Geohumanities and 3D surveying technologies: new discoveries on the structure of Palazzo Pitti

Adele Meucci [1-2*], Lidia Fiorini [1-2]

[1]GeCO Lab, Dept. of Civil and Environmental Engineering, University of Florence, Via di S. Marta, 3 - 50139 Firenze, Italy
(adele.meucci, lidia.fiorini)@unifi.it
[2]La Sapienza University of Rome, P.le A. Moro, 5, 00185 Rome, Italy

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1. Extended Abstract

The integration of spatial data and historical sources profoundly enriches architectural research, providing the opportunity to formulate more robust hypotheses grounded in objective evidence. In this context, geomatics goes beyond merely documenting architectural heritage; it contributes to a more dynamic and nuanced understanding of buildings and their histories, thus becoming a fundamental pillar of the Geohumanities (Bodenhamer et al., 2010).
One of the main innovations introduced by geomatics in this field is the ability to create three-dimensional models of buildings, overcoming the limitations of traditional two-dimensional representations. The 3D representation enables a more detailed and intuitive view of space, allowing researchers to explore the structure from different angles and to analyze relationships between various parts of the building in depth. Furthermore, this approach offers great flexibility for survey technicians, who can manipulate point clouds acquired through techniques such as Terrestrial Laser Scanning (TLS) and Structure from Motion (SfM) photogrammetry, examining every detail during data processing. Thanks to these technologies, it is possible to acquire highly detailed point clouds that accurately replicate the building's geometry and its components, enabling more precise and in-depth analyses. However, fully leveraging these technologies in this context requires training that goes beyond technical expertise. It is essential for professionals involved to also have a humanistic background that allows them to correctly interpret the data within the historical and architectural context of the building. Only with solid interdisciplinary training is it possible to fully understand an edifice's transformations over time and to analyze its state of preservation, thereby significantly contributing to research and heritage conservation.

The paper illustrates how integrating geospatial data with archival and secondary sources provides innovative tools for understanding complex systems such as historic buildings, exemplified in the case study of Palazzo Pitti in Florence. The survey of the palace, conducted between 2019 and 2021, combined various tools and techniques, including terrestrial and UAV photogrammetry, laser scanning, and a control network measured using GPS and a total station. This approach follows methods similar to those described by (Grussenmeyer et al., 2011), who explored the fusion of high-resolution photogrammetric data with laser scans for accurate documentation of cultural heritage.
Christian Greco (Greco, 2019) emphasizes how *"the digital revolution has already profoundly transformed our cognitive approach"*: digitalization has changed the way we conduct research and interact with artifacts. The ability to georeference the information contained in documents gives them renewed meaning; this awareness, combined with the understanding of the physical and material nature of the building, stimulates new questions and alternative answers.
A first result of this methodological approach was presented in (Fiorini et al., 2023), focused on the digital reconstruction of the *"Spiral Staircase"* created by Bartolomeo Ammannati in the north wing of the courtyard of Palazzo Pitti, which was demolished in the 19th century.
This study summarises the results of a specialization thesis (Meucci, 2024) and focuses on a small interstitial space on the noble floor of the palace, within the Palatin Gallery, between the *Anticamera degli Staffieri* and the *Sala Verde*. This is one of the few unfinished spaces in the complex, and it is accessed through a hatch in the ceiling of one of the passage rooms between the two halls (Figure 1). It is a narrow, hard-to-access, unlit space that only accommodates installations, which is perhaps why it was overlooked in previous surveys and studies. However, the increasing flexibility and miniaturization of laser scanning systems have allowed for 3D documentation, though not entirely exhaustive. The scans were referenced using overlap with data recorded in the rooms below. It is important to note that this procedure enabled the correct referencing of data relative to the entire building. This aspect is particularly relevant, as hypotheses and considerations regarding construction aspects require comparisons and measurements referenced to elements in other parts of the building, as described below. This made it possible to conduct analyses on the digital model of the complex structural articulation and the various traces of successive interventions over time. Its position within the palace and the architectural structures found there raise several unresolved construction-related issues regarding the entire palace, such as the original floor plan of the noble floor and the configuration of the counter-façade of the 15th-century palace, attributed to Brunelleschi.

