

Article

Digital Documentation and Analysis of Palladian Microarchitectures: From 3D Models to Knowledge-Based Information Systems

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Abstract

Chimneypieces, washbasins, well heads, and sinks by Andrea Palladio represent refined design works following architectural systems on a reduced scale, even if systematic documentation and analysis of them is still limited. This paper introduces the custom knowledge-based Information System (IS) developed to study the design patterns and proportional relationships of these microarchitectures, after their digitization. The research employed smartphone-based photogrammetry to replicate fifty-seven chimneypieces and additional microarchitectures across twenty historical buildings; digital models were collected and organized into the IS enabling systematic typological and dimensional analysis. Proportional deepening revealed recurring ratios consistent with Renaissance treatise recommendations, alongside systematic variations suggesting design flexibility within theoretical frameworks. The IS integrates 3D architectural models by metadata attributes, providing a replicable framework for heritage documentation that combines scholarly rigor with technological accessibility. This approach offers new insights into Palladian design principles while establishing a scalable model for architectural heritage documentation and analysis.

Keywords: Andrea Palladio; information systems; 3D databases; smartphone photogrammetry; historic chimneypieces; microarchitectures



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1. Introduction

Andrea Palladio (1508–1580) played a pivotal role in the classical transformation of sixteenth-century Venetian architecture. His buildings, and even more so his treatise, shaped the urban and rural landscape of Veneto, in Italy, with huge repercussions and influences also in northern Europe and the United States of America that are still evident today. An aspect less thoroughly examined by historiography is that Palladio was not only a designer of great structures but also a meticulous creator of their functional furnishings. Beyond his celebrated villas and public buildings, Palladio paid remarkable attention to designing essential domestic elements including chimneypieces, washbasins, well heads, and sinks that served both practical and aesthetic purposes within his architectural compositions. These functional elements, recognized as design objects also in the recent exhibition “Palladio Designer” (12 April–5 May, 2024, Palladio Museum, Vicenza), represent sophisticated examples of what can be defined as Andrea Palladio’s microarchitectures, which are characterized, adopting modern terminology, as works that adhere to architectural rules and shapes on a reduced scale, demonstrating the same rigorous application of classical

principles found in his larger architectures [1]. They frequently refer to the syntax of traditional architectural orders, incorporating columns and entablatures, while in other instances they consist of sequences of cyma moldings, astragals, and other components that constitute the fundamental vocabulary of the classic architectural ornamentation.

Among the surviving microarchitectures of the Vicentine architect, the most substantial collection comprises the chimneypieces in his buildings, supplemented by other typologies such as well heads and washbasins. The matter of chimneypieces is arguably the most historically significant, having been addressed in Renaissance architectural treatises as elements essential for ensuring comfort in urban and country residences, transcending their former role as mere cooking hearths. As Vincenzo Scamozzi writes: “Chimneypieces are as necessary for daily use as it is known that man could hardly live a comfortable and civil life without Fire, especially in temperate regions like Italy and France [...]” [2]. This topic presents dual interest: firstly, in exploring their formal aspects as interior design elements, and secondly, in analyzing their technological and engineering functionalities. Palladio emphasizes the importance of this subject by dedicating a brief chapter to chimneypieces in his “Four Books of Architecture” [3], likely drawing from earlier architectural treatise traditions. This research presents the results of a systematic investigation into Palladian microarchitectures through the proposal of an integrated digital documentation process. The primary objective was to establish a comprehensive Information System (IS) capable of capturing and collecting geometric complexity, material characteristics, and construction techniques inherent in these architectural elements. Even though the IS was built upon well consolidated software frameworks, the data scheme was layered to meet the requirements of scholars interested in these architectures, keeping interoperability standards apart in this development stage. To achieve this goal, a structured four-phase workflow was developed and implemented:

1. systematic digital acquisition of microarchitectural elements through photogrammetric smartphone-based techniques;
2. computational processing of acquired data to generate geometrically accurate three-dimensional digital replicas;
3. development of visualization systems to facilitate accessibility and interpretation of the digital models; and
4. creation of a dedicated knowledge-based IS designed to systematically collect, organize, and analyze geometric and material data, thereby enabling comprehensive comparative analysis. This final phase represents the principal contribution of the present work, establishing a novel framework for the systematic documentation and analytical investigation of architectural heritage elements at the microarchitectural scale.

This paper is organized as follows. An initial *Introduction* defines the knowledge domain within which the proposed work is situated, establishing objectives and providing a brief historical contextualization of Palladian microarchitectures.

The Section 2 synthetically outlines state-of-the-art pertaining to the technologies employed to collect data related to the chimneypieces and other artifacts. This section is organized in a modular way to highlight the background and the techniques adopted in every part of the research.

The Section 3 presents the outcomes in the digital replication of chimneypieces and the other digitized artifacts as collected into the IS.

A Section 4 follows, in which main elements of this work are critically mentioned: the innovation in the process is discussed, together with the implications of the outcomes and the limitations of both workflow and IS.

A Section 5 summarizes all the achieved results and outlines future research prospects and advancement opportunities.

The Microarchitectures by Andrea Palladio

Sebastiano Serlio, in Book IV of his “General Rules of Architecture” [4], while noting the absence of ancient sources in Vitruvius, distinguishes two chimneypiece typologies: those constructed according to architectural orders and predominantly projecting from wall thickness, and those recessed and executed in rustic work. Vignola, in his “Rules of the Five Orders of Architecture” presents a single drawing of a polychrome marble chimneypiece situated in the bedroom of Cardinal St. Angelo in his Palace in Rome [5].

In his treatise, Palladio primarily focuses on engineering aspects, including smoke management and chimney flue dimensioning. Referencing ancient heating methods, he describes the trilithic form of the chimneypiece, composed of two pilasters (columns or modillions) supporting an architrave topped by a pyramidal hood that could be crafted “most delicately, entirely removed from the Rustic style.” While the treatise never includes detailed graphic representations, chimneypieces are identifiable in building plans, though generally depicted using the same convention as windows in drawings.

A few decades after Palladio, Scamozzi revisited the subject in his “Idea dell’Architettura universale” [2], again noting “that we have nothing of these in ancient buildings, and modern Architects have written very little about them.” He provides both functional and formal guidelines, such as preferring placement at the center of a room’s long wall, potentially between two windows or doors “almost like the mouth and nose between the eyes.” Scamozzi describes and illustrates three types to be employed based on aesthetic and functional considerations: Lombard style (or pavilion style), particularly suited to walls of limited thickness and characterized by a projecting architrave supported by columns, pilasters, or statues with a pyramidal hood above; French style (or *Roman style*), possible only with substantial wall thickness to accommodate the recessed chimneypiece (a type previously described by Serlio); and finally, the type called *half-French style* (or half-pavilion, also known as Venetian style), which represents an intermediate approach between the previous two but without the pyramidal hood. Scamozzi also provides recommendations for determining chimneypiece dimensions to ensure proper proportion relative to the heated space. The overall size is compared to “a well-formed man,” a reference previously found in Serlio’s text. However, while Serlio indicated that the total height should not exceed that of a person’s head to avoid glare, the Vicentine architect specified that the maximum height should slightly exceed that of a person, while the minimum could not be lower than shoulder height for larger rooms, or chest height for smaller ones. Scamozzi was the first to suggest specific length-to-height proportions, favoring ratios of 4:3 or 5:4, while accepting a square 1:1 form for smaller spaces.

These sources demonstrate attention to chimneypieces based on a well-established architectural tradition and practical experience complementary to technical knowledge, where measurement served as both a functional and aesthetic cornerstone. Indeed, Leon Battista Alberti in his “De re aedificatoria” had already indicated how to determine ideal chimneypiece placement in rooms, describing dimensional characteristics from the hearth to optimal smoke dispersion [6] references.

2. Materials and Methods

2.1. Digital Acquisition of the Microarchitectures

The identification of recurring morphological features and the metrical survey of a significant corpus of microarchitectural elements constitute the basic research approach underlying the documentation and analytical framework presented in this paper.

Through the digital replication of a selection of microarchitectures—including fifty-seven chimneypieces, two washbasins, two well heads, and one sink distributed across twenty buildings—this study examined typological and morphological characteristics, general and detailed dimensions, proportions, decorations and stucco works, orientation and room placement, seeking to identify rules and principles followed in their execution. This operation proves useful not only for characterizing these works but also for guiding attribution decisions and establishing possible genealogies. The research included both works of certain Palladian attribution and others of more dubious provenance, or works certainly created by other artists, to foster comparative frameworks.

Traditional education of architects integrated survey methods with architectural analysis as a unified epistemological framework, wherein practitioners developed understanding of classical principles through direct empirical observation, measurement, and graphic documentation of existing structures [7,8]. Contemporary digital survey practices have undergone significant transformation through information technology integration, transitioning from conventional two-dimensional documentation protocols to three-dimensional workflows encompassing reality capture technologies (including terrestrial laser scanning and automated photogrammetry), computational modeling and data management systems, and immersive visualization platforms (virtual reality, augmented reality, and additive manufacturing) [9,10]. This technological evolution has generated a disciplinary dichotomy, resulting in the progressive autonomization of surveying methods from the architectural design practice [11]. Contemporary methods have increasingly adopted quantitative, numerically driven deductive techniques, while architectural design practice keeps its foundation in qualitative, visually oriented inductive approaches. This divergence has compromised the historically symbiotic relationship between measurement and design, potentially diminishing the experiential dimension of architectural knowledge acquisition that characterized the traditional practice [12]. Also, the adoption of tools and equipment somehow difficult to manage, or needing specifically trained operators, represents a constraint in the conscious survey of historical architecture. The result is that contemporary digital heritage documentation, despite technological sophistication, often lacks the experiential reality of what it attempts to document.

