ON THE RELATIONSHIP BETWEEN GEOMATICS AND CONSERVATION: LESSONS LEARNED FROM INTEGRATED RESTORATION LABORATORIES

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ABSTRACT:

The paper aims at investigating results, research perspectives, and limitations emerging from the synergy between geomatics and conservation. Recent didactic experiences carried out in restoration laboratories at Politecnico di Milano are illustrated and discussed. The authors tested innovative techniques for surveying with particular attention to the conservation problem. The aim was to exploit novel 360° virtual/immersive environments able to collect and manage data traditionally useful for conservation projects such as thematic maps of historical building techniques, construction technologies, deterioration pathologies, and data from diagnostics. Results are presented for two case studies completely different in terms of shape, pathologies, and reuse: the Albergo Diurno di Porta Venezia in Piazza Oberdan, and the Church of San Vittore and the Forty Martyrs (both in Milan). The work carried out with students allowed one to evaluate the pros and cons of a novel 360° immersive solution. The outcomes suggest other possible uses in related activities. The last part of the paper reconsiders the proposed "renewed" relationship between geomatics and restoration. Starting from the basic requirements of existing regulations, the paper explores the research fields and practical applications that could benefit from an intersection of geomatics and restoration.

1. INTRODUCTION

The educational path in architecture in the last biennium of the master degree at Politecnico di Milano (Milan, Italy) requires experience in restoration laboratory. A laboratory must be composed of more than a single discipline. In the case of courses in the School of Architecture at Politecnico di Milano, such discipline is preservation combed with the different fields of surveying: innovative surveying techniques, representation, surveying, or digital modeling.

Such a decision is "natural". It comes from the traditional vision about the real relationship between the two fields: the survey has always been a preparatory and indispensable phase for any design related to the built environment (Cardaci et al., 2018). On the other hand, a historical digression about this relationship would be very long. Previous work by several academics (who studied its evolution) confirms an obvious but not less important consideration: the survey was (like the use of historical sources) a non-neutral instrument, indeed capable of endorsing the choices of restorers (Pertot, 1994).

The different restoration theories have an immediate impact on what must be detected, measured, and analyzed in a restoration project. On the other hand, such aspect does not diminish the importance of the scientific component of the work. Indeed, "the person who chooses the types of analysis, and after he/she interprets the result, must know really well the monument and must develop an interpretive model of the problem. If this does not happen, the scientific analysis is not verifying a hypothesis, and it is not useful … an important fact that often non-scientists are not able to appreciate concerns the supposed objectivity of the scientific results, which could be questioned. The results of an analytical study are conditioned by the chosen approach: for example, a chemist chooses the appropriate method to check if what he is imaging could be within the scope that requires to be studied" (Torraca, 1988).

2. THE TRADITIONAL VISION AND THE INTERVENING CHANGE

What are the biggest issues in the survey of an ancient building considering preservation design? Is it possible to consider a different approach for the geometric survey? What did the restorers mean when they say "what type of survey for restoration?" (TeMA, 1996).

First, a trivial consideration. Restorers pay more attention to anomalies than similarities. We could briefly say (the debate on this topic would be very long and probably inappropriate) that restorers want the survey to be an active part of a deep learning process; otherwise, no restoration may be scientifically acceptable.

Preservation is not a "pure scientific discipline". However, it is important to recall that restoration continuously uses scientific procedures.

The digitalization process has modified the typical approach followed by architects in their professional activity, among which the procedures to manage and organize interventions. Tools and techniques for (digital) surveying changed. This change had a significant influence and the types of deliverables produced in the project. For instance, hand-measurements are today used to integrate laser scanning or photogrammetric results, notwithstanding they remain a valid tool with centimeter-level precision for technical drawings.

In this "new" scenario, considerations on some recent experiences can be useful to comprehend new questions and doubts. Such mutual geomatics/restoration understating can be useful and promising. It opens new opportunities for future collaboration between geomatics and restoration.

For example, architect specializations often require to assign survey work to third parties. The idea is very simple. A surveyor produces the deliverables. So, the survey becomes an independent component before the design phase, sometimes limited to the identification of geometrical profiles or measurements of the “space” in which the project will be set.

It is easy to imagine all the negative consequences in the restoration field. In fact, knowledge of constructive techniques is essential because it reflects the social history that those techniques represent. Similar considerations are valid for building pathologies. We could simply say that geometric, material (in terms of constructive technologies), and degradation aspects should be considered together. A slogan can summarize such matter: “know for preserving, preserve for knowing”. It means that without knowledge and recognition of the multiple values and problems embedded in a historic building, there is no possibility for preservation.

