4).

The resulting 3D model has a satisfactory level of development, classifiable in BIM field as LOG C (UNI 11337-4:2017). Some works (Castagnetti et al., 2016) have highlighted a level of uncertainty associated with the point cloud generated by the Pagasus Backpack system that could make it difficult to describe architectural details (Fig. 5).

Therefore, in this context, where the detail and an accurate description are key factors, the instrument does not seem to achieve the performance of a high-end scanning laser placed on a tripod as can be expected from a tool developed to produce a massive and fast documentation.

4.2 The static terrestrial laser scanning

To achieve the high levels of detail necessary for a complete and satisfactory 3D model of the Ducale Palace, a dense acquisition campaign using a static laser scanner was organized.

The work was divided into 5 days according to the closing hours of the National Gallery. In the survey project the rooms open to the public were privileged in order to have the data necessary for the museum management.

The tools used are the C10 laser scanner and the most advanced P40 model, both of Leica Geosystems. In total, 81 scans were performed with the first and 175 with the second instrument.

The difference is due to the faster scanning speed of the P40, which also demonstrated greater precision and quality of data due to hybrid technology and automatic data filtering.

No targets have been acquired for the alignment of the scans, but the whole registration phase was managed by software from cloud to cloud algorithms (ICP), through the smart alignment function.

To optimize the working time, the various resolutions were chosen, higher in the most important rooms, in order to reach in some cases a LOG E (UNI 11337-4:2017). In the table 1, the parameters of comparison between the instruments and the chosen characteristics are shown. The Ducal Palace is a very large historical complex of approximately 7500 square meters for each elevation (4 in total). Figure 6 shows the scan positions of the two instruments and the scanned surface.

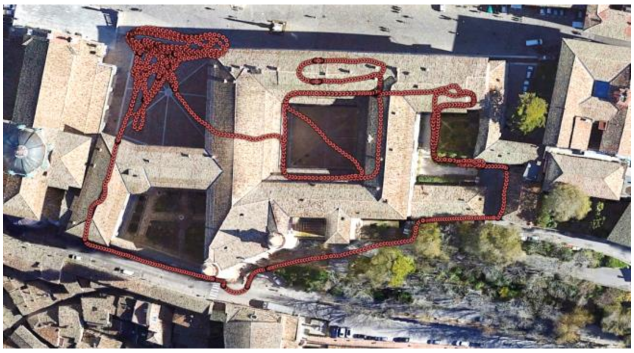

Fig. 3: First track calculated, viewed in Google Earth with klmz file, where is clearly recognizable the dynamic initialization phase.

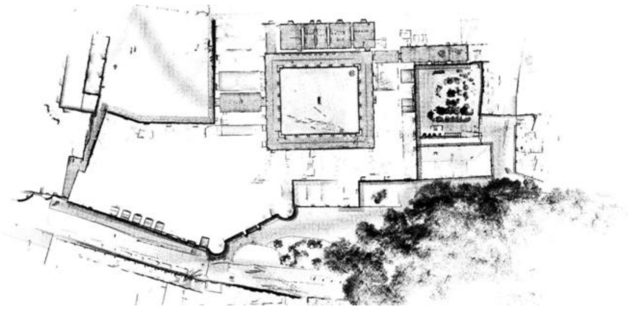

Fig. 4: Point cloud generated by first track. Silhouette mode view of the horizontal plan (Cyclone sw).

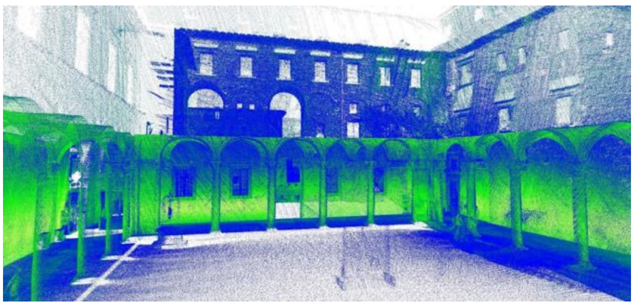

Fig. 5: Perspective view of point cloud of courtyard of the duke. In this detail view, the striped effect due to use the laser profilers is evident.