While smartphone technology progressed significantly with photogrammetric applications [13,14], with automatic correction capabilities for geometric distortion, lens shading, and chromatic aberration, two fundamental limitations persist that affect accuracy in architectural and heritage documentation.

The first limitation is hardware-based: smartphone cameras employ tiny image sensors that cannot capture as much light as larger SLR camera sensors [15–17]. Additionally, the high pixel density causes light interference between adjacent elements, compromising image quality for precise measurement purposes [18,19].

The second limit concerns radiometric consistency, which is crucial for architectural and heritage documentation [20,21]. Despite extensive experimental validation of smartphone capabilities in recent research [22], there is still insufficient investigation into smartphone radiometry. This represents a significant gap since consistent radiometric performance is essential for reliable architectural documentation. Furthermore, smartphones operate as complex “black boxes” containing proprietary software and hardware solutions that are not transparent to users. This opacity prevents quick verification of critical parameters necessary for validating captured data quality and reliability. To address these challenges, users need to develop deeper technical understanding to achieve professional-level results in architectural heritage documentation through smartphones, since the most recent commercial offerings offer levels of resolution, sharpness, and color management

comparable to prosumer reflex cameras, making them suitable for effective photogrammetric applications [10,23].

Due to these reasons, the acquisition of microarchitecture was conducted following a protocol designed to ensure data comparability across different smartphones used. Briefly (since the acquisition stage is not the focus of this script), the standardized acquisition parameters are summarized as follows:

- Resolution: Constant 12 MegaPixels across all devices (many different smartphones were used).
- Equivalent focal length: Approximately 24 mm across all shooting networks.
- Shooting distance: Kept constant at approximately one meter from the surfaces to be digitally documented.
- Ground Sample Distance (GSD): 0.2 mm/pixel, ensuring geometric uniformity across different surveys and proper level of detail.
- Theoretical accuracy: 0.4 mm (1σ), inferred from the adopted GSD.

Smartphone positioning was systematized through the consistent use of tripod supports at variable heights, eliminating unwanted movements and motion blur phenomena. The acquisition geometry provided a minimum 35% overlap between consecutive shots, keeping this standard even in presence of considerable chimneypiece heights and complex decorative apparatus (Figure 1).

Decoration often assumes importance in characterizing the microarchitectures, particularly in the Veneto region where ornamentation often integrates with hood architecture, as Luisa Attardi reports in her monograph [24]. Images (with average coverage of at least one hundred twenty shots per chimneypiece) were acquired in RAW format (following the DNG schema) to offer maximum quality and flexibility for editing. Even though each camera manufacturer has its own RAW format, this was chosen from all smartphone models used, ensuring uniformity of collected information and enabling subsequent correction of shots according to a homogeneous criterion.

According to a definition provided by the American Society for Photogrammetry and Remote Sensing, photogrammetry is “the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting images and patterns of electromagnetic radiant energy and other phenomena” [25]. Digital reconstructions from images of historic chimneypieces provide reliable, detailed metric data on materials and aesthetics, enabling in-depth analysis of architectural elements [26].

The survey campaign spanned three years and was also oriented toward educational and didactic objectives [27], successfully employing photographic technology while utilizing simple, easily transportable tools adaptable to various survey conditions, specific choices were made regarding instrumentation and workflow. The selection of these devices was carefully evaluated, considering several advantageous factors. Primarily, they offer considerable flexibility in use. Additionally, they allow for the employment of low-budget accessories that are readily available on the market and compact in size.

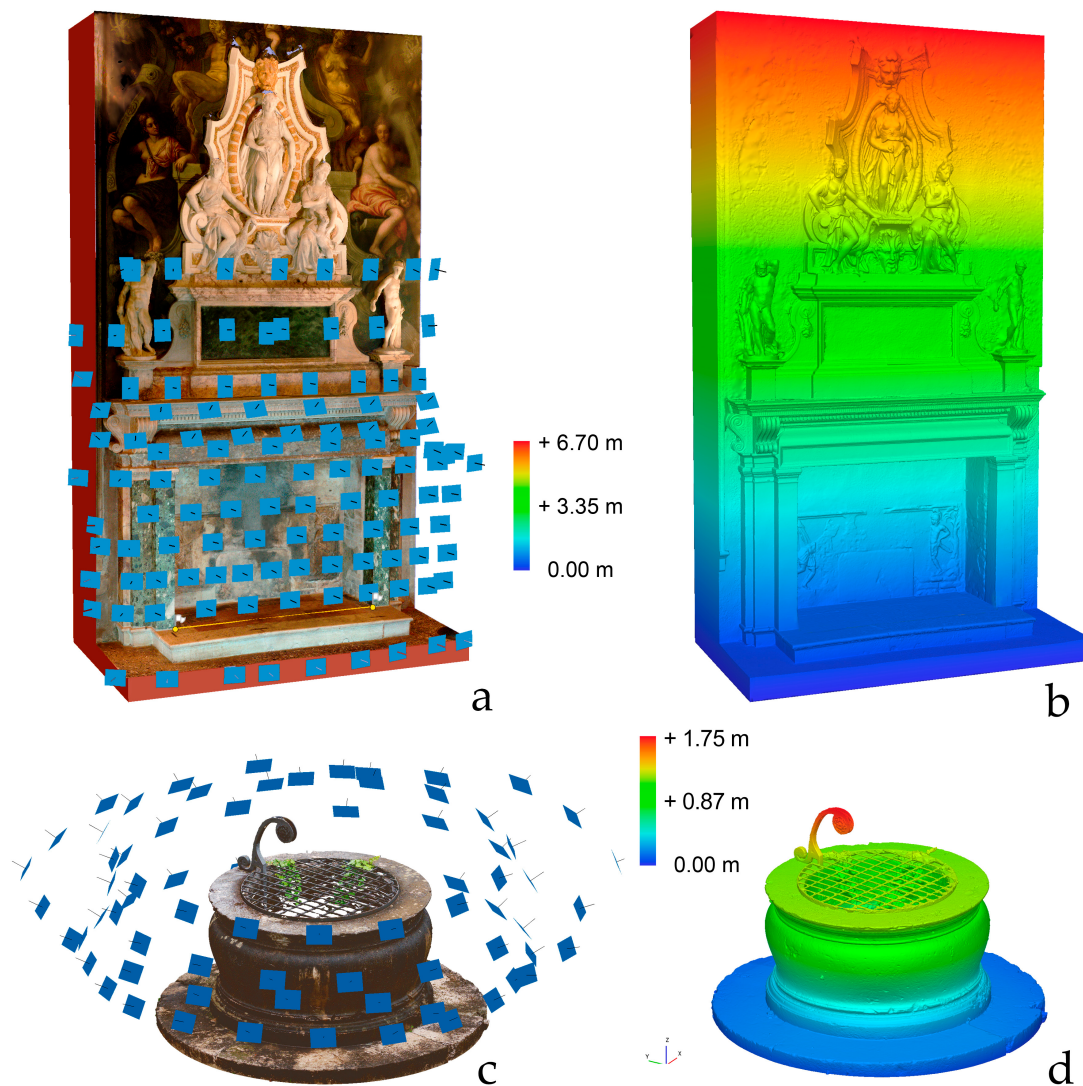


Figure 1. The camera network with the shooting positions (a,c) and the elevation diagram that includes the upper decorations for the chimney piece at Palazzo Ducale in Venice (a,b) and the well head at Villa Porto Colleoni in Thiene (c,d).

2.2. Production of the 3D Models for the Informative System

From the virtual models generated by photogrammetry, physical miniature copies (maquettes) were created using stereolithographic 3D printing (Figure 2), transforming digital models into tangible objects that allow appreciation of both the diversity and common features of different chimney piece types.

These miniatures, exhibited during the “Palladio Designer” exhibition [1], echo the Renaissance practice of using small reproductions of classical architecture as reference for projects and reconstructions [28]. The workflow employed is standardized in its configuration, though specific procedures and software were developed for various areas of intervention. The comprehensive process adopted to reproduce Palladio’s microarchitectures can be summarized as shown in Table 1. In particular, Color Correction (CC)—an operation necessary to get images in which chromatic rendering is not influenced by the lighting conditions present at the time of shooting and which differ in all buildings—was carried out following the automatic method and software developed by the University of Bologna, called SHAFT (SAT & HUE Adaptive Fine Tuning) [29].



Figure 2. The models of the chimneypieces prototyped using stereolithographic 3D printing as exhibited during the “Palladio Designer” event at the Centro Internazionale di Studi di Architettura Andrea Palladio (CISAAP) in Vicenza. Every maquette was displayed on a reference map (a) including human figures to communicate proportions to visitors (b).

Table 1. The Process of 3D Model Generation for the Studied Palladian Chimneypieces.

Step	Process Stage	Stage Goal
1	Photographic Capture In Situ	Acquisition of images with camera network ¹ based on the features of individual chimneypieces.
2	Image Format Conversion	Transformation of images into computer-processable format, starting from photographs minimally or not at all influenced by smartphone software.
3	Color Correction (CC) and Image Sharpening	Colorimetric correction for accurate color reproduction and increased sharpness for details.
4	Camera Orientation	Digital evaluation of point positions in object space (actual chimneypiece) in relation to the shooting center of image space (photograph).
5	3D Mesh Reconstruction	Interpolation of points from depth maps to generate 3D polygonal surfaces (meshes).
6	Texture Generation and Application	Production of maps to represent materials and colors, then applied to the 3D meshes.
7	Model Scaling	Final 3D models’ scaling to get canonical vector views properly dimensioned.

¹ The camera network is typically planned before the survey. It defines the distance of station points from the object to be photographed (thus the resolution), as well as the position of the “network” of shots to be distributed to achieve adequate overlap for reconstructing the entire subject.

