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STEFANO BERTOCCI
FEDERICO CIOLI

Franciscan Landscapes

Conservation, Protection and Use of Religious Cultural Heritage in the Digital Era

vol. 2

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This volume collects the papers presented at the concluding conference of the European project 'F-ATLAS: Franciscan Landscapes: The Observance between Italy, Portugal and Spain' that took place in Assisi, May 11-13, 2023.
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Façade of the Basilica di Santa Maria degli Angeli, Assisi (Italy). Drawing by Stefano Bertocci.

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REMOTE SENSING ARCHITECTURAL SURVEY EXPERIMENTS FOR HISTORICAL HERITAGE: COMPLEX OF SANTA CROCE IN FLORENCE AND THE CHALLENGES OF DOCUMENTATION

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Abstract

The Department of Architecture at the University of Florence has a strong focus on monumental architectural heritage documentation and conservation. They collaborate with organizations managing heritage sites, responding to requests like the one from the Opera di Santa Croce. The department embarked on a project to survey the Basilica of Santa Croce in response to the Opera's needs, aiming to create a digital database for architectural and art descriptions. Simultaneously, they began experimenting with remote sensing documentation systems, primarily to support traditional architectural surveys and assist Federico II University lecturers in developing a BIM-based maintenance plan. These experiments, conducted in 2020 amid the pandemic, aimed to showcase the potential of three-dimensional documentation tools and the integration of point cloud databases with parametric BIM models. Specific portions of the Santa Croce complex were chosen for experimentation, including the external façade, the internal side aisle, the Pazzi Chapel for two-dimensional graphic restoration, and a portion of the Chiostro Grande for BIM modeling. These efforts demonstrate the department's commitment to preserving and documenting architectural heritage.

Keywords: Santa Croce, remote sensing, digital survey, architectural survey, architectural drawing.

Fig. 1
Aerial view of the Basilica and the Santa Croce area.

1. Introduction

The interest of the Department of Architecture of the University of Florence in monumental architectural heritage, aimed at its documentation and conservation, is traditionally one of the main lines of teaching and research (Bertocci, Parrinello 2015); there are frequent contacts with the companies that administratively manage places of high patrimonial value, for these reasons. The project to survey the Basilica of Santa Croce stems from our Department's response to the requests of the Opera di Santa Croce, which recently concluded a research agreement aimed at the bibliographic documentation of texts describing both the architectural features and the works of art within the complex (Verdiani, 2002). At the same time, for technical and design requirements, our research group was asked to begin experimentation on morphological remote sensing documentation systems, with multiple purposes: on the one hand, dialogue with the Opera's technical office, for the drafting of traditional architectural surveys using data from a digital database; on the other hand, to support the work of some lecturers at the Federico II University in charge of drafting a maintenance plan to be applied through the BIM methodology, an initial account of which you will find in a text within these proceedings.

Therefore, in 2020, at the height of the pandemic crisis, a series of experiments began to demonstrate the potential of three-dimensional documentation tools and to verify the possibilities of dialogue between point cloud databases and parametric BIM models (Coli et al, 2022). In order to carry out these experiments, some portions of the Santa Croce complex were taken as examples, and in particular: as regards two-dimensional graphic restitution, the surfaces of the main external façade as well as the internal side aisle on the south side, and the adjacent Pazzi Chapel were involved; as regards BIM modelling, a portion of the Chiostro Grande was used.

2. Methods

2.1. Digital documentation

The portions of the Santa Croce complex that were taken into consideration to test the digital survey, provided for different digital acquisition systems that would allow for different levels of in-depth graphic rendering, both two and three-dimensional, of the architectural qualities and material qualities of the architecture of the complex; for all the case studies, a base was created using range-based methodologies, integrated with image-based survey supported as needed by UAV, drone instruments, so as to allow for the mapping of surfaces not visible from human height (Bertocci et al., 2020). The architectural surveying process was developed following a workflow that envisaged the articulation of operations over several phases: the planning of the survey is the first part of the process, fundamental for planning the activities in the field, understanding what instrumentation, what techniques and what precautions will be most suitable for data acquisition. This phase is preliminary to the survey campaign.

During this phase, drawings, diagrams and eidotypes were produced, which were useful in setting up the survey strategies, in order to clarify the surfaces to be mapped through remote sensing. After having planned the operations to be carried out, the field survey phase began; as mentioned above, for this phase, with the interest of combining the needs of the client and those of the research, it was decided to experiment different image-based and range-based digital acquisition systems in order to give an overview of the possibilities of representing the different methodologies applied in the monumental field on portions of a religious complex of high patrimonial value (Pancani et al., 2020). A number of case studies have been chosen to verify and present the potential offered in the documentation and representation of this monumental architecture; before addressing the actual survey methodologies, it is worth listing the case studies and the main architectural characteristics and representative requirements that allowed for a tailor-made survey design.