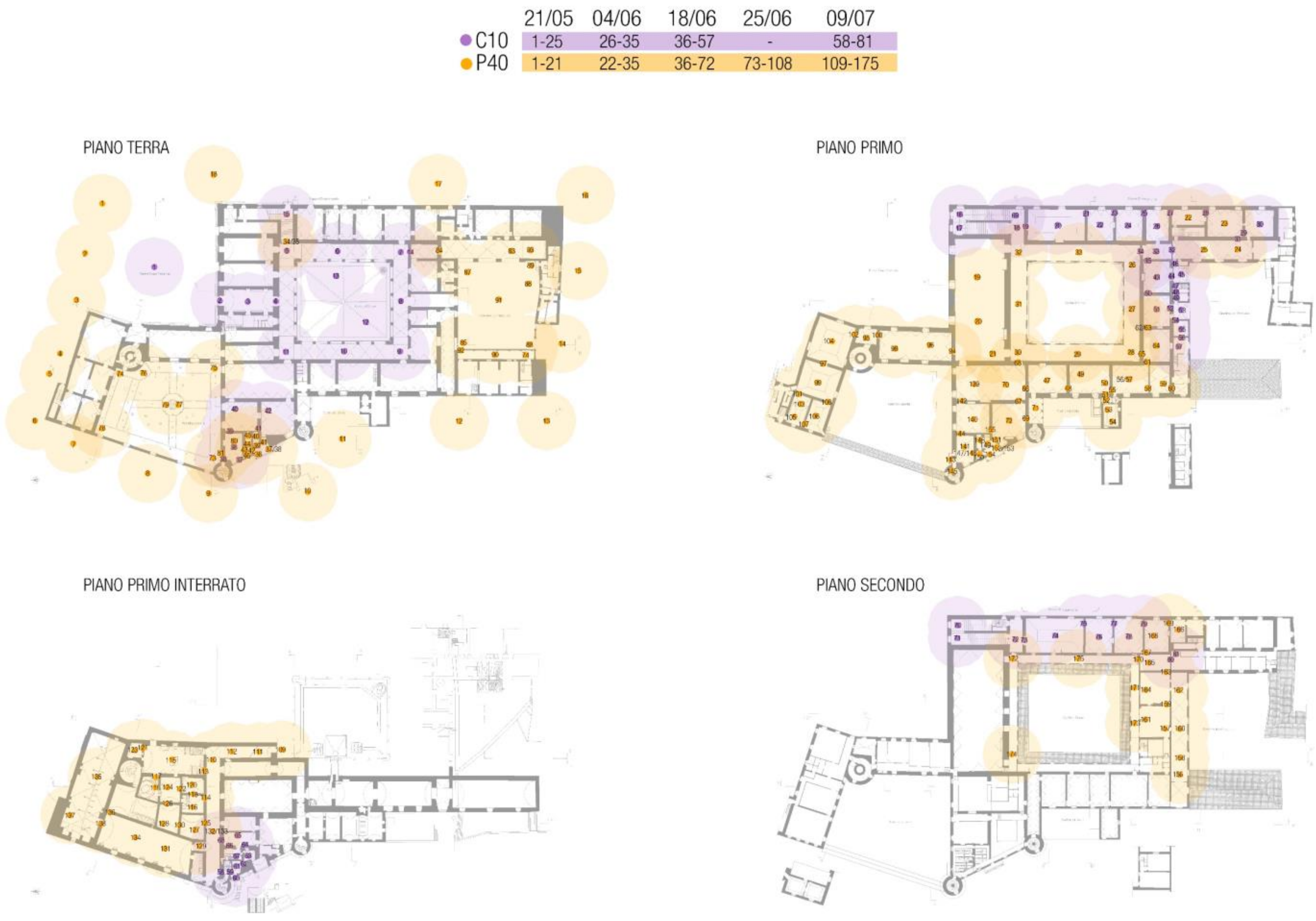

Fig. 6: Laser scanning survey: plans with scanner location. Two different tools used.