The corrected shots were processed using photogrammetry to achieve camera alignment and generate depth maps (2D images representing 3D point distances through color-coded pixels). These maps enabled the 3D mesh creation via Poisson’s algorithm [30], while selected images provided the texturing for visual realism (Figure 3). The resulting models were scaled to real dimensions using in-situ verification measurements obtained through both traditional methods and terrestrial laser scanning with a Leica Geosystems BLK360 (G1) device, which offers 6 mm lateral resolution at 10 m distance (Figure 4).

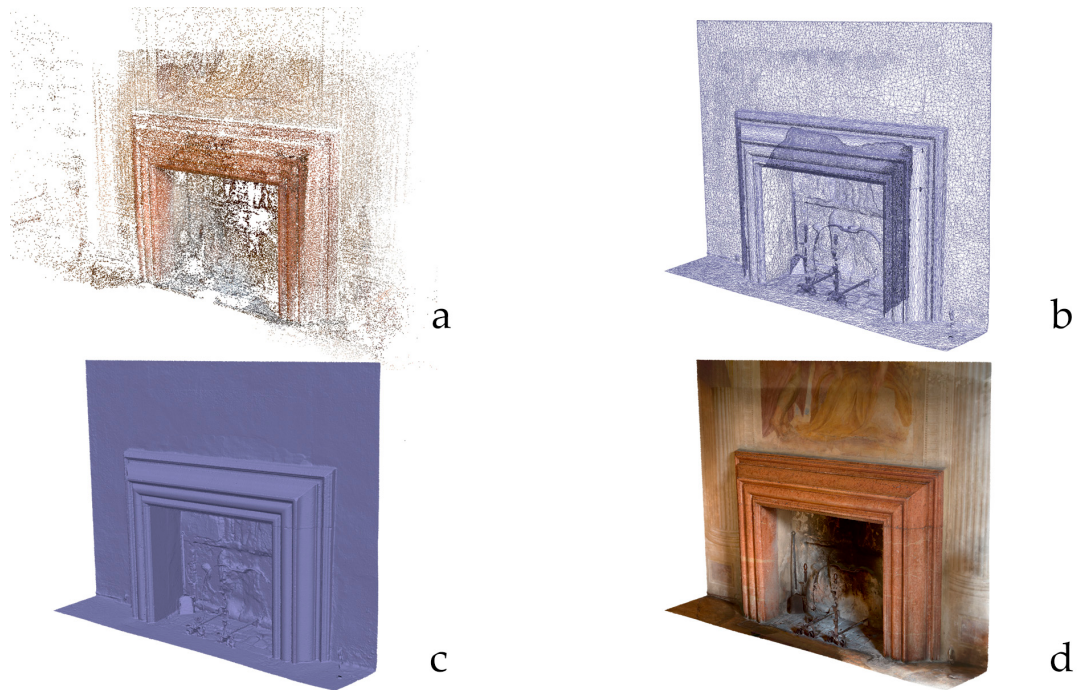


Figure 3. The generation of chimneypiece 3D models: the sparse point cloud resulting from camera alignment (a), the generation of the mesh (b), the processing of geometry to eliminate noise due to sensor characteristics and improve the surfaces (c), and finally the CC texture applied to the polygonal mesh (d). The images show the chimneypiece surveyed at Villa Foscari, known as “la Malcontenta” in Mira (VE).

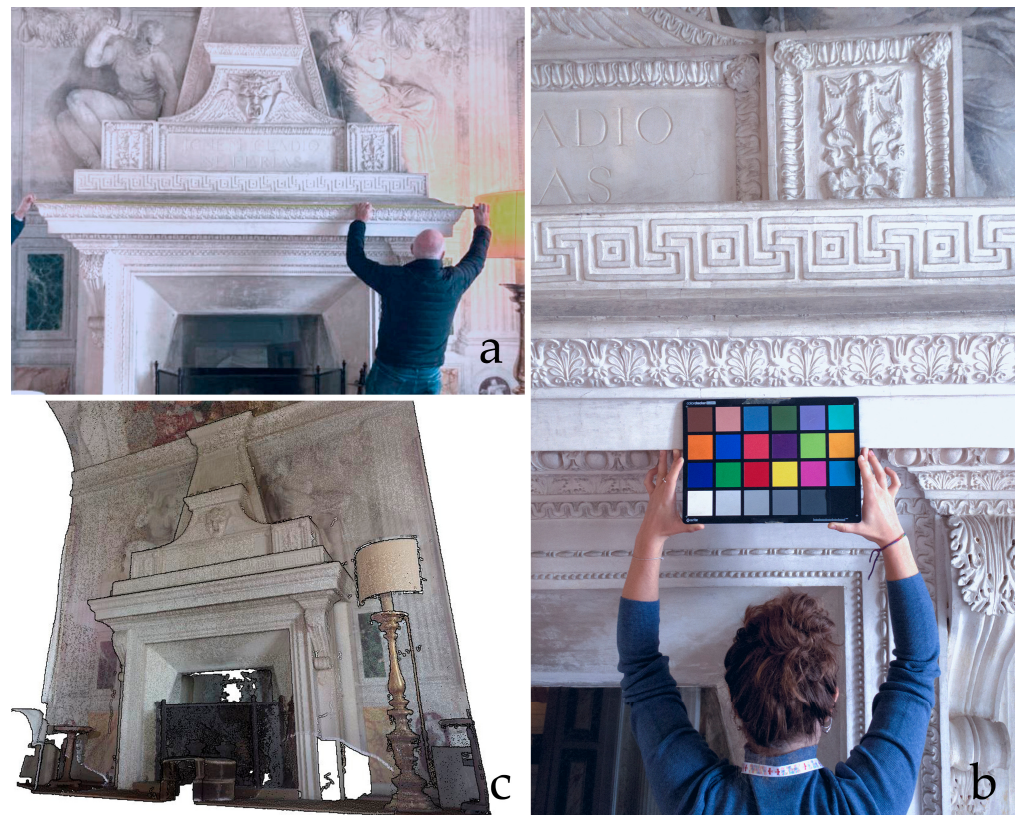


Figure 4. Verification measurements: direct checks (a), in place color checked shooting (b), reference point cloud acquisition (c) at one of the chimneypieces in Villa Barbaro in Maser (TV).

2.3. Design of the IS for Extensive Analysis

The documentation and analysis of architectural heritage increasingly require sophisticated management systems capable of handling heterogeneous data types and supporting interdisciplinary research approaches.

In [31], Heritage documentation is described as “the systematic collection and archiving of tangible and intangible elements of historic structures and environments. Its purpose is to supply accurate information that will enable correct conservation, monitoring and maintenance for the survival of an artefact”; these principles fostered the interest in web-based IS for microarchitectures, with the requirements of facilitating multi-user access and cross-disciplinary collaboration, while being an open-source technology to provide sustainable solutions for long-term data preservation and system maintenance [32].

Such system must accommodate granular information aggregation and organization [33], enable cross-referencing between different thematic areas, and provide capabilities for identifying patterns, semantics and relationships, as happens within large datasets management for heterogeneous objects [34,35]. A knowledge-based IS effectively centralizes and structures the collected data [36], following where possible standards [37], being a culture’s collector [38], ensuring consistency and updatability of information, also useful to manage data for building components’ typologies as, for example, in [39]. The specific requirements for documenting Palladian microarchitectures needed to properly manage dimensional, formal, and contextual data while supporting statistical analysis of typological variations and proportional relationships, overcoming the typical limitations of fragmentary or poorly accessible data collections [40].

The system’s requirements (as later implemented) were:

- Web-based access interface for multi-user remote consultations,
- Use of open-source technologies,
- Granular organization of information,
- Cross-links between different thematic areas,
- Ability to provide statistics on the recurrence of different typologies and case studies of chimneypieces.

Since the amount of information related to each architectural object was complex and directly connected to the buildings in which they are located, datasets collected were broken down into macro-areas with their sub-categories, such as:

- Buildings,
- Microarchitectures,
- Artists (when not attributed to Palladio),
- Stone materials.

For each microarchitecture, data related to both dimensional and aesthetic/decorative aspects were entered, to try to identify macro-groupings based on proportional as well as formal aspects. In particular, the data entered were:

- Location information
 - Building reference,
 - Floor reference,
 - Room dimensions.
- Dimensional information on the chimneypiece (Figure 5),
 - Total width (distance between jambs) [defined as A],
 - Total height (excluding any hood) [defined as B],
 - Width [defined as C] and height [defined as D] of the firebox opening,
 - Jamb thickness [defined as E].

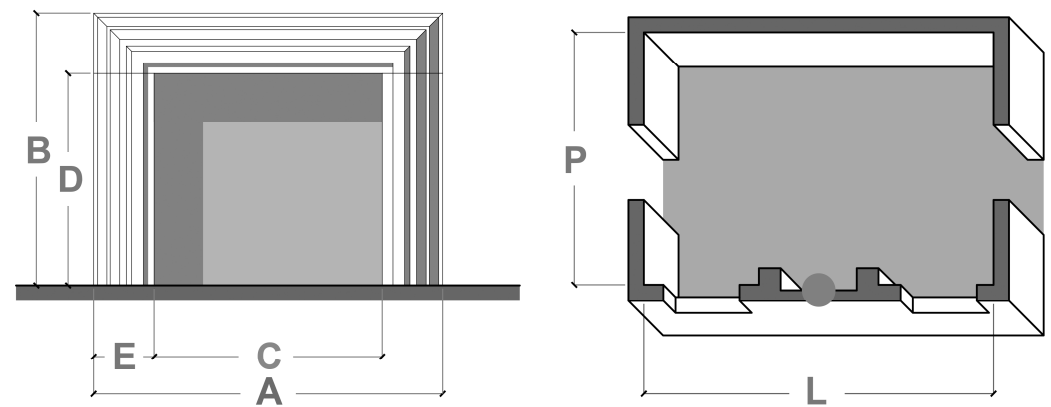


Figure 5. Diagram of the parametric distances measured for calculating proportional ratios; letters have been used to identify the measured and compared quantities, also in the subsequent images and tables.