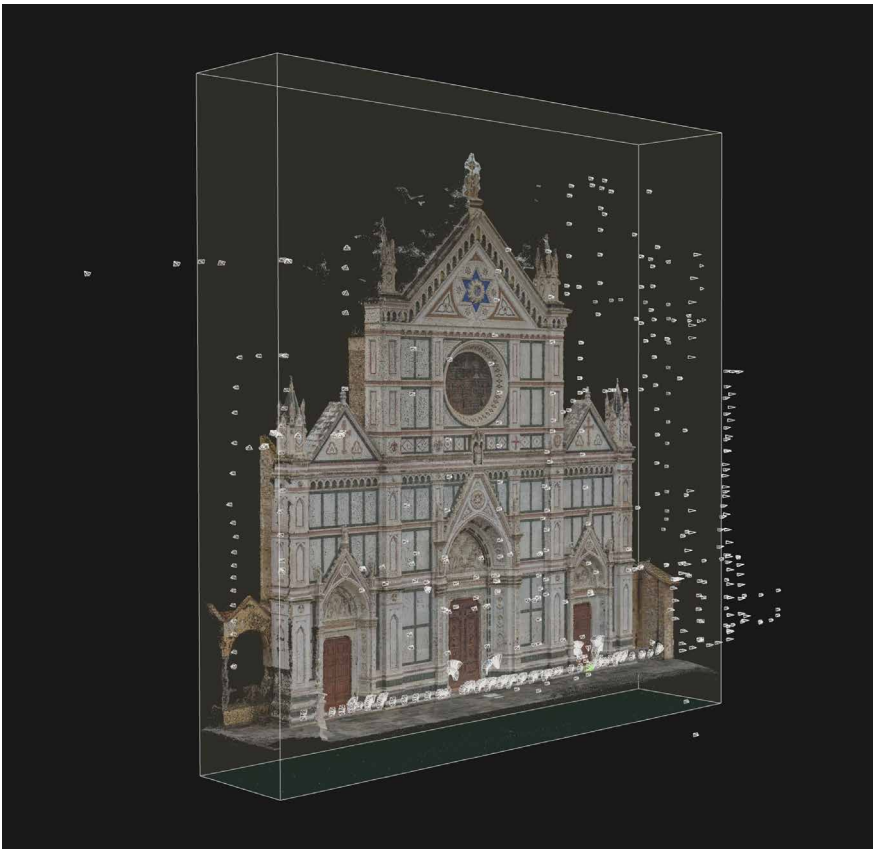

Fig. 2
Aerial photogrammetry by drone of the the façade of the Basilica di Santa Croce.

opposite page
Fig. 3
Cross-section of the side aisle of the Basilica of Santa Croce, superimposed view of wireframe and orthoimage.

2.2. Basilica

With regard to the fulcrum of the religious complex, the Basilica, only a portion including the volumes of the south-facing side aisle facing the cloister leading to the entrance of the Pazzi Chapel was chosen as a case study; in addition to the Basilica's interior surfaces, all the exterior surfaces were also surveyed with an acquisition campaign that involved the entire exterior cloister and the Chapel itself itself designed by Brunelleschi.

For the basilica's interior, laser scanning was used right from the start, and the stations were designed to be dense enough to provide data rich in details, so as not to leave any shadow cones or undetected parts of the architectural structures and altars and their decorative apparatus; then the walls photogrammetrically surveyed from the ground, with particular attention paid to all the decorative elements of the basilica's nave, from the altars to the tomb slabs.

opposite page
Fig. 4
Orthoimage of the façade of Santa Croce.

For the exteriors too, the first phase of the survey was by laser scanner; in this case, the less articulated decorative apparatus made it possible to position the less dense stations. In the external part, the photogrammetric survey from the ground was supplemented by drone survey, fundamental for surveying the highest areas that cannot be reached from the ground. In the final phase, two-dimensional drawings representing the floor plan and sections, both longitudinal and transverse, were produced, visualising both the entire nave internally and externally as well as the rooms within the side aisle and the external portico.

2.3. Basilica's facade

The façade of the Basilica di Santa Croce was surveyed with particular attention to the decorative apparatus present on the entire front; at first, laser scanning was carried out, and strategic points very close to the façade were chosen for the positioning of the stations, remaining with all of them on the portion of the churchyard; this choice was dictated by the great crowding of Piazza Santa Croce, which could have affected the clarity of the data surveyed. The choice of acquiring close points resulted in the positive aspect of having a very dense point cloud in the lower part of the façade, but negatively affected the numerous shadow areas especially in the upper part. The deficiencies found in the laser scanner survey were subsequently integrated with the SfM survey; in this case the photographic campaign was very detailed and focused on drone shots of the upper parts, as well as the lower parts not detected by the few ground scans.
In the final phase, the one in which the 2D drawings were drawn, in this case the focus was shifted to the materiality and the façade, with detailed descriptive drawings that could help the study of both the material and structural state of conservation of the surfaces.

