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DIGITAL ANASTYLOSIS AND THE VIRTUAL RECOMPOSITION OF ARCHITECTURAL FRAGMENTS

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Abstract

The paper investigates digital anastylosis as a methodological approach for reconstructing lost architectural compositions virtually. By combining material evidence with advanced digital modeling, the research aims to recompose the fragmented partition of St. Christopher's choir through a structured comparative analysis of forms, proportions, and stoneworking techniques. Integrating historical documentation and high-precision surveying has formulated a plausible hypothesis regarding its original configuration. The results highlight how digital technologies facilitate architectural interpretation and enhance heritage conservation strategies. This approach provides an active tool for understanding architectural transformations, providing a more profound exploration of stratigraphic processes and spatial relationships within historic structures, ultimately offering new perspectives on the potential of digital methodologies in reconstructive analysis.

Keywords

Comparative analysis, Digital modelling, Gothic screen, Simulation, Structured-light 3D scanner

1. *Framing the reconstruction issues and its challenges*

In the assessment of the evolution of architecture into its stratification, the fragment's topic is essential to comprehending the building's transformational stages. This is because it illustrates how the past, present, loss, and recomposition are related. The fragment is never a passive component. It possesses a layered memory, reflecting the formal language of a specific building period. It serves as an interpreter of material culture, its construction techniques, and, most importantly, the alterations that have impacted it. In this perspective, the fragment becomes an active residue - a witness that can be reintroduced into a new context or reinterpreted in light of new instances - despite losing its original integrity. When these pieces transform into unpredictable elements, detached from their original context, they retain their worth. Instead, it appears they re-evaluate it in accordance with the new setting and the new role they are required to fulfill.

For instance, consider the choir partition pieces in the church of St. Christopher at the Charterhouse of Ferrara. The items were disassembled and partially cataloged, subsequently used in various decorative provisions: some were re-arranged within the Baratelli antechamber (Fig. 1); others were placed in the city's collections of ancient marble museum, and finally, a few were dispersed or, perhaps, used as paving stones or ground into the mortar. Isolating these parts from their original semantic context uncovers an episode that underscores the duality of fragments: remnants of a disjointed past, yet also dynamic entities capable of producing a new narrative revealed in a settled architectural design. Their reutilization prompts methodological inquiries that look for investigation: how to reinstate a coherent understanding of their initial configuration? Which instruments should be utilized to examine and, if feasible, restate their original configuration?

Digital anastylosis is a novel approach that combines material and immaterial data. It provides the opportunity to practically reconstruct a phase based on interpretative solutions derived from the formal significance of their incomplete nature. The objective is not to physically reconstruct what has been shattered or is presently scattered. The objective is to employ modern technology to reconstruct the original configuration of the partition accurately.

Fig.1: Charthous of Ferrara, the Baratelli antechamber.

Examining each element's proportions, spatial relationships, and function within its lost context is part of this. This methodology, utilizing three-dimensional models and virtual simulations, facilitates historical study and enables the formulation of interpretative solutions that offer a contemporary perspective on the studies about the original spatial configuration of the Carthusian choir.

The paper analyses this important case study, investigating the dual role of the fragment as both a remnant of the past and a resource for the present, situated between physical preservation and digital reconstruction. From a perspective that blends memory and valorization, the objective is to present a methodological path that combines the scientific rigor of direct source study with the innovation provided by digital technologies. This will show how digital anastylosis can become an effective tool for understanding, valorizing, and narrating the fragmented heritage made up of the erratic elements of the partition.

Virtually reconstructing and reliving a portion of the stratification that is no longer readable due to the events that have changed the entire Carthusian complex has been made possible by the use of extensive digital information modeling that can reconstruct both the architectural spatiality of the presbytery area of San Cristoforo's and the micro-architecture that formerly surrounded the choir. This operation enhances our understanding of the Carthusian monastery and contributes to the broader discussion on Ferrara's architecture, highlighting a pivotal chapter in the historical development of the Carthusian institution.