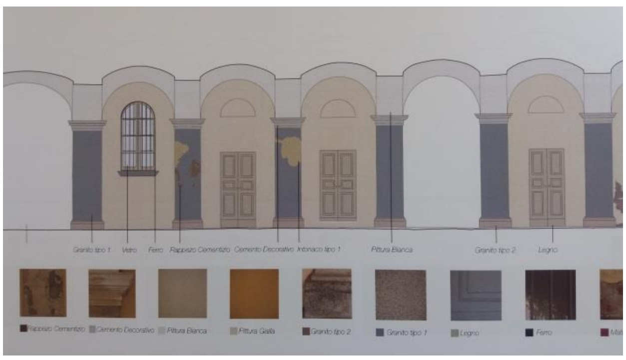
Consequently, the answer to the question “what survey for restoration?” is to represent not only pure building geometry but also material consistency, i.e., the whole constructive techniques and the single elements, and deterioration.

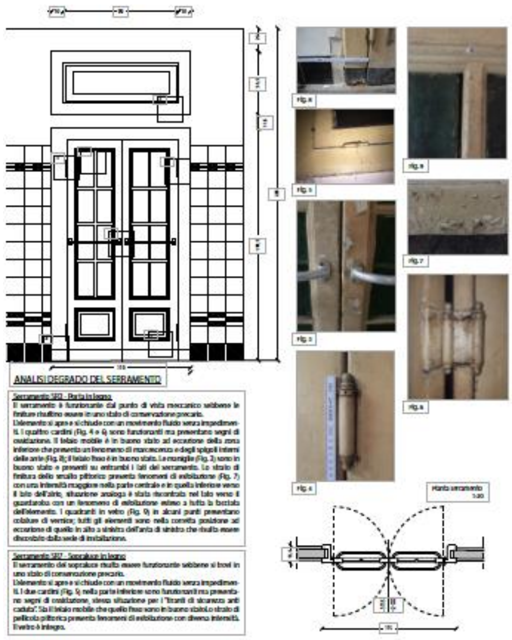
This is the way we decided to proceed during our teaching activities. We tried to stimulate recognition of constructive elements, how they are made, and which relationship they have with other elements.

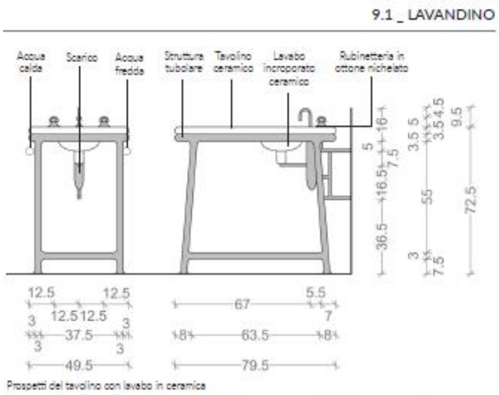
This could be explained with a basic example. The description of a window is not a list of of materials (wood and iron). A window has a role. It has a connection with masonry (i.e., a point that often gives problems because of thermal bridges). It has a specific size, an opening direction, a wooden frame with a glass that has a thickness, a technical typology, specific properties, etc.

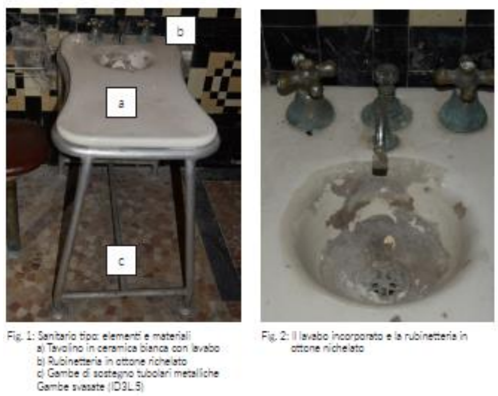
The examples in the different following figures (1-4) below clarify this concept, for which many words would be necessary.

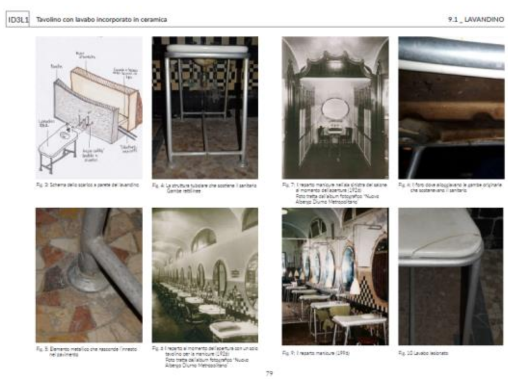
As the survey must offer an important part of the information required for preservation, it must join the historical dimension, (given by the occurred building stratifications), its material structure, and the problems related to decay. The survey can be the instrument that plays an essential role in every analysis (based on direct and indirect sources) as well as the actions related to the modifications in the past, and an archival for preservations activities necessary for posterity. This is an issue widely discussed in Mingucci et al., 2012.