The first useful considerations, relating the structures surveyed in the interstitial space to their location within the broader context of the entire palace, concern the floor plan of the noble floor of the 15th-century building. In fact, the three-dimensional point cloud model provides an immediate visualization of how the jamb of the arch present in the interstitial space is perfectly aligned with the masonry that separates the large vaulted room from the adjacent barrel-vaulted space on the ground floor. The dimensions of the arch in the interstitial space and the springing height coincide with those of the barrel vault in the room below (Figure 2). This hypothesis is further confirmed by the presence in the interstitial space of a fragment of a springing frame, identical in form to the frames at the springing of the barrel vault in the room beneath. This suggests that the structures surveyed in the interstitial space confirm the similarity in the floor plan of the noble floor and the ground floor, a fact historically documented in Alessandro Pezzano's 1577 re-

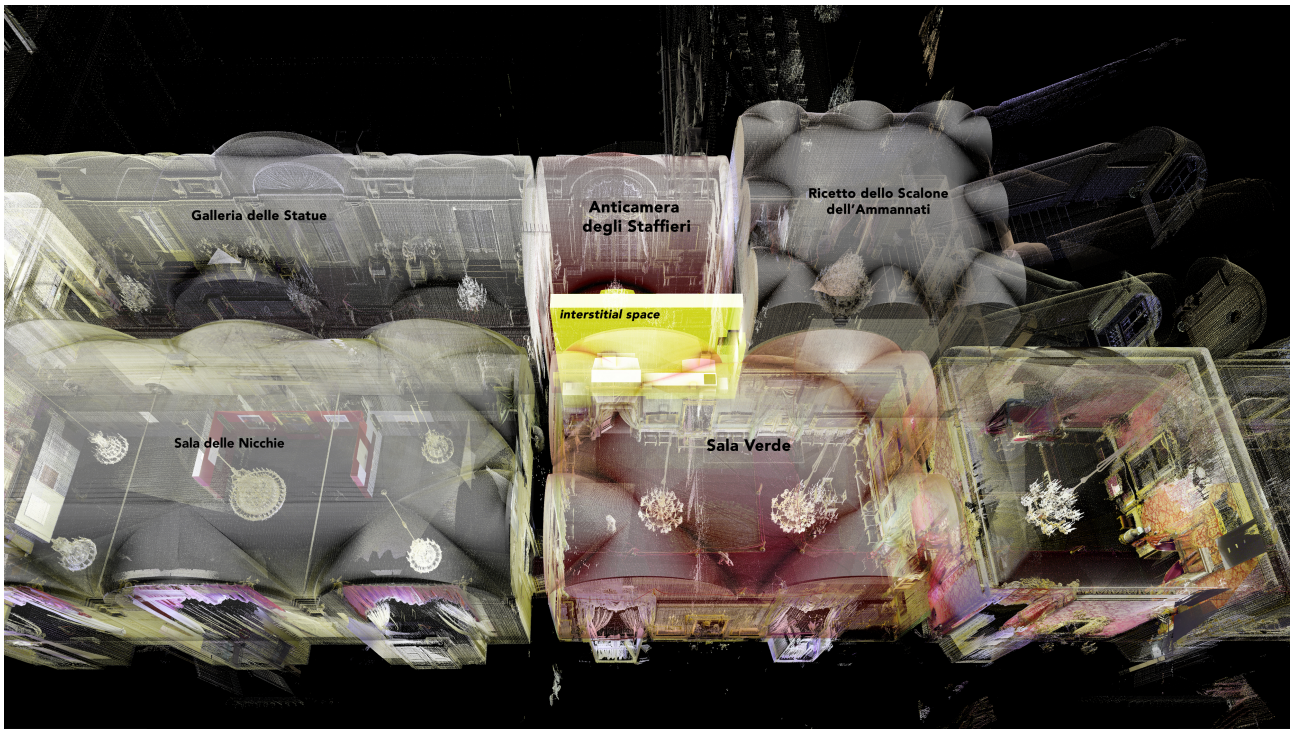

Figure 1. Contextualization of the interstitial space on the noble floor – point cloud model.

port (Pezzano, 1577) and the floor plan of the first floor drawn by Furttenbach (Futtenbach, 1628), dated between 1617 and 1621, and now further supported by these architectural evidences. The original floor plan of the 15th-century palace is identified based on the ground-floor drawing made by Alfonso Parigi il Vecchio in 1566 in his notebook (Parigi et al., 1547). This plan consists of a large central hall, two symmetrical barrel-vaulted rooms, and two other symmetrical rooms covered by cross vaults. This plan is confirmed by the current structures on the ground floor, but also by the supporting masonry in the basement; and, in light of these new findings in the interstitial space under study, also on the first floor.