The design process was interdisciplinarly backed, encompassing field surveys, historical-architectural analyses, and computer modelling. In order to integrate modern research methodologies with cutting-edge digital visualization and analysis technologies, specialists with complementary skills - from the history of architecture to the ability to read building characteristics through the study of construction techniques, from the signs that transformations have left to information technology - have worked together.

A crucial aspect is the recurrent interplay between digital technology and historical-philological research. 3D-modelling techniques are essential for assessing the morphology of the architectural elements of the partition's micro-architecture and its systematic restoration, accompanied by a detailed examination of the primary source. This iterative methodology has established a cyclical process: digital modeling has offered crucial assistance in comprehending the building at a specific stage of its life cycle. At the same time, historical-philological research has perpetually enhanced and polished the virtual restitution, facilitating ongoing refinement of the investigation and heightened critical awareness in the presentation of the Carthusian structure. The collaboration between conventional methods and

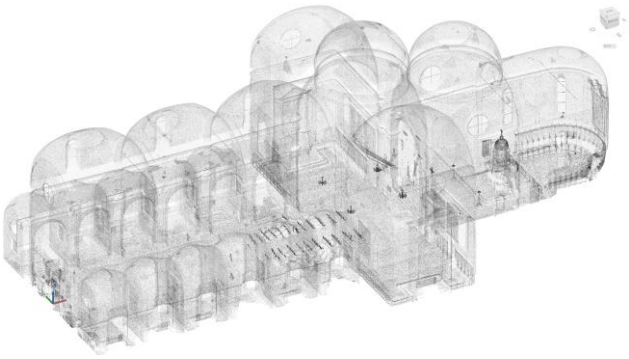

Fig.2: The 3D point cloud survey of the church of St. Christopher at the Charterhouse of Ferrara.

cutting-edge technologies has broadened the scope of analysis and interpretation. It has established a replicable framework for examining and enhancing lost architectural assets. This provides novel insights for inquiry into architectural history and conservation.

2. *Fragment as a narrative device in architectural stratification*

2.1. *Fragmentation and architectural reuse as silent witnesses*

Before discussing digital anastylosis, it is crucial to consider the semantic and methodological implications of the fragment, as it is the starting point of the topic from which reconstructive hypotheses are derived. The fragment is not merely a relic of the past but represents a point of intersection between historical memory and the interpretation that has been made in the various transformative phases. The dual function of this material trace of a lost entirety demands a critical approach that investigates its partial and decontextualized nature. As a polysemous entity, it is susceptible to new narratives that contribute to its integration in various and evolving reconstructive processes, while it can also restore information on proportions, construction techniques, and original formal choices. The fragment's dual function is the key. It possesses a narrative potential that is not fully realized in its original context. Anastylosis and its digital shift are fertile ground for experimentation and valorization of the built cultural heritage. The partition members' fragmentary nature serves as a reminder of the irreducibility of material history to a linear narrative. By digitally recovering and reusing fragments, it is possible to achieve more than merely bridging a divide and refining the gaze to recognize the complexity of the past. The architectural fragment, torn from its original context and repurposed in the Baratelli antechamber, is the tangible sign of a dialogue between the silence of loss and the rebirth due to transformation. More than mere residual material from the previous architectural draughting, it serves as a testament to stratified intentions. This process of despoliation and relocation reveals a critical aspect of the processuality in the stratification of the Carthusian compound: the ability to assign a new identity to the elements, thereby transforming the fragment into a medium that connects different material cultures and eras. Consequently, the act of reusing fragments is, therefore, both conservative and creative in nature. The selection of a fragment and its subsequent enhancement within the composition of a new architectural edition has meant the rejection of mere musealisation, with the result that the component elements of a common testimony have been preserved.