- Formal information on the chimneypiece,
 - General typology,
 - Typological elements,
 - Decorative apparatus.
- Artistic information on the chimneypiece,
 - Artists involved,
 - Stone materials used.

These macro-families were further detailed by the presence or absence of typological elements such as:

- Bracket jambs (trilithic chimneypieces),
- Lion's paws (trilithic chimneypieces),
- Jambs with caryatids/telamons (trilithic chimneypieces),
- Jambs with capitals (trilithic chimneypieces),
- Side, upper and lobed brackets,
- Abstract band with/without pulvinus,
- Sculptural decoration on the hood (trilithic chimneypieces),
- Pictorial decoration on the hood (trilithic chimneypieces).

Since chimneypieces serve not so much a decorative function but as a functional one, it was decided to examine more extensively the rooms in which they are located, to verify the presence of possible proportional relationships between the dimensions of the chimneypiece and the environment in which it is placed. Based on the defined layout, the IS can determine and visualize the proportional relationships between the different parts of the chimneypiece and the room.

This way, their records in the database include:

- Room typology (large, small, square),
- Flat/vaulted ceiling,
- Cardinal orientation of the wall where the chimneypiece is placed,
- Perimeter/internal wall,
- Length of the chimneypiece wall,
- Depth of the other wall,
- Room height.

From a more technical perspective, the custom system was based on a web platform created ad hoc, through a MySQL relational database and logic programmed in PHP language backend. The framework was designed to allow data entry even after the writing

of this paper, ensuring the possibility of continuous updating of content over time. In particular, the utility of such a system lies in its ability to extract aggregated quantitative information, quickly responding to a series of questions necessary to understand the functioning of the microarchitecture within the more complex organization of the building and how it was meant to be used:

- Are recurring formal typologies recognizable?
- How many times are certain decorative solutions used?
- Are there preferences in the choice of chimneypiece location with respect to room exposure and wall selection?
- Do proportional relationships exist between the parts of the chimneypiece in relation to the room in which it is placed?

3. Results

3.1. Outcomes from the Digital Acquisition

The acquisitions stage of the process led to the creation of several scaled 3D models for the microarchitectures. Starting from these digital replicas, 2D vector drawings were created with detailed architectural representations of plans, elevations and sections, as well as detailed views at a larger scale of the profiles of lintels and jambs to highlight constructive and decorative details.

The three-dimensional models, systematically organized in the IS and produced following the process described, led to a considerable number of records for each location (Table 2), providing a complete view of the design and construction variants and constants found in the analyzed contexts.

Table 2. Synoptic table of the microarchitectures collected in the IS, including locations, orientation of the main facades of the buildings in which they are located, and their authorship (? are used to indicate hypotheses of uncertain attribution).

Location	Facade	Microarchitectures	Positions	Attribution
Palazzo Barbarano in Vicenza	N-E	2	N-W	Andrea Palladio
Palazzo Ducale in Venice	S-W	2	S-W	1: Andrea Palladio; 2: Vincenzo Scamozzi
Palazzo Thiene in Vicenza	N-E	2	N-W	Bartolomeo Ridolfi
Refettorio S. Giorgio Maggiore in Venice	S-W	2	S-W	Andrea Palladio
Villa Almerico Capra, known as “la Rotonda”, in Vicenza	-	4	N-E, S-W	Andrea Palladio
Villa Arnaldi in Meledo di Sarego (VI)	S-E	2	N-E, N-W	Andrea Palladio
Villa Barbaro in Maser (TV)	S-E	4	N-E, S-E, S-W	Paolo Veronese (?)
Villa Chiericati in Vancimuglio (VI)	S-W	4	N-E, S-E, S-W	1: Domenico Gropino (?); 2–4: Andrea Palladio
Villa Cornaro in Piombino Dese (PD)	N	9	N, E, S, W	1–3, 5, 8, 9: unknown; 4, 6, 7: Francesco Muttoni (?)
Villa Emo in Fanzolo di Veduggio (TV)	S	4	E, W	Andrea Palladio
Villa Foscari, known as “la Malcontenta”, in Mira (VE)	N-E	2	N-E	Andrea Palladio
Villa Garzoni in Pontecasale (PD)	S	2	E, W	Iacopo Sansovino
Villa Godi in Lonigo di Lugo (VI)	W	10	E, N, W, S	1–6, 8–10 Andrea Palladio; 7: unknown

Table 2. Cont.

Location	Facade	Microarchitectures	Positions	Attribution
Villa Pisani in Bagnolo di Lonigo (VI)	S-E	3	N-E, N-W	1: Vincenzo Scamozzi; 2: unknown; 3: Andrea Palladio
Villa Pisani in Montagnana (PD)	S-W	1	N-E	Andrea Palladio
Villa Poiana in Poiana Maggiore (VI)	N-W	4	N-E, N-W	1: Francesco Muttoni; 2–4: Andrea Palladio
Villa Porto Colleoni in Thiene (VI)	S-E	1	S-E	Andrea Palladio
Villa Repeta in Campiglia dei Berici (VI)	S	1	N	Andrea Palladio
Villa Trissino in Cricoli (VI)	S-W	2	N-E, S-W	unknown
Villa Trissino in Meledo di Sarego (VI)	S-W	1	E	Andrea Palladio (?)

3.2. Outcomes from the IS

The diverse datasets extracted from the comprehensive 3D model documentation were systematically integrated within the system, which consolidates multiple data categories through a structured framework accessible via a web-based graphical interface that can likely be, in the future, made accessible to a wider audience (Figure 6).

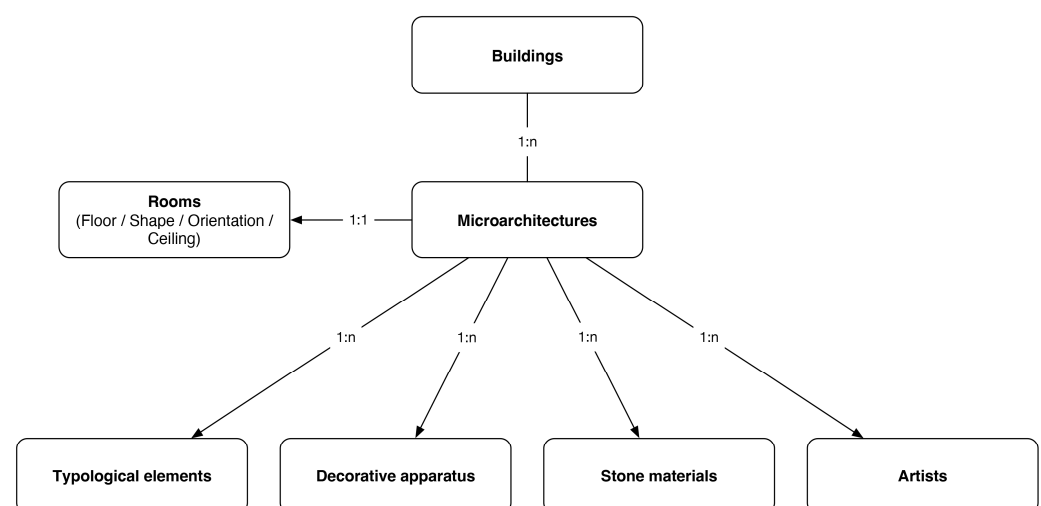


Figure 6. A conceptual diagram of the IS layout with its different sections.

The “Home” section provides an introductory overview of the main statistics related to the data contained in the system, offering a global view of the collected information and its general characteristics, such as aggregated data for chimneypiece typologies, proportions of occurrences and ratio values between widths and heights.

The “Buildings” section provides access to content structured by building, allowing detailed consultation of data and graphics related to each chimneypiece, facilitating access and analysis of information for individual architectural contexts.

The “Microarchitectures” section is dedicated to individual records of the surveyed works, including 2D vector drawings and 3D models, which offer a detailed and interactive representation of the characteristics of each constituent element. For each microarchitecture, the necessary series of both metric and formal information are displayed (Figure 7), including:

- typology: chimneypiece (abstract band type, traditional trilitic, or sculptural), wash-basin, sink, well-head;
- presence of morphological characteristics: corbel jambs, lion paws, jambs with caryatids/telamons, jambs with architectural order, lateral or upper brackets, bands with ears, sculptural decoration, pictorial decoration;
- main dimensions: overall width and height, width and height of the chimneypiece opening, jamb width;
- room information: dimensions, ceiling type (flat, vaulted), chimneypiece wall (long or short, perimeter or internal, orientation).