2.4. Chiostro Grande

The Chiostro Grande was treated in part differently from the previous examples; the objective of the survey in this case was in fact the three-dimensional modelling of the building, to be subsequently also treated with BIM modelling. The survey in this case consisted of an initial phase of detailed laser scanning survey, both of the exterior and of the interior spaces such as that of Cappella Pazzi. This was also followed by the photogrammetry part, concentrated on the buildings facing onto the cloister, for the material restitution of the environments, also in this case useful for the understanding of the three-dimensional models (Parrinello, 2018).

2.5. Workflows

The laser scanner acquisition method, used for the creation of an accurate descriptive model of the Basilica's morphology, is able to provide a measurement within predetermined error parameters: the single scan, in fact, depending on the instrument model, guarantees high reliability, in our case millimetric. Unfortunately, the same cannot be said of photogrammetric reconstructions: the SfM (Structure from Motion) survey from the ground and from

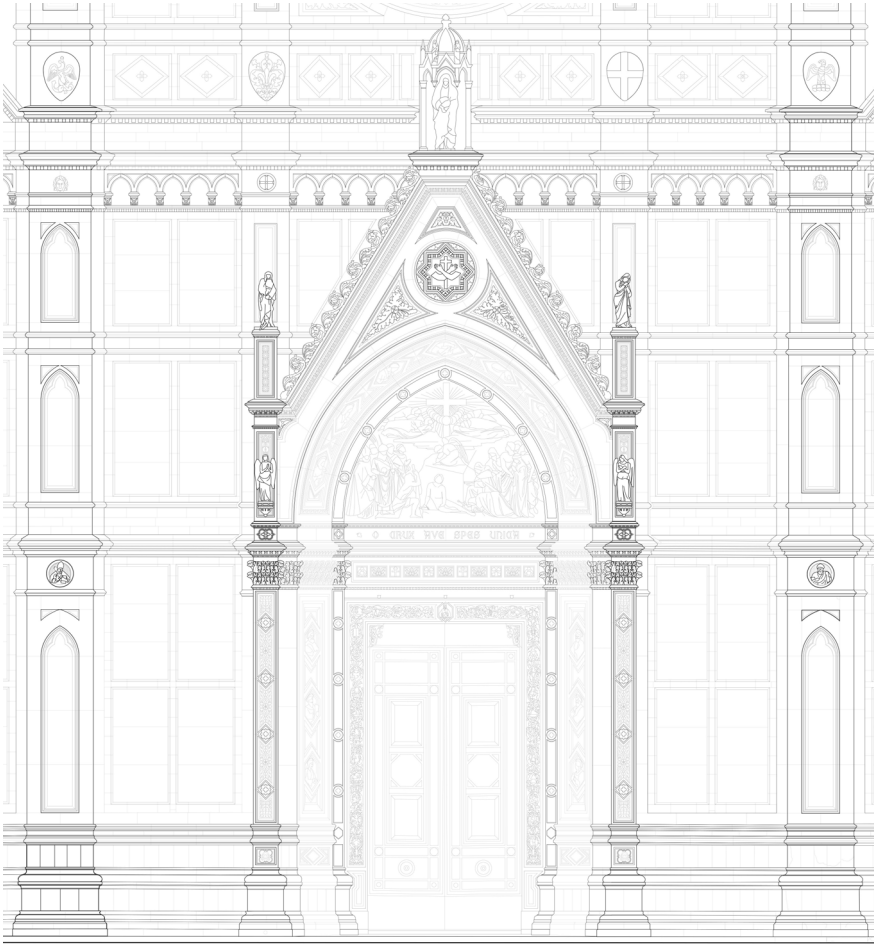

Fig. 5
Drawing of the façade of Santa Croce, wireframe view.

opposite page
Fig. 6
External section Pazzi Chapel, wireframe drawing, point cloud and orthoimage.

a drone, used for the creation of three-dimensional models descriptive above all of the materiality of the walls concerned, does not guarantee the correct reconstruction of the point clouds, which are influenced by numerous and diverse problems linked to the light source. For this reason, after an accurate control of the registration process, the laser scanner survey was taken as the morphological basis, whose polar coordinates were used to verify the control points of the photogrammetric survey, both from the ground and from drone (Bertocci et al., 2020). The data from the different acquisition systems were used to create the technical drawings (plans, sections and elevations), through a consolidated methodology involving the extraction of geometries from the laser scanner's point cloud

data, and the materiality of surfaces from photogrammetric acquisitions: both databases were appropriately subjected to data certification protocols in order to verify the reliability of both the registration of the scans and the calibration of the photoplanes on the point cloud (Pancani, Bigongiari, 2020).