Figures 1-4. “Describing is intended as the progressive approximation that always brings us a little closer to what we want to say. At the same time, it always leaves us a little unsatisfied. So we must continually get back to have a closer look. Then, we have to try to express better what we have observed” (Calvino, 1993).

3. THE TEACHING EXPERIENCE

The availability of innovative surveying methods was exploited with our students, who had to understand the functioning of the two chosen case studies as a whole system. This could be apparently trivial but the traditional way based on the "sub-division" of buildings using plans and sections leads to a two-dimensional vision. Plans and sections are often used as static pictures, losing the real (3D) nature of the building.
This limit is evident when the project requires an overview of the crack pattern, in which damages cannot be considered as happening in independent locations. Such consideration is valid for most thematic maps necessary in the preservation project. The analysis must not detect and describe decay as a static phenomenon. We must understand the reason which caused deterioration. In this sense, it is much easier to see the problem in three dimensions.
It is important to underline that the problem should be approached in terms of process (i.e., what is happening and why), rather than in terms of effect (i.e., how to identify a pathology). This has an impact on the instruments used to record and represent such aspects. For example, we could consider the traditional way used in the past for the survey of historic buildings. The (manual) and exhaustive survey used to reproduce as much as possible the reality remind us the novel of Borges, in which the main character wanted to trace the world at a scale 1:1 (Eco, 1992).
Let us represent all the fine and little details, such as a lacuna perimeter, every single brick, or every single nail. This gives a static situation, i.e. a sort of photograph. Certainly, producing accurate and detailed drawings of all the visible elements is a hard exercise. Such exercise allows the specialist to developed great confidence with the building.
However, it is better (perhaps) to abandon the millimeter level of detail in reproducing the plaster lacuna. It is better to understand that external factors will act and change these borders. So, the approach followed by the authors is not an intense drawing activity of all the elements.
Nowadays, many changes occurred leading to a renewed vision of the entire process (Della Torre and Pracchi, 2004) that emphasizes the need of coherent, coordinated and programmed activities for study, prevention, maintenance, and restoration (Article 29, Italian Code of Cultural Heritage, Legislative Decree 42, 2004).

Figures 5-6. Palazzo Natta, Como. The first survey was drawn by Beatrice Colombo and Roberta Peri in 1990, the second one ten years after.

4. THE TWO CASE STUDIES

The two case studies are completely different in terms of shape, pathologies, original use and problems of reuse. The only shared characteristic is the period when they were built: second half of the Twenties in the past century. This period is particularly interesting because it features a fundamental transition for constructive techniques: concrete started to become very popular.
The Albergo Diurno di Porta Venezia in Piazza Oberdan (Milan) is an underground structure. The Diurno was designed for both travelers (the main station was very close) and local inhabitants. Public baths were not available in all houses. The Diurno offered services for personal hygiene with hot water. Such "poor" function should not be misunderstood: the businessmen who opened the Diurno had the intention to provide the maximum comfort, sophistication and luxury in some parts. More economical services were located in separated areas. This is the reasons why many fine details were designed by the famous Italian architect Piero Portaluppi, who designed most important villas and apartments for the Milanese bourgeoisie.
The municipality of Milan (owner) is giving the place in concession agreement to the FAI (Fondo Ambiente Italiano) in exchange for the restoration work.
The second case study is an abandoned church, San Vittore and the Forty Martyrs. The church was built when this suburban area of Milan was growing due to the migration from South Italy. The population grew very fast and a larger modern church was required soon. The church inherited some parts (e.g., the altar and some frescoes) from an eighteen-century church in the center of the city, which was demolished because of the new development plan. Today, the Church is an interesting mix of old pieces and new ones pretending to be old, with a story of different uses. An example is the basketball court traced on the floor. The basked was still on the balcony close to the organ.
In this case, the priest asked us to design an intervention considering the needs in the neighborhood, i.e. a mix of profit and nonprofit activities. Thus, we asked for some help from an agency specialized in finding locations for different events.

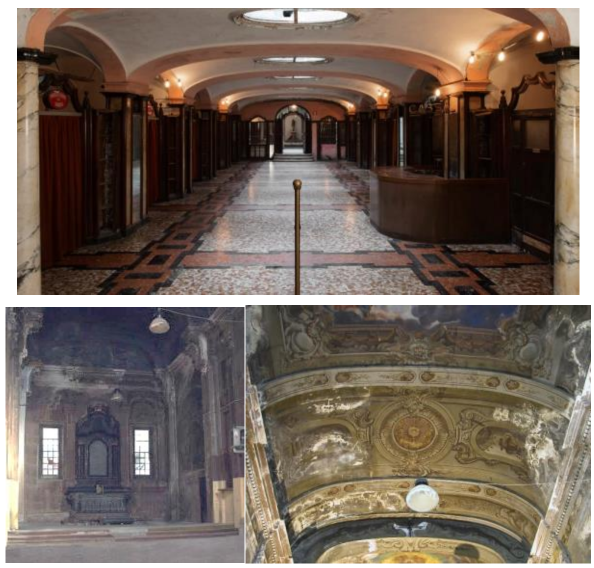


Figure 7. The case studies: Albergo Diurno (top) and Church of S. Vittore (bottom).