	floor #	overall shape		fireplace shape				jambs		room			
		A width	B height	A:B ratio A:L ratio	C width	D height	C:D ratio D:B ratio C:L ratio	E width	E:B ratio E:D ratio	L width	P length	L:P ratio	
Villa Almerico Capra "la Rotonda"													
 CERINO TRADIZIONALE		T 1	223.6 cm p6 @3 m1	202.9 cm p5 @8 m1	 $\Delta 0.18\%$ $\Delta -0.37\text{cm}$  $\Delta 2.97\%$ $\Delta -6.85\text{cm}$	168.0 cm p4 @8 m2	154.0 cm p4 @3 m3	 $\Delta 0.00\%$ $\Delta 0.00\text{cm}$  $\Delta 1.19\%$ $\Delta 1.82\text{cm}$  $\Delta 0.59\%$ $\Delta -1.00\text{cm}$	27.8 cm @9 m1	 $\Delta 4.09\%$ $\Delta -1.19\text{cm}$  $\Delta 0.71\%$ $\Delta -0.20\text{cm}$	8.45 m p23 @8	5.31 m p14 @10 m2	 $\Delta 4.52\%$ $\Delta 24.00\text{cm}$
 CERINO TRADIZIONALE		T 2	223.6 cm p6 @3 m1	202.9 cm p5 @8 m1	 $\Delta 0.18\%$ $\Delta -0.37\text{cm}$  $\Delta 2.97\%$ $\Delta -6.85\text{cm}$	168.0 cm p4 @8 m2	154.0 cm p4 @3 m3	 $\Delta 0.00\%$ $\Delta 0.00\text{cm}$  $\Delta 1.19\%$ $\Delta 1.82\text{cm}$  $\Delta 0.59\%$ $\Delta -1.00\text{cm}$	27.8 cm @9 m1	 $\Delta 4.09\%$ $\Delta -1.19\text{cm}$  $\Delta 0.71\%$ $\Delta -0.20\text{cm}$	8.45 m p23 @8	5.31 m p14 @10 m2	 $\Delta 4.52\%$ $\Delta 24.00\text{cm}$
 CERINO TRADIZIONALE		T 3	223.6 cm p6 @3 m1	202.9 cm p5 @8 m1	 $\Delta 0.18\%$ $\Delta -0.37\text{cm}$  $\Delta 2.97\%$ $\Delta -6.85\text{cm}$	168.0 cm p4 @8 m2	154.0 cm p4 @3 m3	 $\Delta 0.00\%$ $\Delta 0.00\text{cm}$  $\Delta 1.19\%$ $\Delta 1.82\text{cm}$  $\Delta 0.59\%$ $\Delta -1.00\text{cm}$	27.8 cm @9 m1	 $\Delta 4.09\%$ $\Delta -1.19\text{cm}$  $\Delta 0.71\%$ $\Delta -0.20\text{cm}$	8.45 m p23 @8	5.31 m p14 @10 m2	 $\Delta 4.52\%$ $\Delta 24.00\text{cm}$
 CERINO TRADIZIONALE		T 4	223.6 cm p6 @3 m1	202.9 cm p5 @8 m1	 $\Delta 0.18\%$ $\Delta -0.37\text{cm}$  $\Delta 2.97\%$ $\Delta -6.85\text{cm}$	168.0 cm p4 @8 m2	154.0 cm p4 @3 m3	 $\Delta 0.00\%$ $\Delta 0.00\text{cm}$  $\Delta 1.19\%$ $\Delta 1.82\text{cm}$  $\Delta 0.59\%$ $\Delta -1.00\text{cm}$	27.8 cm @9 m1	 $\Delta 4.09\%$ $\Delta -1.19\text{cm}$  $\Delta 0.71\%$ $\Delta -0.20\text{cm}$	8.45 m p23 @8	5.31 m p14 @10 m2	 $\Delta 4.52\%$ $\Delta 24.00\text{cm}$

Figure 7. An example of chimneypieces' records in the IS, with icons to access vector drawings and 3D models, and all linked data attributes (Villa Almerico Capra, known as "la Rotonda"). Measurements are automatically expressed in the ancient Vicenza feet system (1 foot = 35.7 cm, indicated with "p"), subdivided into sub-multiples of once (indicated with the symbol "@", where 12@ = 1p) and minutes (indicated with the symbol "m", where 4m = 1@).

Coming to metric data, the dimensions of the microarchitectures were evaluated from the digital models obtained from photogrammetric processes, while room width values

were derived from surveys from the 1960s–80s in possession of CISAAP, integrating them, when necessary, with measurements indicated by Palladio in his Four Books.

In this case, it is important to consider that these provide an idealized vision of buildings that do not necessarily consider actual construction conditioned by pre-existing conditions and client needs. The comparison between surveyed dimensions and those reported in the treatise often highlighted deviations. Each measurement entered in the database, in centimeters or meters, is also automatically expressed by the software in the ancient Vicenza feet system, subdivided into sub-multiples of inches and minutes to make evident the measurements originally adopted for the surveyed works.

Based on the metric dimensions entered the IS can identify the various proportional relationships that best approximate the actual measurements and show them in a statistical layout (Figure 8).

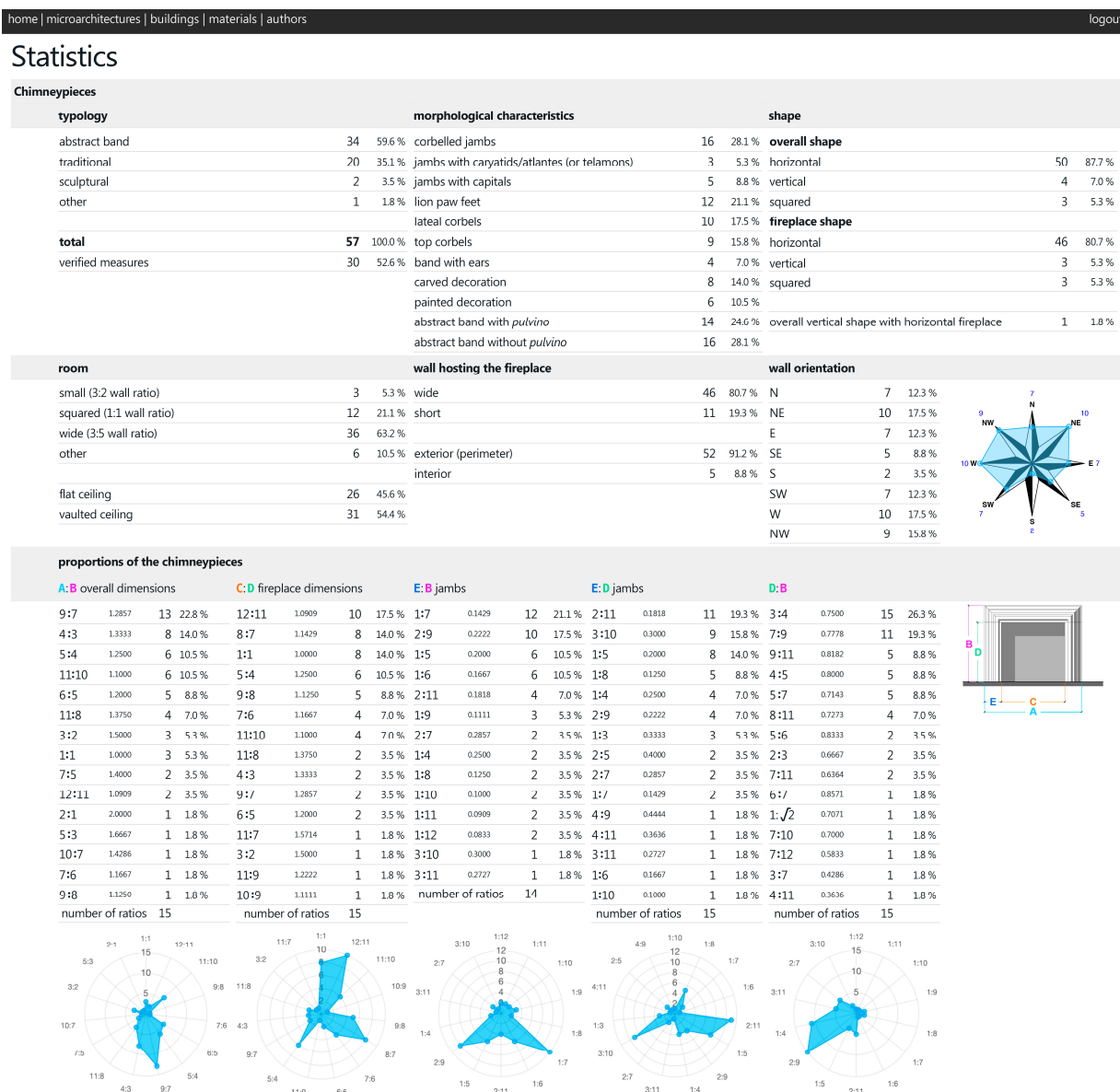


Figure 8. The main access screen of the IS designed for microarchitectures: the web interface offers a broad overview of the data collected in the database.

Also, referring to how chimneypiece dimensions are described in Renaissance treatises, these notable ratios were inferred (Figures 9 and 10) between:

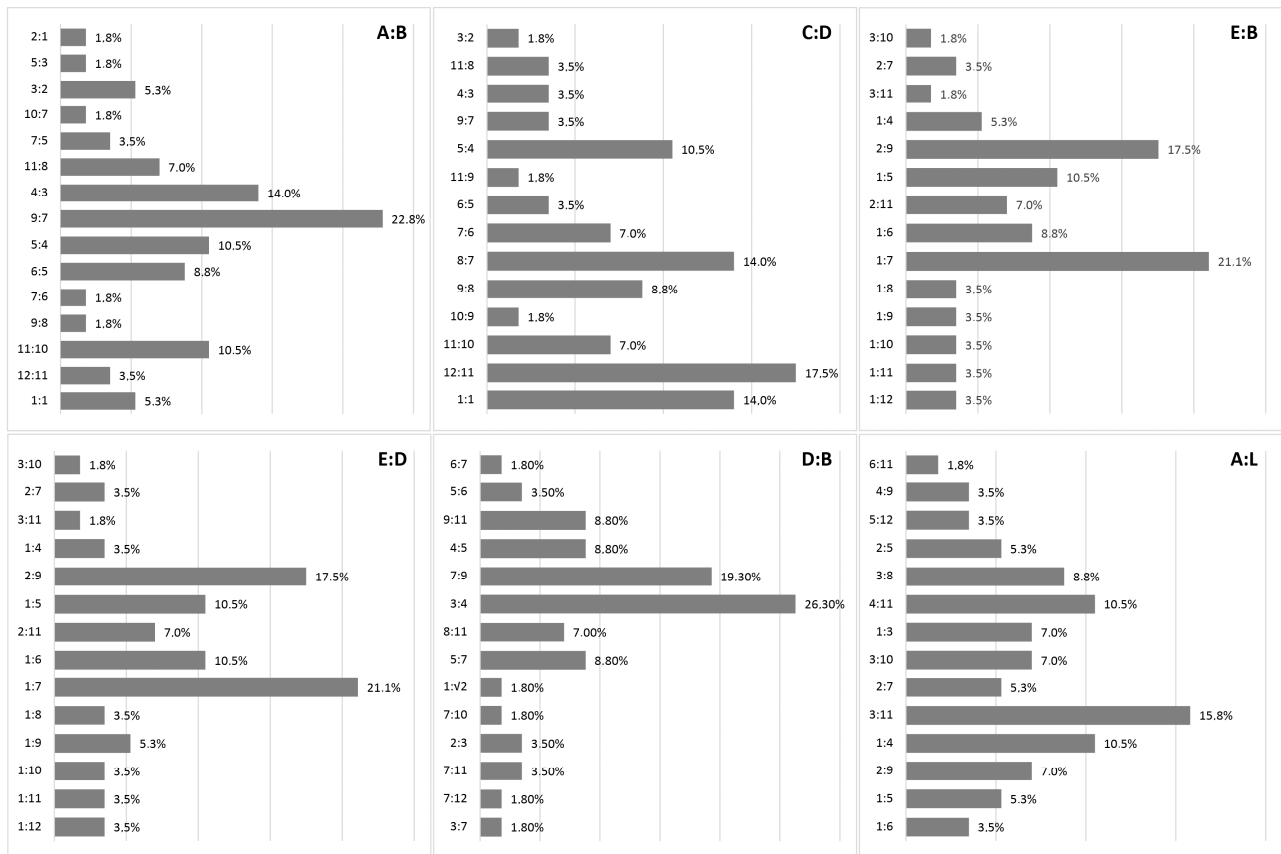


Figure 9. Distribution graphs of proportional ratios as displayed by the IS. Ratios are ordered according to their absolute value to highlight any groupings around mathematically close values.

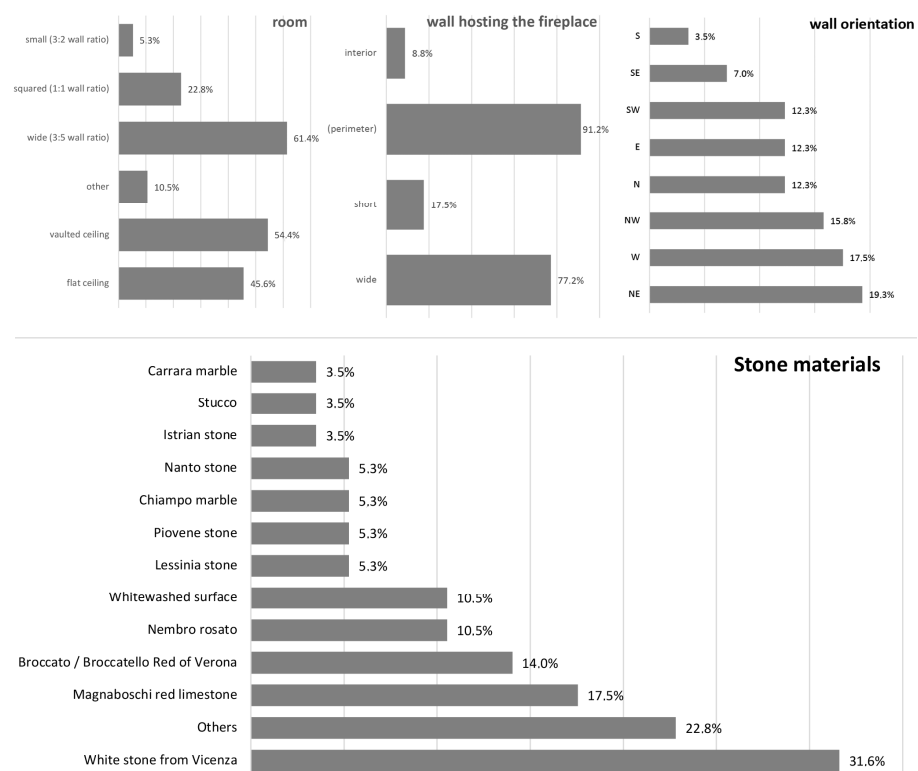


Figure 10. Aggregated statistics extracted from the IS: room's features, categories for hosting walls, their orientations and the different stone types in the collected microarchitectures.

- overall width and height, with relative horizontal or vertical orientation (A:B)
- width and height of the chimneypiece opening (C:D)
- overall height and opening height (B:D)
- jamb width and chimneypiece and opening height (E:B, E:D)
- chimneypiece width and length of the wall on which it is placed (A:L).

The lack of precise information regarding wall and ceiling heights prevented the evaluation of additional ratios that would involve these dimensions. For chimneypieces, which constitute the predominant category of microarchitectures, the following three typologies were identified (Figure 11):

- Abstract band chimneypieces,
- Traditional trilitic chimneypieces,
- Sculptural chimneypieces.



Figure 11. 3D models in the IS to summarize the three typologies of chimneypieces that were identified: abstract band ((a), Villa Cornaro in Piombino Dese), traditional trilitic chimneypieces ((b), Palazzo Ducale in Venice), and sculptural chimneypieces ((c), Palazzo Thiene in Vicenza).

The collected indications made it possible to identify them according to typological criteria and geometric/constructive attributes as expressed synoptically in Figure 12.

The ‘traditional’ ones are composed of a trilitic system of jambs and lintel with generally a decorated triangular hood (33% of analyzed cases), while those with an ‘abstract’ form are composed of a continuous molded band that wraps around the fire opening (61%). Escaping from this distinction are the purely sculptural chimneypieces of Palazzo Thiene in Vicenza, the work by Bartolomeo Ridolfi.

The trilitic form is the most monumental, which projects into the room and offers the opportunity both to insert sculptural elements in the chimneypiece to support the lintel, and for a high-relief or pictorial apparatus placed in the hood above.

The abstract band solution instead projects only a few centimeters from the wall and is therefore a purely geometric stylization played on the contrasts of lights, shadows and

reflections determined by the choice of moldings and the use of polychrome stone materials. Proportionally, some recurring ratios have been highlighted (Figure 9 again), such as 4:3 and 5:4.

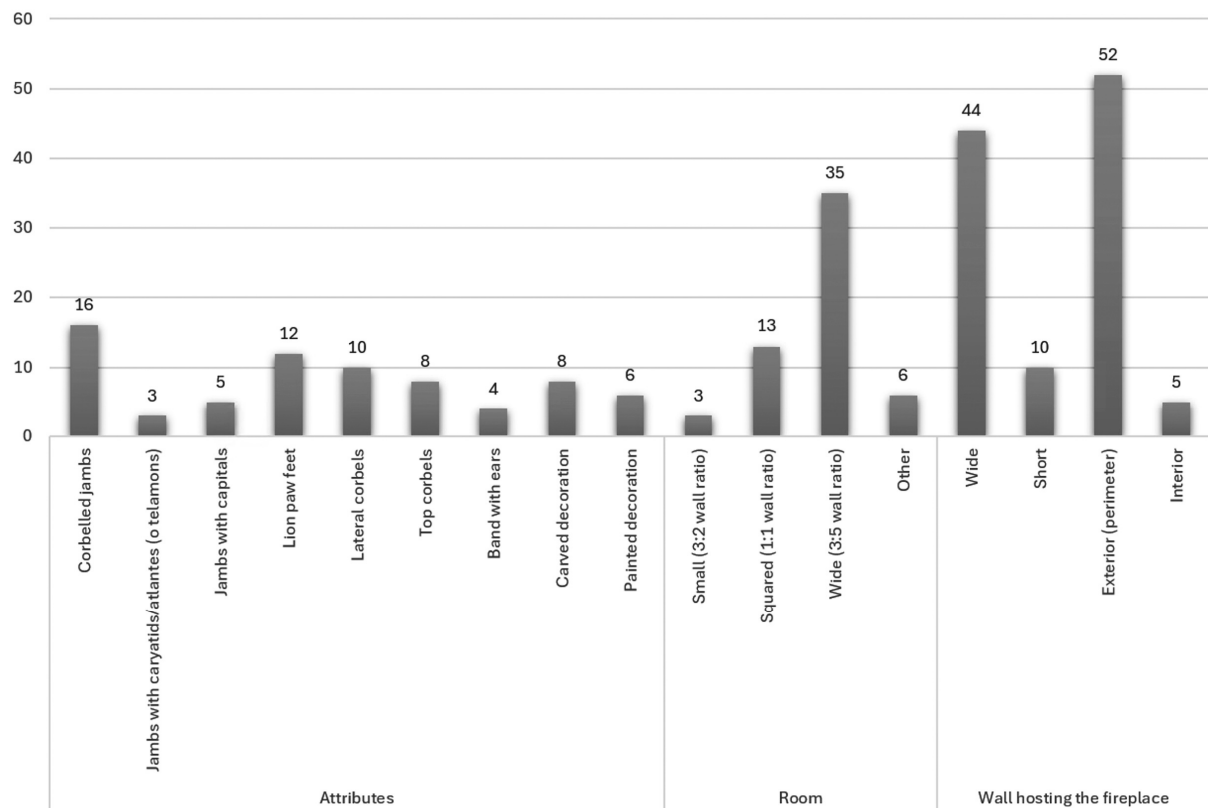


Figure 12. Synoptic diagram of general characteristics of the chimneypieces and their consistency.