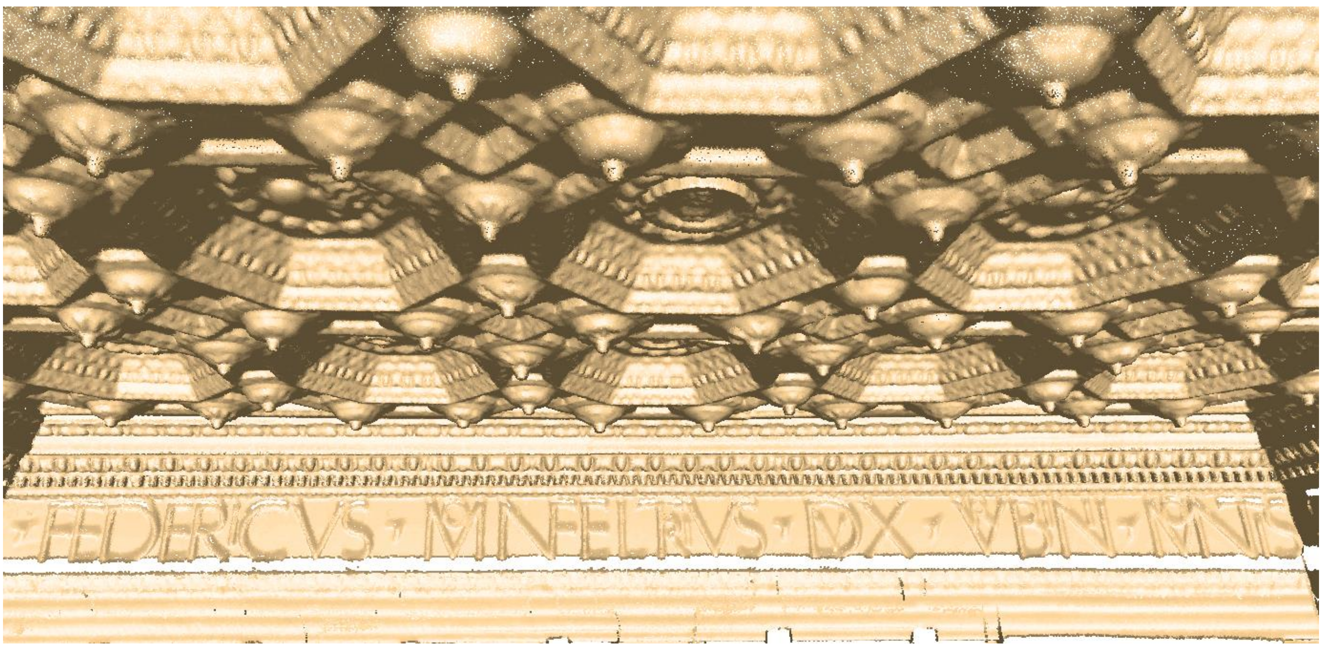

Fig. 7: Detail of point cloud of the ceiling and the frame of Studiolo, where it is possible to clearly read: "FEDERICUS MONTEFELTRIUS DUX URBINI MONTIS"

Tab. 1: Comparison between the different laser scanner tools used, the mobile and the static systems.

	BACKPACK	P40	C10
technology	Slam, IMU, GNSS, 2 laser profile, 5 cameras	hybrid laser, camera,	TOF laser, camera
Field of view	Profile + trajectory	Full dome 360x300	Full dome 360x270
Accuracy	10 cm	2 mm	4 mm
Speed	600k p/sec	1mln p/sec	500k p/sec
Range max	50 m	270 m	300 m
Resolution (used)	Not fix	3 mm@10m 6 mm@10m 12mm@10m	1cm@10m
Acquisition time (resolution addicted)	1 hour for big area (very fast)	4 min 2 min 1 min (fast)	6 min (slow)
Processing	Slow but automatic registration	Fast but manual registration	Fast but manual registration

For the outside, 19 scans were made, 18 with P40 and 1 with C10, for a total of 140 million points acquired, at an average resolution of 1 cm to 10 m.

For the splendid inlaid study (called Studiolo) located between the two turrets, a manifesto of the Duke's culture, two very high-resolution scans were necessary, allowing to read a millimetric detail even on the coffered ceiling (Figure 7), with 254 millions of points for only this room.