5. TECHNICAL ASPECTS OF THE METHOD

This section briefly illustrates and discusses the main technical aspects which led the authors to try out the proposed approach based on 360° images.

5.1 Why use a 360° camera?

The proposed solution exploits 360° images captured with low-cost cameras. The commercial market offers several 360° sensors with a prize variable 100$ (or less) to professional cameras (prize > 10,000$). The camera used in this work is a Xiaomi Mijia Mi Sphere 360, which has a cost of about 300$. The spherical image has a resolution of 6912 × 3456 pixels and can be created by stitching pairs of front- and rear-facing images. The software for image stitching is Madventure 360 Camera, which is available for both mobile and desktop platforms.

The following reasons motivate the choice to try out such sensors:

1. opportunity to rapidly capture the entire scene around the user (the camera can be pointed to any direction), without requiring special knowledge of photographic techniques;
2. limited cost supported by rapid technological advances in the market of 360° images, with growing availability of sensors featuring better geometric and radiometric resolution;
3. possibility to integrate 360° images with software for panoramic tours. This allows users to (i) virtually navigate multiple images and (ii) to associate information;

On the contrary, digital documentation from 360° images has the following disadvantages when compared to images captured by “normal” photographic cameras:

1. lack of commercial software for metric rectification i.e., removal of perspective distortion to turn images into measurable maps;
2. lower resolution when compared to traditional photographs taken at the same distance;
3. less control on illumination conditions.

The previous list has technical pros and cons valid for generic projects. Section 7 in this paper describes pros and cons during restoration activities, that are more specific and should makes the reader aware of the limits of the proposed method.

5.2 Data acquisition and processing

Data acquisition with 360° cameras is a relatively simple operation. First, the camera is placed on a tripod. The connection with a mobile phone allows us to set camera parameters (exposure, etc.). The camera is then triggered obtaining a preview on the mobile phone. This allows the user to recapture the same image after modifying some parameters when the image does not fit basic photographic requirements.

Data processing consists of the conversion of the front- and rear-facing images captured by the fisheye lenses into a single spherical projection. Such operation is relatively simple and can be carried with Madventure, which uses the relative orientation parameters of the two cameras. The result is a set of spherical images acquired from different points, which can be imported into 3DVista Pro to create a virtual environment where multiple information can be associated to each image.

3DVista Pro allows the creation of a virtual tour where images can be linked and navigation becomes an immersive experience. On the other hand, the aim of this work is not a traditional virtual tour. We wanted to develop and test a novel procedure able to store and provide information gathered during the workflow of restoration projects.

The idea is to provide rapid access to information, which can be stored and retrieved in the virtual tour. The tour becomes a sort of visual database, which can be exploited simply through a web link and accessible icons.

More details about the development and use of the proposed method are described in the next sections using the two case studies.

6. RESULTS

6.1 Creation of the virtual environment

After collecting images with a 360° camera, the creation of the virtual environment is carried out using 3DVista Pro. The software allows one to produce virtual reality tours based on panoramas, which simulate multiple points of view like in the case of a “static” observer. In fact, virtual navigation is a rotation of the point of view, without the opportunity to freely navigate the scene (translation). Complete navigation is instead possible when a complete 3D model is available.

On the other, the proposed solution is surely much faster and less expensive than a processing workflow requiring the creation of a 3D model, using both “pure” geometric models or parametric BIM.

As mentioned in the previous section, the method must not be intended as a method for virtual tour generation. The idea is to associate typical information gathered in restoration projects to icons in a virtual environment of the whole building. The virtual environment is made up of multiple spherical images, which can be explored using hotspots or choosing next location on a simplified map. Then, the aim was to provide a novel solution able to guarantee rapid access to information available in different formats (such as photographs, reports, descriptions, drawings, texts, videos, etc.), including existing and new information generated during the restoration project.

The user can explore the building and access such information not only from personal computers, but also from mobile devices (e.g., tablets), which can be used on-site. This solution is surely less cumbersome than traditional VR approaches based on virtual glasses. The method can also be extended and incorporated in completely VR or AR environments. The software has all the tools to complete this final step, although this solution was not tested in our case studies.

A sliding bar allows the user to move the visualization between the original image, the image with additional information about construction technologies, or the image with information about condition assessment and pathology descriptions. The selection of specific elements provides extra windows, revealing other files that can be downloaded, printed, or used directly in the virtual tour.

The method is also able to incorporate additional information in terms on new spherical images (e.g., those acquired in different periods for the analysis of the occurred changes), or information in terms of descriptions, external photographs, videos, new drawings, charts, weblinks, etc.