2.2. *From physical displacement to digital reassembly*

Similarly to an incomplete mosaic, the remaining fragments encourage the reconstruction of the composition's meaning rather than its form. Consequently, the fragmentary elements of the partition stand as witnesses to an absence that poses numerous questions. The partition is not merely a "missing element"; rather, it is an entity that is endowed with autonomy of forms and evocative power. It can foster a dialogue between the past and the present through 19th-century transformations, in which spoliation and reuse represented a compromise between pragmatism and symbolism. In each spoliated fragment, the anthropological gesture is manifested as an act of violence – the dismembering, the breaking – and as a recognition of the value of what the elements represented until the moment before their dismantling. Thus, the relocated fragments are no longer solely a testimony to the past but a metaphor for continuity in discontinuity. The stone elements fitted in with the new Baratelli antechamber layout are no longer considered to be matter; rather, they are regarded as a symbolic bridge between periods, thereby serving as a reminder that their recovery was not a plain and simple nostalgic act but rather a transformation of fragments into a new spatial entity. Consequently, these fragments are a critical element in the dialogue between the past and the present, as they embody a semantic tension in their condition of being detached from the original whole. The physical remnants of the micro-architecture from which these parts originate serve as material evidence and as an autonomous entity capable of generating a new narrative, even if the matter is entirely resolved using a digital approach. In this context, celebrating diversity and plurality within a unitary composition is essential for comprehending the role of the fragment and its ability to generate cultural value in a digital

process of recomposing erratic elements. In terms of intricacy and proportional relationship of forms, each of these elements is a unit that reflects the complexity of its original whole. The decorative richness of the bases, pilaster shafts, candelabras, and capitals is a manifestation of a variety that is not yet exhausted in the original whole but is still powerfully evident in their condition as distinct elements, as revealed by an analysis of these elements. The presence of fragmentation does not reduce the piece's worth; instead, it emphasizes the fragment's ability to narrate the intricacies of the architectural setting of St. Christopher's *tramezzo* framework, from which it originates through its distinctiveness. The concept of variety is the generative principle of a coherent narration, which is characterized by the plurality of potential arrangements and changeable collocations. The partition fragments serve as tangible evidence of a transformation process, in which elements decontextualized from the original micro-architecture are repurposed in the antechamber's arrangement to establish a new, meaningful compositional organization. The virtual relocation of these fragments within their original context is facilitated by the application of digital anastylosis, which enables the reconstruction of the composition in its entirety and provides a multifaceted interpretation of its historical and architectural significance. This approach extends beyond the restoration of lost unity by ideal recomposition of the original layout, instead enabling an exploration of the variety of proportions, decorations, and spatial relationships within the choir, thereby facilitating a multifaceted interpretation of the fragments. Fundamental significance is attached to the partition's fragmentation and subsequent synthetic recomposition.

2.3. The Baratelli antechamber and the legacy of the carthusian choir

The present investigation is derived from the study conducted by Fabbri, Lopresti and Marcolini, which transcribe the economic specifications for the deconstruction of the stone components of the choir screen. The document offers a critical perspective on the logistical and financial framework that controlled the disassembling of architectural elements, thereby revealing a relevant historical moment in the Chartusian compound during its transformation into a municipal cemetery. The operational dynamics of deconstruction in the church presbytery can be reconstructed by analyzing these records while examining how the deliberate removal and repurposing of built elements is possible to make the assumption on the articulated process of adaptation within the antechamber of Baratelli's burial chapel. Specifically, ten marble members, including pilasters and half pilasters with capitals and bases that previously arranged the choir screen, are positioned to decorate the room and create an antique frame. Entablatures and stucco copings complete the frame. Hence, the presbytery of the church of San Cristoforo and the antechamber were subjected to a digital survey to determine the pilasters' original and current locations. This operation aimed to establish a metrically reliable virtual environment that could be thoroughly analyzed to generate a hypothesis regarding the digital relocation and reconstruction of the pilasters within the Carthusian temple (Fig. 2). The acquisition encompassed not only the ten pilasters, six of which in their entirety, and four of which were divided into half, but also other elements that were likely to have been part of the screen partition or, at least, the liturgical apparatuses of the Carthusian church. These elements were located in the *Anticella* (i.e., the antechamber) or the Casa Romei Lapidary Museum of Ferrara. The following artifacts were detected: the entrance portal to the cell proper and four sculpted corbels from the *Anticella*; two half-pilasters similar to the eight aforementioned from the antechamber; a tabernacle (attributed to the workshop of Alfonso Lombardi); and fourteen fragments of figured friezes, some of which bear the CAR trigram of Carthusian (figs. 3, 4).