The laser scanner survey of the Basilica of Santa Croce was designed to obtain an adequate datum to allow the description of all the elements characterising the building, with a distinction between interior, exterior and façade due to the different morphological and decorative features. The design of the survey was also fundamental for the placement of the positions of the instrument's shooting points; these were studied so as to be able to provide, once the individual scans were combined, a complete overall datum. The scans were also evaluated in the light of the various planned survey campaigns, which took place several times over the years. The scans were therefore designed in such a way as to ensure a high point coverage for the complex surfaces, such as the façade and the parts concerning the Pazzi Chapel, with a consequent increase in the size of the morphological database of the complex; this required the correct data acquisition design, which was possible using an instrument that guarantees a

high reliability of the measurements. The external part of the nave of the Basilica and the interior spaces that are not richly decorated required a less dense datum and were acquired more quickly. The management of the scan data included an appropriate filtering phase to further limit errors in the acquired points; the recording phase of the scans, thanks to the modern technology of the instrument used, begins as the acquisition of the scans proceeds: once the data has been acquired, it is transferred directly via wi-fi to a computer and pre-aligned with the previous scans, which allows the field survey to be finished with all the scans correctly oriented in a single reference system.The registration phase in post-production therefore required the optimisation of the pre-alignment and a subsequent certification phase of the data through the analysis of the section profiles of the scans. From the general model obtained, high-definition orthoimages were extracted that were useful for polishing the main sections on autocad, leading the point cloud back to a CAD drawing that was able to subdivide both the objects from a semantic point of view and the graphic weight of the lines in the representation (Bigongiari, 2021).

The photogrammetric survey was divided, as mentioned, into two parts: close-range from the ground and aerial via drone. For the close-range photogrammetric survey, several digital cameras were used: a Canon EOS 1100D SLR, all equipped with various lenses, but always set in manual mode with settings as constant as possible (ISO 100-F7), in order to obtain sequential shots with colours and tones as similar as possible. For the aerophotogrammetric survey, a DJI Mavic Pro drone was used, with a built-in 12 Mp camera that allowed the capture of high-definition aerial images, providing a global mapping of the architectural and environmental complex (Bigongiari et al., 2022).

During the shots, great attention was paid to the entry of light, trying to maintain a diffuse light to avoid shadows of its own and those brought onto the building; care was also taken with the distance from the basilica during the shoot, trying to keep it as constant as possible, even though the quality of the finishes of the architecture surveyed obliged some detail shots for the more articulated parts, especially on the façade, to ensure a better three-dimensional rendering of the complex objects. With regard to the methodologies of the shots, they were taken while maintaining an overlap percentage between successive shots of at least 50 per cent, in order to guarantee alignment during processing.

For drone photogrammetry, a linear path with parallel strips was studied to ensure that every point of the facades taken into consideration was included (Arrighetti et al., 2022). These, supplemented with data collected from the ground, which were more detailed in their scope, allowed us to obtain complete models despite the differences in altitudes at which the shots were taken.

The huge amount of photographic material produced by integrating the two acquisition systems led to the consequent reorganisation of the photographs; they were divided by structuring diversified datasets for each macro-environment, in order to create an organised digital archive well prepared for digital processing. For this last part, the potential of the SfM Agisoft Metashape Pro photomodelling software was exploited; it allows the reworking of the data from the photogrammetric survey campaigns, and subsequently the creation of mapped three-dimensional models. The processing of the photogrammetric data for each surface of the complex was produced following the same methodology. It involves the development of four phases: alignment, creation of the dense cloud, creation of the mesh, application of the texture. Once these phases are completed, the result will be the photogrammetric data, which, once exported, will become the photoplane (Parrinello, Picchio, 2013).
Once the production phase of the photo-planes has been completed, the assembly and integration phase of the elaborates produced can be carried out. The elaborates obtained from the polishing of the point cloud, which are rigorous and precise, will be used as the basis for the photoplanes. The latter will be affixed on top of the flush drawings and thanks to them, extraneous elements or noise, points exported by the software but extraneous to the described architecture, will be eliminated.

3. Conclusions

The graphic elaborations obtained show a complete spectrum of possibilities in the field of architectural design coming from digital surveying. These drawings and models will be useful to the administrations to proceed with the survey project of the complex interior, in the same way the historical and architectural research will have a useful database necessary for the correct drafting of in-depth scientific studies based on accurate morphological knowledge.

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Integrating historical research with technological progress opens exciting possibilities to create comprehensive digital archives, virtual reconstructions, and immersive experiences that can bridge the gap between the past and the present.

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