On the east wall of the interstitial space, adjacent to the *Anticamera degli Staffieri*, beneath the arch of the barrel vault described above, there is a large opening with a double infill: one referring to a larger opening and another, inside it, referring to a smaller opening with a stone frame (Figure 3). Corresponding to this smaller stone frame, in the *Anticamera*, a window is painted, attributed to Giuseppe Maria Terreni and dated around 1790. The point cloud model revealed that the frame on this side has its own three-dimensionality, projecting with a molded profile of about 6.00 cm from the wall—details that are difficult to identify when observing the window from inside the *Anticamera degli Staffieri*.
From the three-dimensional point cloud model, it was possible to observe that the larger infilled window is positioned higher than the vault of the *Anticamera degli Staffieri*. This suggests that this opening, if and when it was opened, must have been made before the construction of the *Anticamera* vault. The vault formed the southernmost end of the large loggia on the noble floor, attached to the counter-façade of the fifteenth-century building, constructed by Ammannati — begun around 1563 and completed after the demolition of the *'casa vecchia'* around 1568 — and now divided into the *Anticamera degli Staffieri*, the *Galleria delle Statue*, and the *Sala Castagnoli*.

Before the construction of the loggia, it is thus possible that the large window was opened in the counter-façade of the fifteenth-century building. When Ammannati built the loggia's vault, the opening must have been reduced: the stone frame of the larger opening was cut, and the stone frame for the smaller opening was installed, partially demolishing the masonry on either side of the larger window to inset the smaller frame. This hypothesis is further confirmed by the relative positioning of the two openings in relation to the respective vaults, which explains the misalignment between the two windows: the larger opening is centered on the arch in the interstitial space (possibly corresponding to the pre-existing barrel vault), while the smaller opening is centered on the vault of the *Anticamera degli Staffieri*. The misalignment between the two is only a few centimeters (about 11.00 cm), but enough that one of the jambs of the smaller window, when viewed from the side of the interstitial space, is completely embedded in the masonry (Figure 4). It is evident that this misalignment between the two openings could only be measured thanks to the precise survey and three-dimensional model of the masonry structures, obtained through the integration of various scanning and photogrammetry techniques. The high resolution of the collected spatial data enabled the identification of minimal details and structural misalignments that are not visible to the naked eye, such as the 11.00 cm discrepancy between the openings, thus opening new research perspectives on the architectural evolution of the building.
In conclusion, the significant findings of the study have provided confirmation of the floor plan of the fifteenth-century palace on the noble floor and have provided an initial indication of one of the openings on the rear façade of the palace, revealing part of the original configuration of the counter-façade. The use of geomatics, combined with the study of archival sources, has proven essential for deepening the understanding of the historical transformations of Palazzo Pitti and for providing a solid foundation for future conservation interventions.

Figure 2. Longitudinal section passing through the interstitial space (highlighted in yellow) and correspondences with the structures of the interstitial space and those on the ground floor.