In order to facilitate typological groupings and comparisons between the parts, each model thus produced was assigned a distinctive identification code and inserted into an abacus.

Fig.3: 3D model of a *tabernacolo* originally from the Chartusian temple.

Fig.4: 3D model of a frieze fragment, likely part of a trabeation, featuring the Carthusian trigram CAR. Nowadays, the artifact is exhibited in the lapidary collection of the Casa Romei Museum.

Additionally, each element came with a description and information regarding its current location (Fig. 5). The procedure resulted in a series of critical elaborations on the case study and the method itself.

The pilasters that were discovered between the antechamber and the museum are made up of three stone elements: a slender Attic base, a shaft with mirroring framed by an ovoli motif, and a Corinthian capital with leaves supporting volutes, a curved abacus with a boss fleuron. The figurative variations observed in the pilasters are evident in the shaft surfaces, which contain candelabra of variable shapes, and in the central part of the capitals, where masks and plant motifs alternate. The abacus framework enabled the initial division of the pilasters into two typological macro-groups, each consisting of four and six examples. These macro-groups are further explained upon in the next paragraph.

To evaluate the digital models, it was determined that the morphological information of the surface pattern should be distinguished from the color variations. This was primarily because the material, which may have been homogeneous, well-processed, or even painted, is now subject to degradation phenomena that prevent an accurate comprehension of the model. Therefore, it was essential to turn off the texture in order to observe the sculpted pattern, which is well-preserved in nearly all elements without interference from undesirable color variations (Fig. 6). The dimensional and proportional comparison of the models was necessary to confirm the actual relationship of the half-pilasters exhibited in Casa Romei lapidary museum to the same corpus present in *Anticella*, as their background had already been linked to the Certosa (Fig. 7). The pilasters from Casa Romei are perfectly consistent with one of the typological macrogroups in Anticella. The Anticella wall box's internal angles are marked by pilasters, vertically divided into half, and tilted against the long sides of the antechamber. These elements are the most degraded; they exhibit mechanical scratches, extensive and sketchy reintegrations in mortar, pulverization, and efflorescence in the lower, moist, and saline areas.

Nevertheless, the decorative elements unequivocally suggest that the four sections were derived from two intact parts. The pairings oppose one another regarding the shafts and the capitals.