The loggia on the lower floor was digitized with a similar goal and method: 10 high-resolution scans to capture the outer space and the adjacent Chapel of Forgiveness and Temple dedicated to the Muses, with 1155 millions of points.

The large amount of data acquired has generated the big files that require careful management: only the project file (.imp) has the dimension of 200 GB.

4.3 Images acquisition

The photographic acquisition is an essential part of survey project. In some cases, the images alone contain more information than geometrical survey and are used as an instrument of knowledge and fruition. Some works as (Napolitano, Scherer, Glisic, 2018) show how the combination of virtual tour environments (VT) and informational modeling (IM) can be a very useful database, containing building plans, previous conservation reports, image galleries, past interventions and short descriptions of the conservation issues.

The photographic acquisitions performed were of two types:

- 360 panoramas, for mapping the point cloud and for the virtual tour;
- HD photos, for details and for the most important and rich spaces.

The need for time optimization and the need for high quality have also been combined.

To facilitate the mapping with the scans, the spherical panoramas (Fig. 8) were created by the internal camera of laser scanner or by external camera aligned to center of scan.

In particular, for the C10 laser scanner, from scan 1 to 35, an external camera with a focal length of 18 mm was used. For a good stitching overlap the photos are 38 and the panorama size can reach 16384 x 8192 px, the maximum size accepted for mapping the point cloud. From scan 36 to 81, the lens was replaced by a fisheye with a significant reduction in the number of shots at 8 and a maximum export resolution of 8192 x 4096 px.

For the P40 laser scanner, from scan 1 to 35, the internal camera and factory setting HDR were used. The acquisition times were significantly higher than the ones of the scan; for this reason, the scans from 36 to 175 were made with the ISTAR external camera.

Fig. 8: 360 panoramic photo of the square of the Duke, the entrance to the National Gallery.

Tab. 2: Comparison between the different cameras used: internal and external with various focal. The parameters are related to a single 360 panoramic photo.

	Int Cam _ C10	Int Cam _ P40	Ext Cam _Istar	Ext Cam _Fisheye	Ext Cam _18 mm
Acquisition Time (min)	6	9	2 (shoot + storage)	5 (location + shoot)	10 (location + shoot)
Post production (min)	0	0	0,5 (auto)	2	5
Stitching phase (min)	0 (Auto Import)	0 (Auto Import)	0.5 (auto)	3	5
Resolution (px)	4096 x 2048 (for export)	4096 x 2048 (for export)	5656 x 2828	8192 x 4096	16384 x 8192
Sphere (°)	360 x 270	360 x 300	360 x 290	360 x 360	360 x 360
Mapping phase (min)	0,5	0,5	2	2	2
HDR	no	yes	yes	no	no
Average weight (MB)	7	7	8	30	120

Fig. 9: Plan, sections and details of Loggia near the chapel of the Forgiveness and the temple dedicated to the Muses.

This instrument has 4 cameras that are simultaneously activated and is equipped with a software for creating panoramas with fast stitching and automatic post-production processes. However, the image produced has a non-high resolution of 5656 x 2828 px.

It is clear that the advantages in terms of time have favored this last solution, even if, in addition to low resolution, another important disadvantage is the field of view of the camera smaller than the laser one, creating an ugly cone of black on the colored point cloud.

In the previous table 2, the characteristics of the photographic instruments used can be compared. The parameters shown are those used in the survey campaign.

5. *A 3D digital model for management and fruition*

After the acquisition phase, exhaustive and organized documentation is crucial for conservation of historic structures. The introduction of the third dimension aimed at storing and managing documentation about heritage objects. It offers a more intuitive way to access and manage different kinds of information. The availability of digital 3D rendered models exceeds, in fact, the simple possibility of developing photorealistic reproduction of the 3D real object and it makes available all information in a visual and integrated way.

Since the project dimension is more than 200GB, the data management is not minor, but it is still manageable, ensuring the completeness of the model and the richness of the details. Powerful software and hardware, specific skills and advanced tools for the management and the semantic organization of data are necessary.

The data mining from the point cloud, despite 3D-oriented changes, still leads in both directions: two-dimensional documents, especially for public management assets, and in-depth three-dimensional analysis, more commonly used for enrichment and fruition. Research developments in recent decades, including the important spread of BIM modeling, aim to merge the two concepts.