However, numerous others have emerged, usually not employed in architecture. Many of these numerically ‘spurious’ ratios are close to some of the canonical ones. For example, 9:7 (that is 1.2857) which occurs in almost a quarter of cases can be rounded to 5:4 (equal to 1.25) with a deviation of 2.7%. Applying this deviation to the chimneypiece dimension translates into an error of several centimeters, a margin perhaps excessive for an object of limited dimensions, considering that constructively it is composed of few finished single elements, such as a stone lintel, which can hardly be thought to have been made with this level of imprecision. Moreover, in an era closer to us, the apparent lack of rules in chimneypiece construction was noted. François Rozier, in the *New Complete Course of Theoretical and Practical Agriculture, or Reasoned and Universal Dictionary of Agriculture*, writes that “Among all the construction measures relating to a dwelling, the most commonly neglected are those of chimneys: their position in apartments is almost always sacrificed to the convenience of distributions, and their dimensions are, so to speak, abandoned to the whim and custom of a mason. From such negligence it results that almost all chimneys smoke, and that having left the architect’s hand, they require all the intelligence of an expert chimney sweep to correct the principal defect of their poor construction” [41]. In the Palladian case, it is difficult to imagine that the chimneypieces, with their refined and finely worked profiles and integrated into the rest of the decorative apparatus, could be left to chance and not be the result of a precise design intention. It is likely that a greater number of case studies would allow for better refinement of the distribution of results, making a clearer pattern emerge.

The fact that historical treatises relate chimneypiece dimensions to those of the man finally suggests that there could also be dimensional research less tied to precise multiples of the unit of measurement but rather based on ‘anthropic’ dimensions.

However, the picture that emerges from the comparison of moldings is different, where the comparison of chimneypiece lintel sections has made it possible to establish a more limited number of cases.

In the trilithic chimneypiece typology, the canonical subdivision of architrave, frieze and cornice is easily identifiable. Figures 13 and 14 show the general sections: each chimneypiece, especially for chimneypieces from different buildings, can naturally present minimal variants of form and scale.



Figure 13. Base typologies identified in the IS (grouped in categories referenced with letters) and percentage of their use for molding profiles of abstract band chimneypieces.

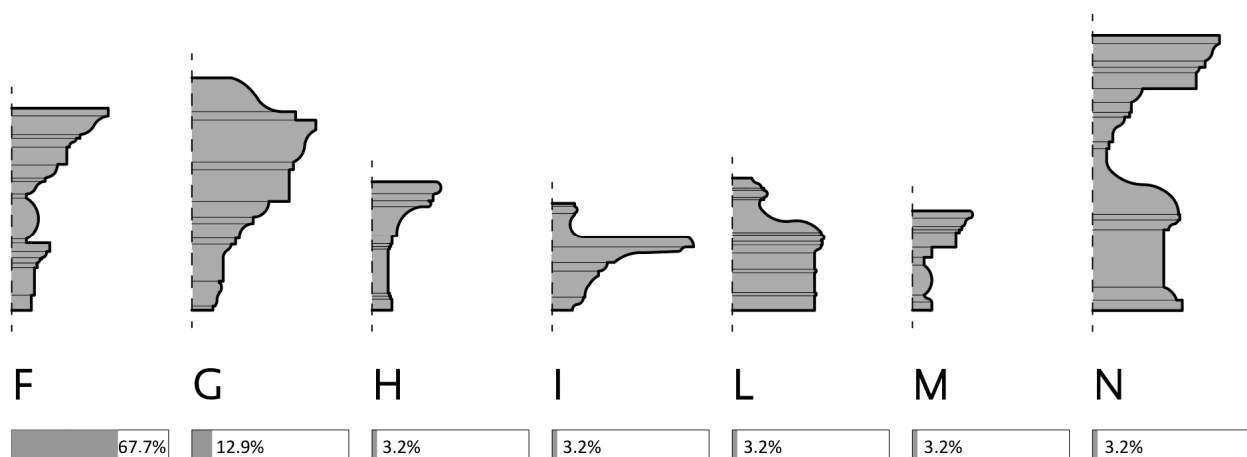


Figure 14. Base typologies identified in the IS (grouped in categories referenced with letters) and their percentage of use for molding profiles of traditional chimneypieces.

The jamb is generally resolved with a bracket, which often presents a lion paw-shaped decoration. A complete order with capital rarely appears; this could be because normally the center-to-center distance between jambs relative to their dimensions is formally excessive. The use of the bracket itself, which projects forward, in addition to allowing the development of the hood, makes it possible to give greater prominence to an element that would otherwise be visually slender compared to the complete entablature above. In abstract band chimneypieces, the structure progressively projects outward from the wall face, reaching its apex at the opening, but maintaining minimal total thickness.

In this case, a great variety of curved and flat surfaces is observed through which the architect achieves those plays of light and shadow that allow the element to stand out from the flat surface of the wall. Beyond the scale variations between chimneypieces of different sizes, the section profiles are surprisingly similar for family groups (Figure 14 again). Particularly recurring is typology E which is employed in 52% of the analyzed cases.

4. Discussion

Innovations and implications: The smartphone-based photogrammetric approach applied in this workflow represents significant progress from traditional heritage documentation methods that often rely on expensive, specialized equipment. While the geometric accuracy of smartphone photogrammetry is proved in literature, this research contributes novel insights into its application for detailed architectural microarchitecture analysis. The achieved accuracy for the explored microarchitectures, proves sufficient for proportional analysis and representation of Renaissance architectural elements, challenging the assumption that high-end equipment only is always necessary for scholarly documentation.

Typological classification and historical context: The identification of three distinct chimneypiece macro-families as one of the outcomes of the custom knowledge-based IS developed—abstract band (61%), traditional trilithic (33%), and sculptural types—provided new empirical evidence for understanding Palladian design principles. The predominance of abstract band chimneypieces suggests a preference for geometric simplification over classical orders in domestic contexts, contrasting with Palladio's more canonical approach in public architecture.

Proportional analysis and design intent: The recurring ratios of 4:3 and 5:4, while consistent with Renaissance treatise recommendations, appear alongside numerous “spurious” ratios that approximate canonical proportions. The 9:7 ratio (occurring in 25% of cases) deviating only 2.7% from the canonical 5:4 suggests intentional design flexibility rather than construction imprecision. This challenges rigid interpretations of Renaissance proportional systems and supports more nuanced understanding of architectural practice versus theory.

Overall IS contribution: The knowledge-based IS developed represents an advancement in architectural heritage documentation. Unlike previous fragmented studies, this centralized approach enables cross-referential analysis and statistical validation of many typological patterns. The system's ability to automatically convert measurements to historical Vicenza feet also facilitates the understanding of original design intentions and construction practices.

Limitations and Future Research: The study's geographic focus on buildings in the Veneto region may limit generalizability to Palladio's broader corpus. Additionally, the absence of precise ceiling height data for all the microarchitectures investigated prevented complete evaluation of vertical proportional relationships.

Future research expanding the dataset to include Palladian works in other regions could validate or refine the identified typological patterns. Integration of advanced analytical tools, including machine learning for pattern recognition and virtual reality for immersive study, could represent promising paths for future development. Nevertheless, some improvements can be added to the IS from a knowledge organization/representation point of view. Possible solutions to enrich content can be implemented including standardized metadata from other sources, such as The Getty Foundation Vocabularies [42] (mainly the Art & Architecture Thesaurus and the Cultural Objects Names Authority), the CIDOC Conceptual Reference Model [43], or MIDAS [44]. Also, the future adoption in the IS of standards such as 5STAR Open Data [45] and FAIR principles [46], will possibly improve

the integration and interoperability of the custom IS with similar ones, to foster a future transition to web.

5. Conclusions

This paper illustrated how the integration of smartphone photogrammetry, 3D modeling, and knowledge-based ISs provides a replicable method for documenting and analyzing microarchitectures by Andrea Palladio. This work considered a huge number of chimneypieces, which were identified in distinct typologies, with abstract band forms predominating over traditional trilithic systems. Proportional analysis, due to the custom IS developed, revealed both adherence to canonical Renaissance ratios and systematic variations, suggesting design flexibility within theoretical frameworks. While the knowledge-based IS provides a scalable model for organizing and analyzing architectural heritage data, enabling both detailed individual studies and broad comparative analysis: the recurring molding profiles, for example, particularly in abstract band chimneypieces, showed standardized construction practices across different buildings and time periods. This approach bridged the traditional gap between architectural surveys and analysis, demonstrating how digital tools can enhance rather than replace scholarly interpretation. The method's accessibility and its relatively cost-effectiveness made it particularly valuable to establish a framework foundation for future expanding documentation to include Palladio's complete microarchitecture corpus. The workflow's adaptability suggested also broader applications to other architectural heritage contexts beyond the Renaissance period. The study ultimately demonstrates that rigorous digital documentation, when combined with traditional architectural analysis, can reveal new insights into historical design practices while creating valuable resources for future scholarship and heritage preservation.

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References

1. Beltramini, G.; Gaiani, M. (Eds.) *Palladio Designer. Camini, Lavamani e Vere da Pozzo*; Officina Libraria: Milan, Italy, 2024.
2. Scamozzi, V. *Dell'Idea dell'Architettura Universale*; Part Two, Book Six, Chapter XXXV; Giovanni Battista Pulciani: Venice, Italy, 1615.
3. Palladio, A. *I Quattro Libri dell'Architettura*; Book One, Chapter XXVII; Domenico de' Franceschi: Venice, Italy, 1570.
4. Serlio, S. *Regole Generali di Architettura Sopra le Cinque Maniere degli Edifici, Cioe Thoscana, Dorico, Ionico, Corinthio, et Composito*; Book IV; Francesco Marcolini: Venice, Italy, 1537.
5. Vignola, J.B. *Regola delli Cinque Ordini d'Architettura*; Plate XXXVI; Camera Apostolica: Rome, Italy, 1563.
6. Alberti, L.B. *De re Aedificatoria*; i, 9; Portoghesi, P., Ed.; Edizioni il Polifilo: Milan, Italy, 1966; pp. 96–97.
7. Akboy-İlk, S. The Nature of Drawing in the Changing Culture of Architectural Documentation. *J. Archit. Plan. Res.* **2016**, *33*, 29–44. Available online: <http://www.jstor.org/stable/44113126> (accessed on 21 August 2025).