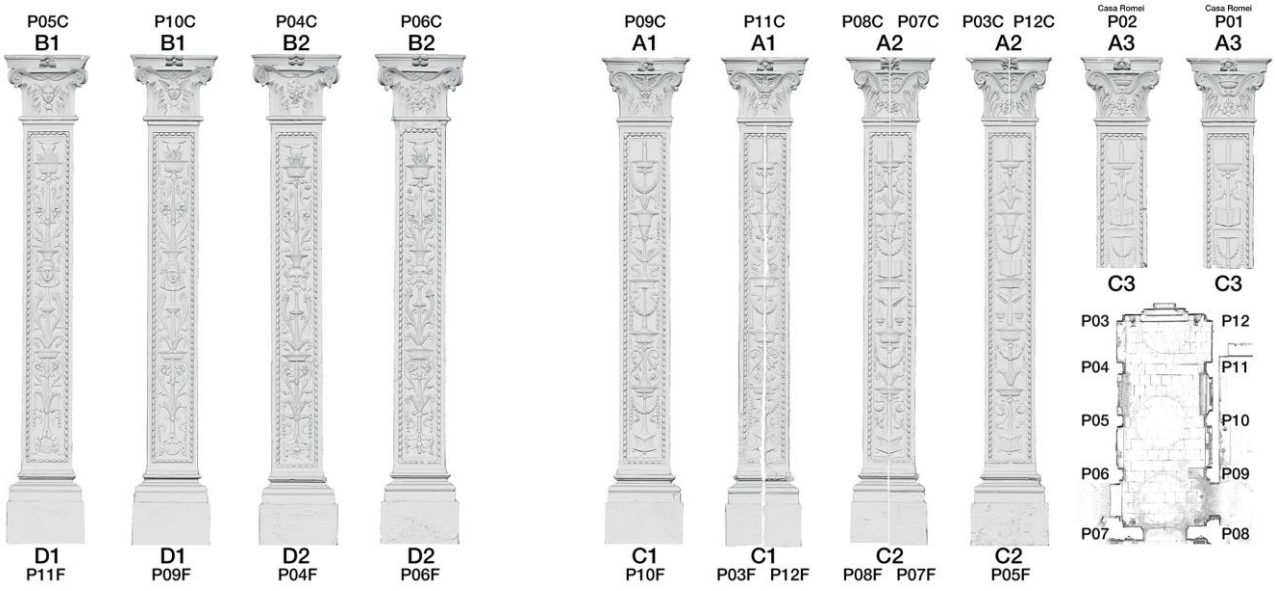

Fig.5: 3D models of the pilaster fragments that originally formed the choir screen of the Church of St. Cristopher. In the bottom right corner, the current arrangement of eight of these samples (six complete pilasters and four half-pilasters at the corners) within the Baratelli antechamber (Shining 3D EinScan-Pro HD with 0,045 mm accuracy for single-scan).

Fig.6: The sculptured pattern of the fragments observed with and without the texture.

By acquiring these sections and virtually juxtaposing them, it is possible to identify sub-horizontal scars that cross the vertical cut in continuity and detect the perfect consistency of the decoration. This suggests that the elements were originally two complete parts fractured before or during the subdivision process into four halves. This likely occurred during the Anticella's corner configuration phase (fig. 8).

2.4. Typological classification into macro groups

Thanks to the parallel projection perspective of the elements in their "naked form," or without the disruption of the tone and material components, the syntactic arrangement of the pieces, the ornamental details, and the surface workings could finally be analyzed. The numerical identification of all the pilasters obtained, together with the recomposition of the fragmented parts as a whole, formed ten components, precisely the same number as reported in dismantling reports from the 19th century. Thus, two major macro groups of six and four components were identified subdivided into two groups.

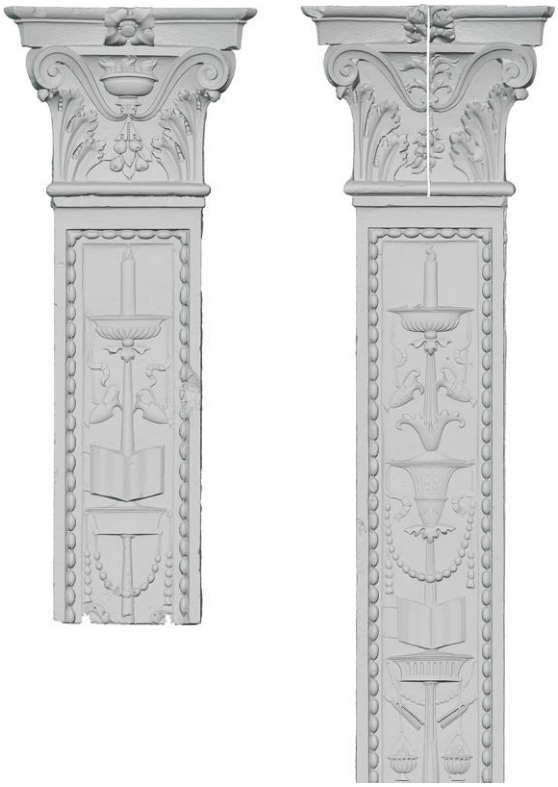

Fig.7: The half-pilasters exhibited in Casa Romei lapidary museum

The capitals are categorized into five groups: A1–A3, B1–B2, whereas the stems are classified into C1–C3, D1–D2.