In this paper, two examples of two-dimensional and three-dimensional data processing on two of the most important spaces of the Ducal Palace at Urbino are shown.

In the first case, in Figure 9, slices and processed views of point cloud, combined with new fitting functions for vectorization, provide all the geometrical and colorimetric information for the knowledge and maintenance of the Loggia on the ground floor, adjacent to the Chapel of Forgiveness and the Temple dedicated to the Muses. The drawings are definitely a LOG E (UNI 11337-4:2017).

Instead, a 3D information system based on the point cloud was improved in the Study of the Duke (Studiolo), containing historical and information captions for the immersive navigation of that very small space, but full of data (Fig. 10). The Studiolo perfectly shows how a digital fac-simile of heritage replaces the original space for an increased use of reality, even better if precious and difficult to access.

The HBIM model of the whole building is still under construction. The geometric starting data acquired from the laser scanner and photogrammetric campaign are enriched by historical information and archive data. The semantic classification of architectural elements adopts historical and structural categories common to historical heritage. This digital reconstruction of the building is also aimed at the historical narration of the different stages of development, expansion and modification that have affected the Ducal Palace as we see it today. The 4D-BIM, usually used for the planning of working time on site, is converted into the simulation of the historical phases.

Fig. 10: Comparison between RGB image and intensity value. Annotation and measurement in the Studiolo of Duke, the Distinguished Men.

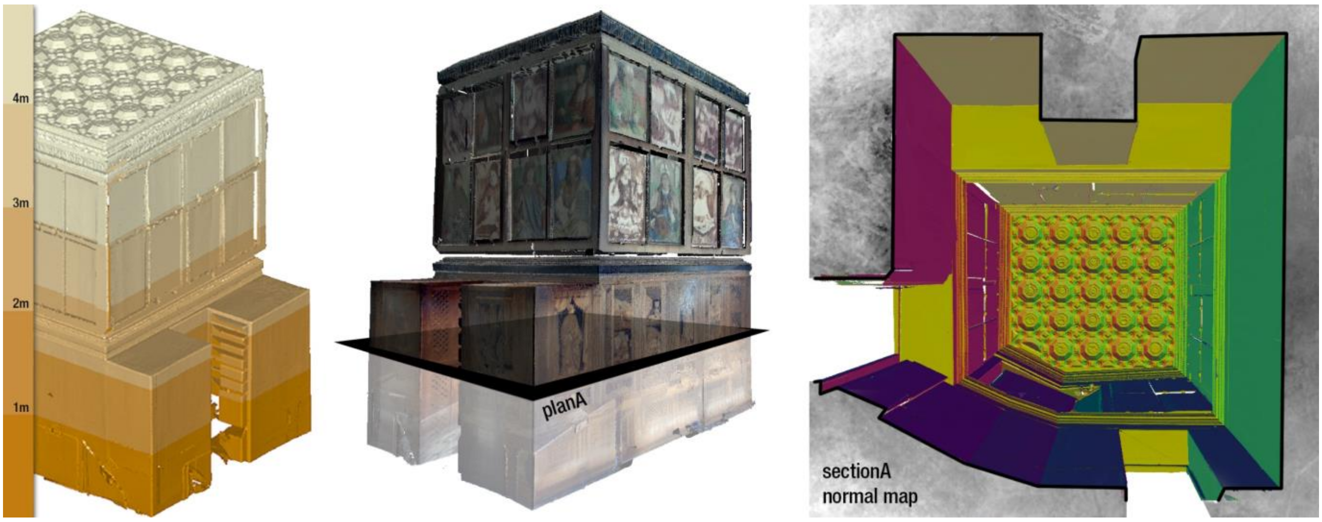

Fig. 11: Data processing of 3D model of the Studiolo. From left to right: elevation map, perspective view, normal map in perspective view of section A.