Overall, the method could be intended as a database linked to the multiple spherical images. Some images of the two virtual environments are shown in Fig.s 8 and 9.

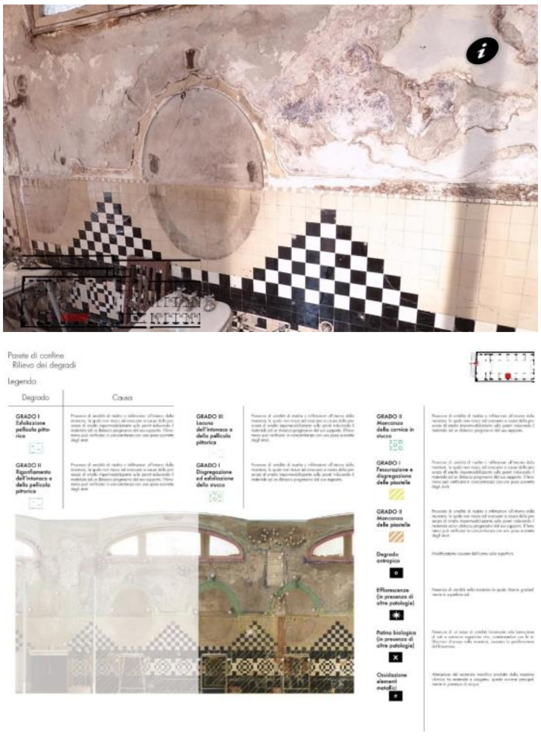


Figure 8. Some images from the work at Diurno di Porta Venezia (the icon with an “i” opens the information report).

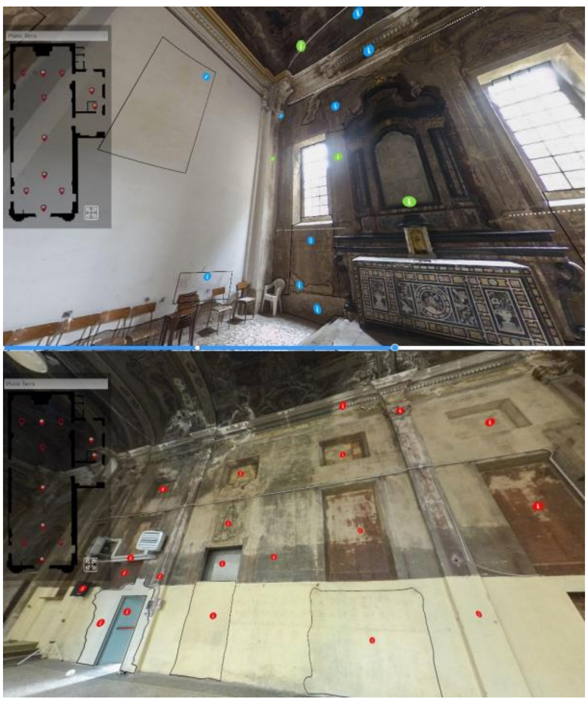


Figure 9. The spherical images in the Church with some icons to access additional information.

6.2 Metric measurements from 360° images

The commercial market provides only limited solutions able to take measurements using spherical images. Although some photogrammetric software (e.g., PhotoScan or Pix4D Mapper) have photogrammetric workflows for scene reconstruction from multiple 360° images, their approach seems not interoperable with the proposed virtual environment.

One of the important parameters to be measured is the area covered by specific pathologies. Measured areas allow cost analysis by multiplying unary costs of specific interventions for the measured area. A typical way to measure such areas is the use of rectified images or orthophotos.

360° images are based on a different camera model (spherical camera model). Procedures used for rectification of standard photographs cannot be used with 360° images. To overcome this drawback, an algorithm able to measure areas from 360° images was developed and implemented in MATLAB. First, the 360° image is oriented towards the area of interest, then mapping from spherical to gnomonic coordinates allows us to generate a new image, which is rectified using external constraints (such as vertical or horizontal lines, or reference points with known coordinates). The focal length of the gnomonic projection is also used in the rectification process to limit the number of external constraints, as described in Barazzetti (2011).

An example of the achievable results is shown in Fig. 10. Here, the small room has been surveyed using a single 360° image. The areas in blue and green were rectified using a preliminary conversion of the spherical image into a gnomonic projection. Then the gnomonic projection was rectified. The procedure can be applied to the other walls of the room.

Figure 10. Example of image rectification with 360° images.

7. PROS AND CONS OF THE EXPERIENCE

Nowadays, BIM is becoming more popular for architectural applications. Some important considerations about the similarities and differences with the proposed approach cannot be ignored.

The proposed approach does not rely on a 3D model. Therefore, most metric capabilities obtainable through BIM are not available. On the other hand, the proposed solution was not developed to replace BIM. The idea was to provide a faster, easier, and cheaper access to precious information through a quick solution for data collection (360° images in this case).