Regardless of the arrangement of the lost partition, the final composition is distinguished by a collection of components that, when viewed from some distance, serve their tectonic role of supporting the entablature. On closer inspection, it becomes clear that these components are infused with a precise variety that can imbue the composition with vibrancy without compromising its syntax. During the cemetery's 19th-century arrangement, shafts and capitals were gathered arbitrarily without considering the correspondence of forms.

The components of macro group A are distinguished by Corinthian capitals featuring two acanthus leaves at the corners and robust volutes with two ribbons flowing off the calyx core. This arrangement makes room for two figurative elements: one positioned above the node and one below it. The classification of these figures enables their categorization into three types:

A1. above the knot, a twisted horn wrapped by two wings; beneath the node, a grotesque mask with a protruding tongue and a beard made of smooth, round petals.

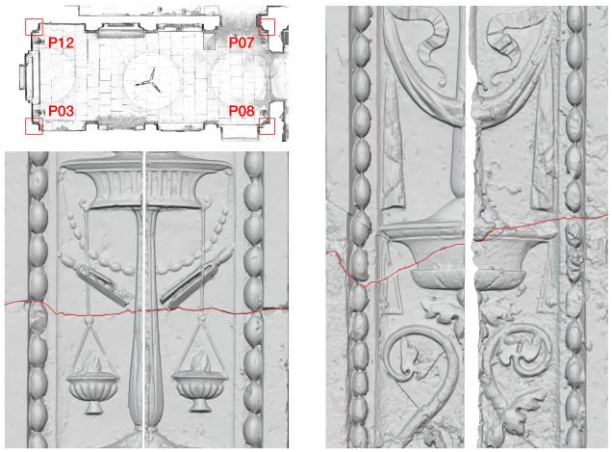

Fig.8: The corner configuration fragments in the Baratelli antechamber.

A2. The second specimen shows rhombinated leaves above the node and a dangling cluster of lanceolate leaves and pear-like fruit below the node. The abacus flower is substituted with an acanthus-like leaf that supports the volutes. Both specimens were used in the corner and subsequently bisected into halves.

A3. With a smooth brazier with three flames above the node and a triangular drill-worked element holding together a bundle of lanceolate leaves and pear-like fruit below, the third group represents the capitals stored at the lapidary.

The components of macro group B consist of Corinthian capitals, characterized by two acanthus leaves at the corners, with lobes interlaced with lacustrine reeds. The calyx's margin shows an elongated water leaf attached to the acanthus leaf. A single ribbon forms the volutes, extending from the calato tangent's upper section to the abacus, while the lower allegorical element is held in place by the knot that links them. The element's shape distinguishes two forms of macro groups:

B1. Two wings putto masks are supported by the knot: one with the eyes and tongue out, and the other with the eyes and mouth shut. The putto possesses two serpentine tails beneath it.

B2. Two free-falling ribbons flank the knot on the right and left, while a centre ribbon hangs a variety of plant species, including fig leaves, lanceolate leaves, spikes, figs, and pears. Four more ribbons flutter over the knot in one of the two instances.

The macrogroup C consists of stems with a figured candelabra, a jug with a lit candle at the top, and a quadrangular stand at an angle to the viewer at the base. Four different-shaped vases, tapered supports, and other ornamental devices are dotted among these components.

C1. A garland of pearls connects the ends of two ribbons that hang from the first vase, with two rows of pearls falling vertically. The two symmetrical dragons in the same vase have tapered bodies and webbed leaves. The second vessel has two triangular pendants. In the third are two free ribbons, a festoon of four-petaled flowers, and palmate leaves. The shaft connecting the third and fourth vases is affixed to the former, with ribbons cascading from it. The fourth vase exhibits two tiers of pearls. The candle holder features a garland-like draping. One specimen from this group is bisected, resulting in two corner supports of the Anticella.