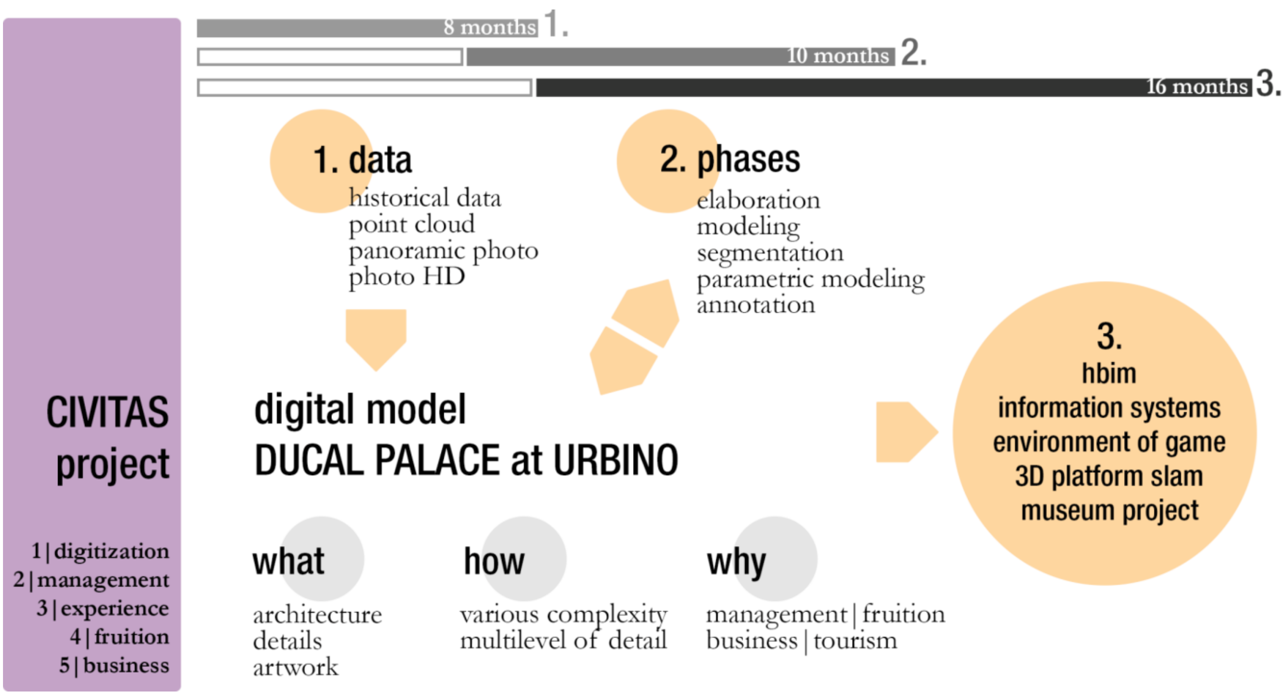

Fig. 12: Scheme of the CIVITAS project. Deepening on the first challenge (the digitization): phases, objects and objectives.

6. Conclusions and future works

The importance of CH documentation is well recognized, and there is an increasing pressure to document and preserve them also digitally. The 3D digital objects are used for many goals like historical documentation, conservation, restoration purposes, Virtual and Augmented Reality (VR/AR) applications, 3D repositories and catalogues, web geographic systems, visualization purposes etc.

This paper shows a complex integrated survey of an important historical building. Ducal Palace at Urbino is the case study of the first challenging aim of the CIVITAS project, which allowed to test of a new wearable acquisition system. The digitization workflow has combined the various sensor and technology at different scales. The goal achieved is the new 3D digital model, obtained also from the wearable mobile mapping systems and managed by an integrated information system.

The quantity and the quality of the expected information required the optimized setup of best practices for the acquisition, processing and management of these big data. According to the principle of documentation of the London Charter, a validated and with high accuracy model guarantees the success of the next applications.

Starting from the first analysis (Fig. 11), the future works, already under way, will concern the achievement of a HBIM model and a more complex and interactive Information System (Quattrini, Pierdicca, Morbidoni, 2017).

In addition to the creation of a parametric and interoperable big model, the possibility of automatic recognition of architectural elements is being tested. The large size of the database requires the development of algorithms for automatic segmentation of the point cloud into architectural small elements that can be associated with automatically and manually customized parametric models.

The results will be involved in Virtual Reality and Serious Games applications, which we will develop with an interdisciplinary team, as shortly summarized in Figure 12.

7. *Acknowledgements*

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