The cost of a BIM and the one for the creation of the 360° environment are notably different: the proposed method is faster and much more cost-effective. The equipment is a low-cost 360° camera, and the association of information can be done with professional software available on the commercial market for less than 800$. In addition, the latest version of Photoshop has new tools able to handle 360° images, confirming the growing interest in this kind of images.

Another consideration is related to the complexity of technical operations. The use of software able to generate a virtual tour from multiple 360° images is easier than modeling with BIM software (e.g., Revit, ArchiCAD, …). The method is therefore valid for both expert operators or users without advanced modeling skills. Finally, the transmission and use of the final product is very simple. Anyone can navigate the immersive environment without specific software licenses or advanced computer capabilities. The result can also be shared online for simple communication with a webpage accessible using a web link.

Although the virtual environment is not a pure 3D, it has the potential to show the structure as a whole. It allows one to simulate human vision and reexamine details or elements missed during an on-site visit, or a photographic documentation that missed specific elements. Moreover, it has practical applications that were not considered at the beginning of this experience.

In the case of Albergo Diurno di Porta Venezia, the FAI considered the model particularly useful as an instrument for evaluating decay and changes (unfortunately very fast) as well as to define the conditions of the site (at different epochs).

In fact, it is possible to have a sort of "starting point" (epoch 0) for every room and every surface. The vision can be updated with new images before and after restoration.

In the case of the Church, the tour was used by an agency specialized in finding locations for events. It is suitable for presenting the building to clients in a way more effective than videos or photographs..

Other possible applications of the immersive tour can be identified in several fields. It could be used by real estate agencies, especially in the case of an outstanding property. It could be exploited for management in concession agreement and in project financing. Another application could be the evaluation the suitability of spaces for disabled people (Marconcini and Pracchi, 2019). There are many other uses such color monitoring for painted surfaces, shelter design in archeological sites, documentation of excavations (Valente, 2017), and anthropological studies of neglected elements such as ancient graffiti (Oreni et al., 2018).

The list is not exhaustive. Everyone can consider other possibilities according to his/her needs, such as the relationship between geomatics and marine archeology, the issues related to new systems for energy production in the landscape, structural monitoring, and so on.

The disadvantages are related to the difficulty in reproducing and describe decay, especially if compared to traditional approaches based on CAD. Although a solution for measuring areas was developed in this work, it is more complicated than typical approaches with rectified photographs. At things stand at the present, no commercial software is able to combine a computational system for areas and costs of the interventions and the simultaneous use of the virtual environment. It is also quite complicated to represent the different phases identified during the survey (stratigraphy). These are just some of the activities where a traditional system based on plans and sections is still easier and faster.

8. CONCLUSIONS

To conclude, we cannot say that this experience was completely successful. We had to face several problems. Some problems were not solved. However, we can surely say that we learned from each other. It was important to clarify what we were looking for, and it was necessary to understand problems and possibilities offered by an integrated use of our different disciplines. A very limited number of outcomes of this experience is reported in the following figures. We believe that such images (made by our students) can confirm the good level of productivity reached by our approach.

We started the paper discussing the importance of a strong relationship between survey and restoration. Nowadays, the internal specialization in different disciplines makes more disconnected the "work of the surveyor" from the "work of the restorer". It is quite common to contract a photogrammetric/laser scanning specialist. Then, his/her deliverables are transmitted to the architect. In the past, the "overlap" between "surveyor" and "restorer" was much larger. We think that such "weak" relationship is not always fruitful.

For example, it is very attractive to use the potentialities of new advanced modeling techniques for the valorization of Cultural Heritage. Sometimes specialists are much more interested in the product itself rather than in expanding doubts, curiosity, and willingness to know the past, which were and still are our objectives, especially in our teaching activity.

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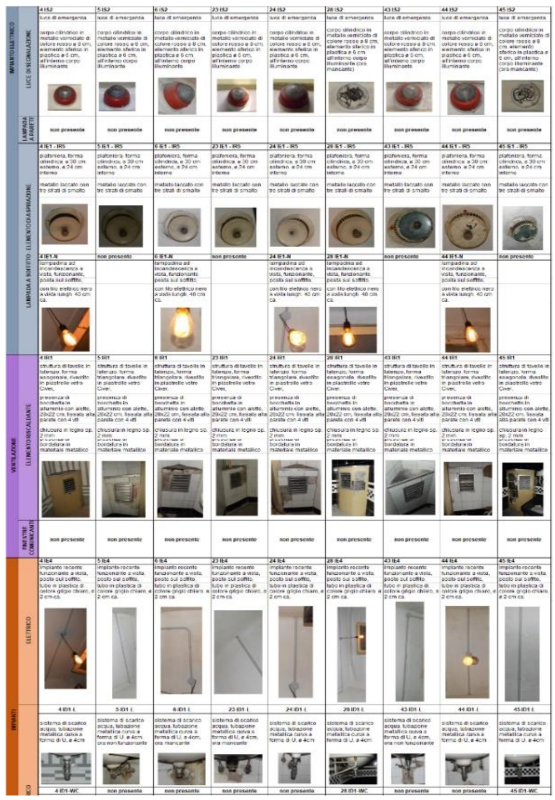