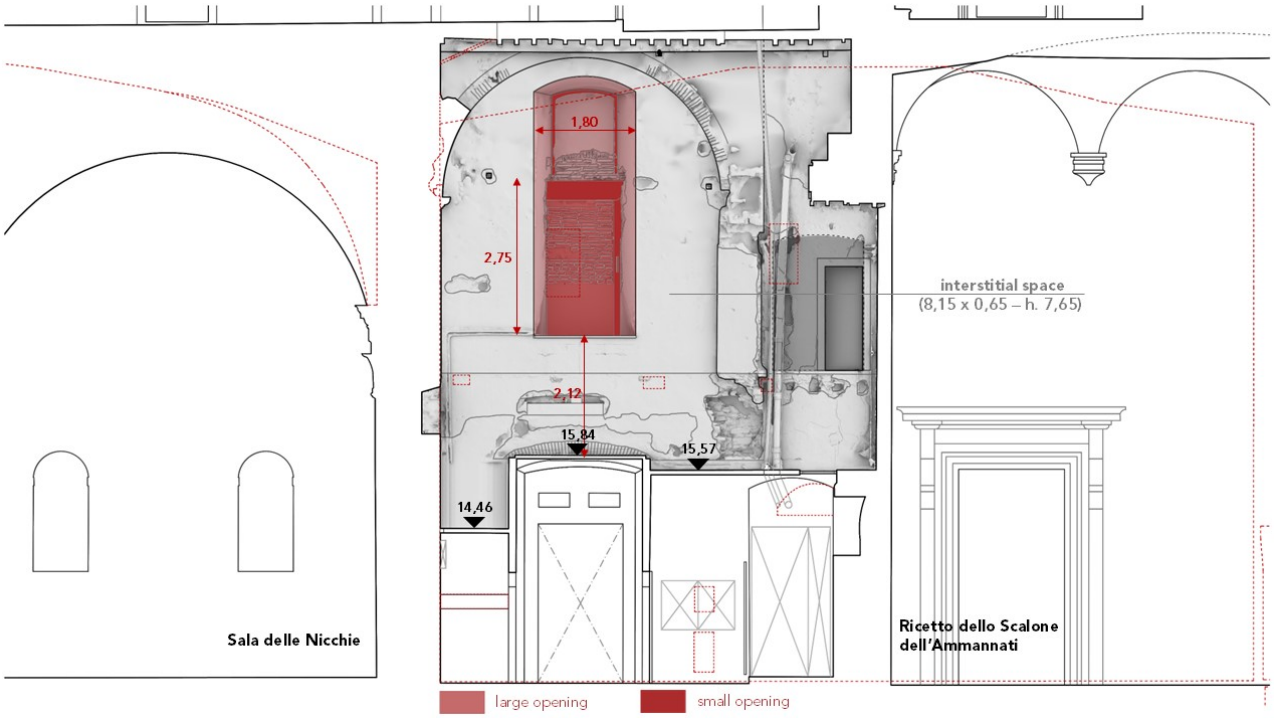

Figure 3. Longitudinal section of the interstitial space, with the two overlapped sealed openings highlighted in red.

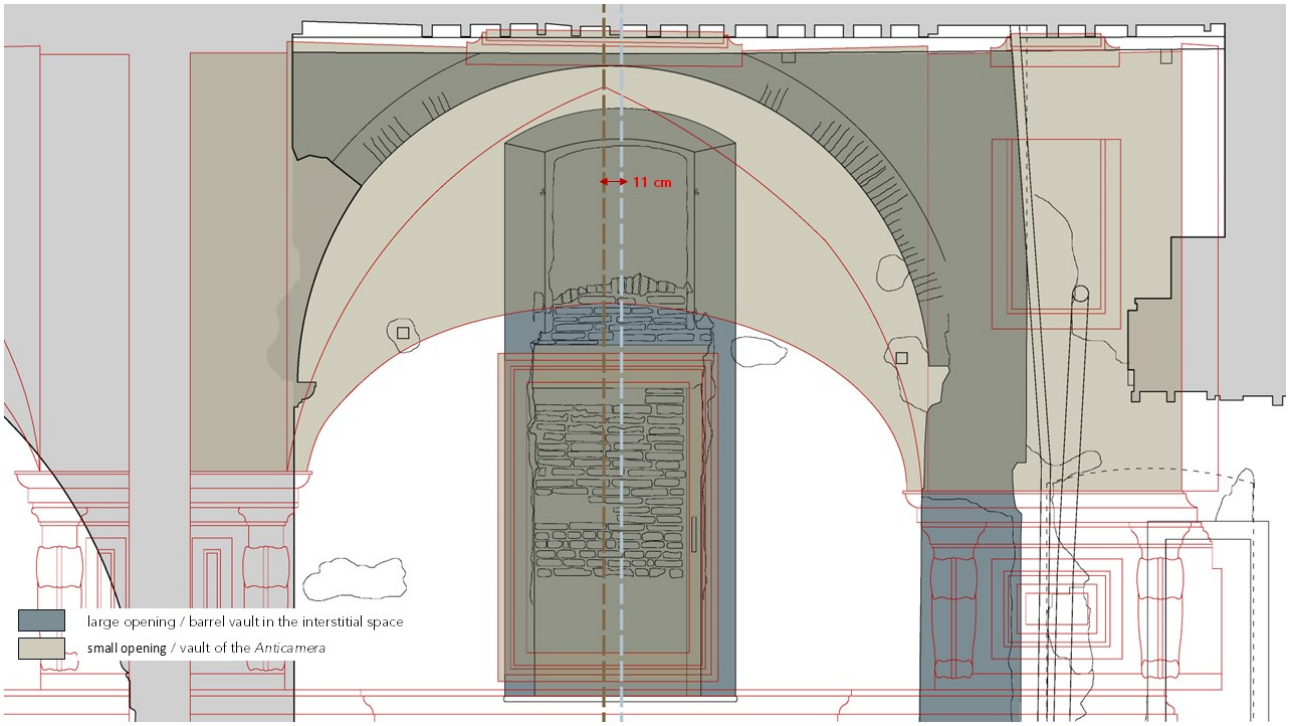

Figure 4. Longitudinal section of the interstitial space – correspondence between the openings and the vaults, and the 11 cm misalignment between the two structures.

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