C2. From the base, two pods and shoots with lance-shaped, runcinate leaves emerge. The initial vessel contains two runcinate leaves, while the subsequent one features a double garland of beads and spindles. A garland of beads and two flamed cups are placed in the third vase with bifurcated pincer-like devices above it. Positioned above the third vessel and in front of the central shaft is an open book secured by two clamps on the left side. The fourth contains a garland of pearls, two rows, and two ribbons. The candle holder apparatus accommodates two ribbons and supports two inclined jugs. One specimen from this group is bisected, resulting in two corner supports for the Anticella.

C3. These are the stems preserved at the Lapidary; from the base, broken by the absence of the lower section, there are two roncinate leaves. As with the other C stems, the fourth vessel has two free pearl strands higher up and a garland of pearls hanging from the vessel's base. An open book featuring two ties for closure on the left side is positioned above and in front of the central stem. The candle holder apparatus accommodates two ribbons and contains two slanted jars. The macrogroup D consists of shafts with figured candelabras. The four samples are characterized by a base element resembling a palm leaf or a fan and a bucranium enclosed by a blazing brazier at the tops. Various elements, including whorls of foliage, vessels, woven baskets, and masks, can be observed between the two.

D1. The initial stem develops runcinate leaves and four-petalled flowers that are enclosed in their own whorls from the bottom up. Two leaves are used to sustain strings of pearls with ribbons. The initial vessel produces two flaming curved cornucopias alongside two runcinate leaves with pods at their extremities. At the highest echelon, a female figure disrupts the stem, wrapped in a veil that is knotted at the lateral parts of the ears. The figure has closed eyes, flowing hair, and a brimmed headdress. A woven basket stands at an elevated position above this. From it, coiled leaves, two pods, and two four-petalled flowers are emitted, each enclosed in its whorl. At higher elevations, clusters of fruit are enclosed by three leaves. The bucranium resides within the terminal flaming brazier, supporting two layers of pearls.

D2. Each of these stems is composed of two distinct components. The allegorical motif is interrupted by the junction, which is located approximately one-third of the way from the base. Either this was an unplanned composition feature or a subtle adjustment to accommodate the higher supports, as no signs of pilasters of varying height remained after the partition was dismantled in 1812. The first stem bears runcinate leaves and a cluster of whorled blooms with four petals; two leaves hold pearl strings fastened with ribbon, while the first vase produces two flame-curved cornucopias and two runcinate leaves. On top of the stem rests a man's mask, which is adorned with a beard separated into three parts by runcinate leaves, a mustache, open eyes, pointed ears that resemble fairground points, and a crown made of beads and expanded leaves. At the base of the mask rests a woven basket that sprouts runcinate leaves, two pods, two whorled flowers with four petals each, and, farther up, clusters of fruit encompassed by three leaves. With the bucranium contained within, the two rows of beads are supported by the terminal blazing brazier. The digital model featured the stonemason's preferred surface processing method, which the Shining 3D EinScan Pro HD structured-light handheld scanner could decipher with a resolution of 0.3 mm. Two distinct coats, or varying degrees of refinement, are observed in the execution of the capitals. Group A defines the leaves through drill work, which is subsequently completed without the use of any other instrument. Leaves in Group B have less pronounced veins and no discernible drill work in their smoother cavities.

All of the shafts' candelabras have a uniformly smooth finish, with some elements featuring rougher grinding to bring out the surfaces of various materials. The smooth and slightly veined bucrania, the fourth vessel of C1 and C2, and the pedestals of macro group C make this quite evident. The abacuses of the capitals display intricate craftsmanship, showcasing a coarser grain texture achieved through the step process.

As the elements described were originally a single ensemble and were part of the presbytery partition that separated the monks' choir from the rest of the church of St. Christopher, it would be helpful to examine the stone fragments to accurately establish the chronology of the temple's construction. Hence, to identify both similarities and compositional differences, the meshes of the two pilaster configurations (those belonging to the choir screen and those defining the architectural composition of the church) were compared, with an emphasis on the technical proficiency of the stonemason, the intricacies of the modeling process, and the surface processing of each element.