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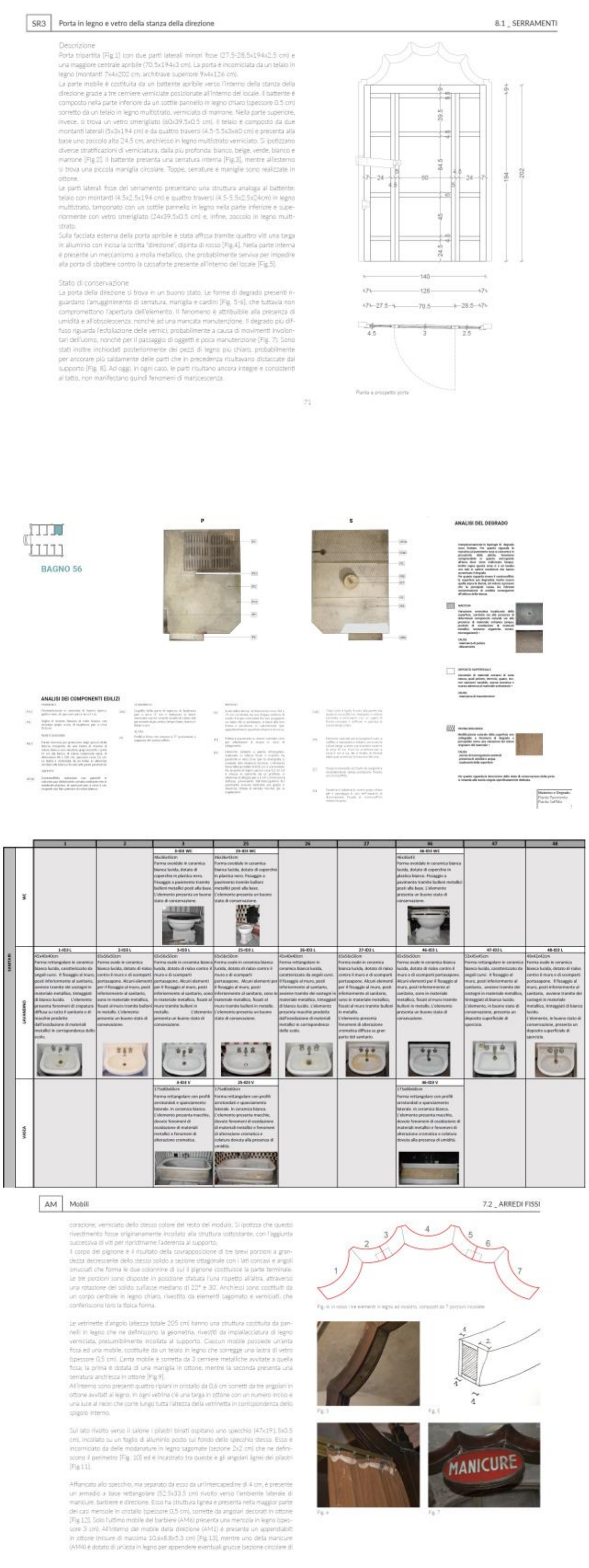

Figure 12. Images of Diurno di Porta Venezia.