8. Warden, R.; Woodcock, D. Historic documentation: A model of project based learning for architectural education. *Landsc. Urban Plan.* **2005**, *73*, 110–119. [CrossRef]
9. Yastikli, N. Documentation of cultural heritage using digital photogrammetry and laser scanning. *J. Cult. Herit.* **2007**, *8*, 423–427. [CrossRef]
10. Apollonio, F.I.; Fantini, F.; Garagnani, S.; Gaiani, M. A Photogrammetry-Based Workflow for the Accurate 3D Construction and Visualization of Museums Assets. *Remote Sens.* **2021**, *13*, 486. [CrossRef]
11. Mayer, I.; Mitterecker, T. Surveying for architectural students: As simple as possible—As much as necessary. *ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci.* **2017**, *IV-2/W2*, 135–141. [CrossRef]
12. McCarter, R. Foreword: We Only Know What We Draw. In *Drawing from Practice: Architects and the Meaning of Freehand*; Welton, J.M., Ed.; Routledge: London, UK, 2015; pp. 11–12. [CrossRef]
13. Burggraaff, O.; Werther, M.; Boss, E.S.; Simis, S.G.; Snik, F. Accuracy and reproducibility of above-water radiometry with calibrated smartphone cameras using RAW data. *Front. Remote Sens.* **2022**, *3*, 940096. [CrossRef]
14. Tuno, N.; Marinković, G.; Mulahusić, A.; Topoljak, J.; Kogoj, D.; Savšek, S. Smartphone-based digitization of historical built heritage documentation. *J. Cult. Herit.* **2025**, *73*, 409–418. [CrossRef]
15. Patonis, P. A Comparative Study on the Use of Smartphone Cameras in Photogrammetry Applications. *Sensors* **2024**, *24*, 7311. [CrossRef] [PubMed]
16. Ramón, D. Camera Sensor Size in Photography—Does it Really Matter? Capture the Atlas. Available online: <https://capturetheatlas.com/camera-sensor-size/> (accessed on 21 August 2025).
17. Patonis, P. Comparative Evaluation of the Performance of a Mobile Device Camera and a Full-Frame Mirrorless Camera in Close-Range Photogrammetry Applications. *Sensors* **2024**, *24*, 4925. [CrossRef] [PubMed]
18. Jasińska, A.; Pyka, K.; Pastucha, E.; Midtiby, H.S. A Simple Way to Reduce 3D Model Deformation in Smartphone Photogrammetry. *Sensors* **2023**, *23*, 728. [CrossRef]
19. Butler, R. The Effect of Pixel Size on Noise. Digital Photography Review. Available online: <https://www.dpreview.com/articles/5365920428/the-effect-of-pixel-and-sensor-sizes-on-noise/2> (accessed on 21 August 2025).
20. Honkavaara, E.; Arbiol, R.; Markelin, L.; Martinez, L.; Cramer, M.; Bovet, S.; Chandelier, L.; Ilves, R.; Klonus, S.; Marshal, P.; et al. Digital Airborne Photogrammetry—A New Tool for Quantitative Remote Sensing?—A State-of-the-Art Review On Radiometric Aspects of Digital Photogrammetric Images. *Remote Sens.* **2009**, *1*, 577–605. [CrossRef]
21. Hernández López, D.; Felipe Garcia, B.; González-Piqueras, J.; Villa Alcàzar, G. An approach to the radiometric aerotriangulation of photogrammetric images. *ISPRS J. Photogramm. Remote Sens.* **2011**, *66*, 883–893. [CrossRef]
22. Markelin, L.; Honkavaara, E.; Hakala, T.; Suomalainen, J.; Peltoniemi, J. Radiometric stability assessment of an airborne photogrammetric sensor in a test field. *ISPRS J. Photogramm. Remote Sens.* **2010**, *65*, 409–421. [CrossRef]
23. Nocerino, E.; Lago, F.; Morabito, D.; Remondino, F.; Porzi, L.; Poiesi, F.; Rota Bulò, S.; Chippendale, P.; Locher, A.; Havlena, M.; et al. A Smartphone-Based 3D Pipeline for the Creative Industry—The Replicate EU Project. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.* **2017**, *XLII-2/W3*, 535–541. [CrossRef]
24. Attardi, L. *Il Camino Veneto del Cinquecento. Struttura Architettonica e Decorazione Scultorea*; Angelo Colla Editore: Vicenza, Italy, 2002.
25. ASPRS (The American Society for Photogrammetry and Remote Sensing). Available online: https://www.asprs.org/wp-content/uploads/pers/1989journal/jul/1989_jul_979-984.pdf (accessed on 21 August 2025).
26. Abergel, V.; Jacquot, K.; De Luca, L.; Véron, P. Combining on-site and off-site Analysis: Towards a New Paradigm for Cultural Heritage Surveys. *DisegnareCon* **2021**, *14*, 13.1–13.14. [CrossRef]
27. Beltramini, G.; Baldissini, S.; Gaiani, M.; Garagnani, S. Training Students in Getting Architectural Knowledge from Smartphone-Based Photogrammetry: The Chimneypieces by Andrea Palladio. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.* **2023**, *XLVIII-M-2-2023*, 195–202. [CrossRef]
28. Gaiani, M. See, Touch, Feel: A Cognitive and Educational Journey through Maquettes. *Disegno* **2024**, *14*, 31–44. [CrossRef]
29. Gaiani, M.; Ballabeni, A. SHAFT (SAT & HUE Adaptive Fine Tuning), a New Automated Solution for Target-Based Color Correction. In *Colour and Colorimetry Multidisciplinary Contributions*; Marchiafava, V., Luzzatto, L., Eds.; Gruppo del Colore—Associazione Italiana Colore: Milan, Italy, 2018; Volume XIVB, pp. 69–80.
30. Kazhdan, M.; Bolitho, M.; Hoppe, H. Poisson surface reconstruction. In Proceedings of the Fourth Eurographics Symposium on Geometry Processing (SGP '06), Cagliari, Italy, 26–28 June 2006; pp. 61–70.
31. Dore, C.; Murphy, M. Current state of the art historic building information modelling. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.* **2017**, *XLII-2/W5*, 185–192. [CrossRef]
32. Baldissini, S.; Gaiani, M. Interacting with the Andrea Palladio Works: The History of Palladian Information System Interfaces. *J. Comput. Cult. Herit.* **2014**, *7*, 1–26. [CrossRef]

33. Yu, C.-H.; Groza, T.; Hunter, J. Reasoning on Crowd-Sourced Semantic Annotations to Facilitate Cataloguing of 3D Artefacts in the Cultural Heritage Domain. In Proceedings of the International Semantic Web Conference, Sydney, Australia, 21–25 October 2013; Volume 8219, pp. 228–243. [\[CrossRef\]](#)
34. Niang, C.; Marinica, C.; Markhoff, B.; Leboucher, E.; Malavergne, O.; Bouiller, L.; Darrieumerlou, C.; Laissus, F. Supporting Semantic Interoperability in Conservation-Restoration Domain: The PARCOURS Project. *J. Comput. Cult. Herit.* **2017**, *10*, 1–20. [\[CrossRef\]](#)
35. Fai, S.; Sydor, M. Building Information Modelling and the documentation of architectural heritage: Between the ‘typical’ and the ‘specific’. In Proceedings of the 2013 Digital Heritage International Congress (DigitalHeritage), Marseille, France, 28 October–1 November 2013; pp. 731–734. [\[CrossRef\]](#)
36. Soler, F.; Melero, F.J.; Luzón, M.V. A complete 3D information system for cultural heritage documentation. *J. Cult. Herit.* **2017**, *23*, 49–57. [\[CrossRef\]](#)
37. Bochenska, A.; Kot, P.; Muradov, M.; Markiewicz, J.; Zawieska, D.; Hess, M.; Antoniou, A. Critical evaluation of cultural heritage architectural standard documentation methods across different european countries. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2023**, *XLVIII-M-2*, 251–258. [\[CrossRef\]](#)
38. Pouloupoulos, V.; Wallace, M. Digital Technologies and the Role of Data in Cultural Heritage: The Past, the Present, and the Future. *Big Data Cogn. Comput.* **2022**, *6*, 73. [\[CrossRef\]](#)
39. Nieto-Julián, J.E.; Moyano, J.; Rico, F.; Antón, D. Management of built heritage via the HBIM project: A case study of flooring and wall tiling. *Virtual Archaeol. Rev.* **2016**, *7*, 1–12. [\[CrossRef\]](#)
40. Thivet, M.; Verriez, Q.; Vurpillot, D. Aspectus: Développement d’une plateforme collaborative en ligne d’analyse des données 3D pour l’archéologie et le patrimoine. *In Situ* **2019**, *39*, 1–19. [\[CrossRef\]](#)
41. Rozier, F. *Nuovo Corso Completo d’Agricoltura Teorica e Pratica, ossia Dizionario Ragionato ed Universale d’Agricoltura*; Tipografia di Valentino Crescini: Padua, Italy, 1817; Volume V, p. 196.
42. The Getty Research Institute Vocabularies. Available online: <https://www.getty.edu/research/tools/vocabularies/> (accessed on 9 September 2025).
43. The CIDOC Conceptual Reference Model (CRM). Available online: <https://cidoc-crm.org/> (accessed on 9 September 2025).
44. MIDAS-Heritage, A British cultural heritage standard for recording information on buildings, archaeological sites, shipwrecks, parks and gardens, battlefields, areas of interest and artefacts. Available online: <https://rdamsc.bath.ac.uk/msc/m24> (accessed on 9 September 2025).
45. Five Star Open Data. Available online: <http://5stardata.info/en/> (accessed on 9 September 2025).
46. The FAIR Guiding Principles for scientific data management and stewardship. Available online: <https://www.go-fair.org/fair-principles/> (accessed on 9 September 2025).

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