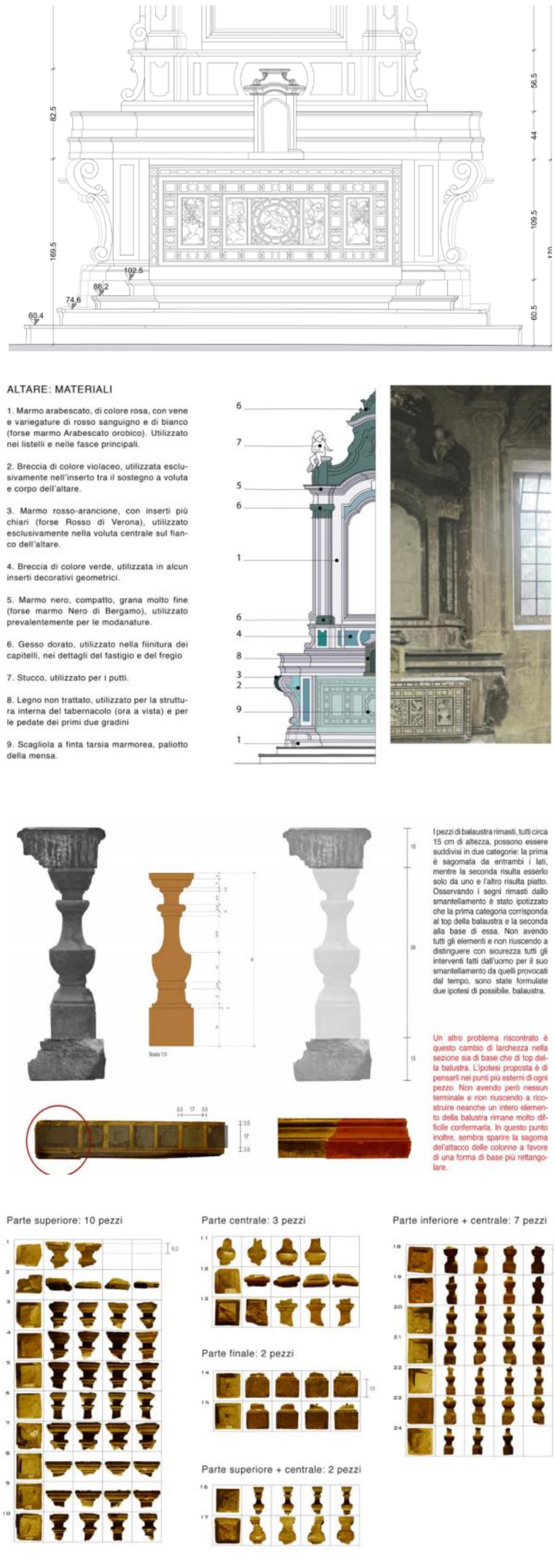

Figure 13. Images of the Church of San Vittore.

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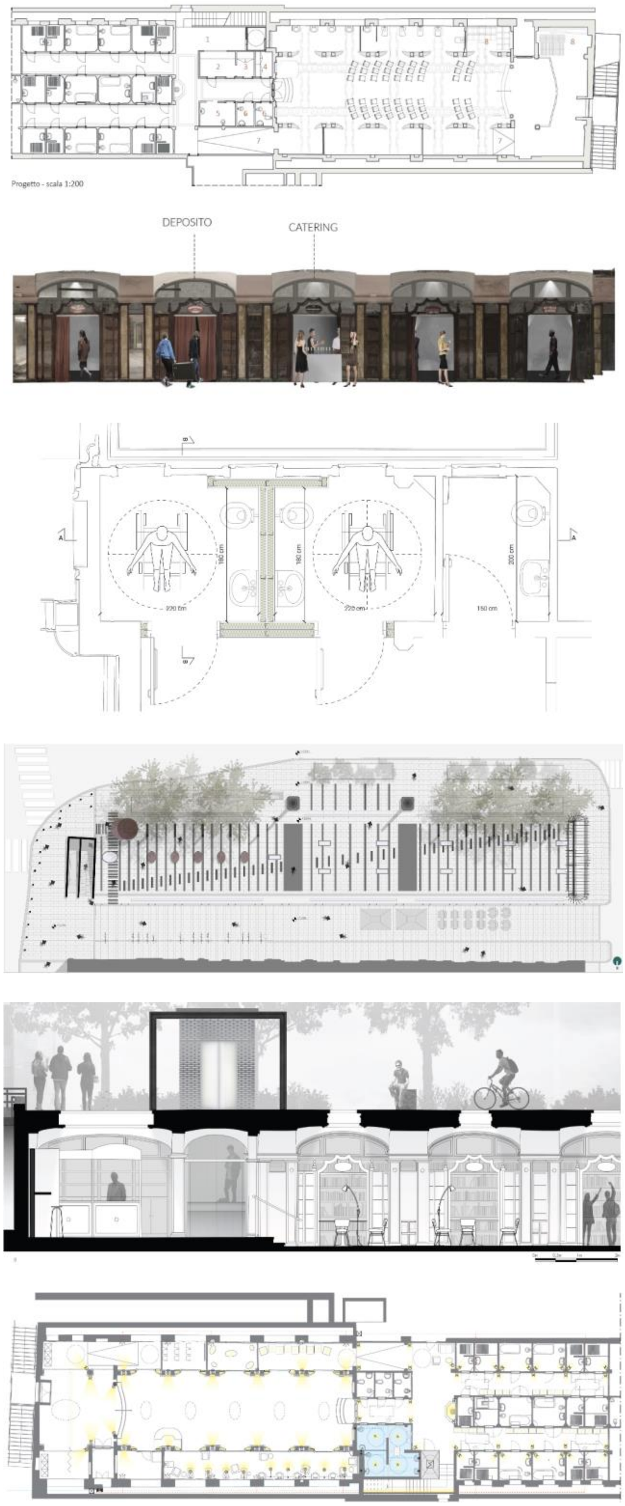

Figure 14. A few images produced by the 6 groups that worked at Diurno. They show the last part of our course: the design phase.

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