The Corinthian type of capitals located within the temple of St. Christopher is the most prevalent design in the Ferrara area, regardless of their order of occurrence. The capitals showcase a curved abacus decorated with a floral design, small volutes resting on angular acanthus leaves, and a freestanding form at the abacus's core. The thematic elements depicted in these capitals are strikingly similar to those characterizing the tramezzo pilasters. These elements include flaming braziers, plant motifs of leaves, blossoms, fruit, baskets, birds with outstretched wings, masks, and candles. A few cases have the volutes protruding straight from the abacus rather than being attached to the array of fittings placed at different heights.

Nevertheless, the most noticeable distinction is seen in the element's proportions: whereas the Anticella's capitals are slender and feature a significant width gap between their narrow base and the broad and airy level of the volutes, the ones within the church seem more compressed, short, and schematically resembling rectangles laid out horizontally.

3. The re-composition of fragments

What remains of the liturgical partition in the Carthusian church of St. Christopher presents a unique opportunity to address the interplay between architectural fragment, typological classification, and digital recomposition. To fully explore this potential, the approach is organized into distinct phases, moving from the analytical observation of physical elements to interpretative synthesis through virtual anastylosis. This structure aims to clarify the logical progression between empirical observation and digital hypothesis formulation, while emphasizing the methodological value of each step. To enhance methodological clarity and clarify the logical progression from analytical observation to reconstructive theory, the topic is articulated to addresses the necessity of distinctly differentiating the objective, systematic description of the fragments, grounded in three-dimensional survey data and morphological classification, from the interpretative phase wherein this data is critically analysed for virtual recomposition. At this junction, the fragment is no longer approached merely as a residue of dismemberment, but as a narrative device capable of evoking the architectural whole. It becomes meaningful precisely when it prompts an ideal reconstruction, reversing the direction of constructional logic to re-establish lost spatial and symbolic coherence. This conceptual reframing allows to maintain the transparency of its internal logic and ensure that design decisions stay traceable and verifiable by separating these levels of analysis and avoiding ambiguity between the documentary dimension and the simulated reconstruction. The shift from the tangible reality of architectural remains to their digital reconstruction is characterised not only as a figurative act, but as an analytical process that uses virtual modelling to examine and investigate plausible configurations rooted in historica.

3.1. Comparative analysis of referential models for the lost tramezzo

This investigation does not aim to promote or justify any philological or typological reconstruction of the original liturgical screen nor to suggest the dismantling of the current configuration of the Baratelli chapel. Instead, it seeks to critically assess the original spatial arrangement of the Carthusian presbytery before the 1597 transformation. This reconstructive hypothesis, with its significant value, is a crucial first step in understanding the architectural rewriting process that culminated in the site's conversion into a monumental cemetery. It also acquires phenomenological value, as it enables the reactivation of spatial memory and symbolic liturgical meanings now hidden.

Screen partitions were key architectural and liturgical elements in delineating the spatiality and functionality of the churches of the pre-Tridentine monastic orders. The surviving fragments of the partition on the chancel of St. Cristopher church are a prime example of how these stone members reflected both liturgical needs and symbolic instances, separating the space intended for the monks from that reserved for the converts. This division revealed the need to preserve the monastic community during the recitation of the Divine Office, which, gathered in the wooden stalls of the choir, was recollected towards the Sancta Sanctorum positioned at the end of the apse. The presence of architectural elements such as pilaster shafts, bases, and capitals in the surviving fragments of the Charterhouse of Ferrara emphasizes how the partition was conceived as a functional structure and micro-architecture. In the formative process of the new Carthusian church, it is conceivable that it was all resolved in the vicinity of the two pilasters of the presbytery. In this first phase, between 1552 and 1597, the year the wooden ciborium was built, it was inevitable that the ten pilasters made up the front of the partition facing the nave so that the wooden choir stalls could be placed on the opposite side. The partition that separated the monks' choir from the rest of the church was designed to meet the specific requirements of the Carthusian community. It is conceivable that the partition incorporated a single central opening, allowing a partial view of the high altar. This would have enabled the observant to participate visually in the liturgical mystery while simultaneously emphasizing the symbolic hierarchy between the secular and monastic worlds.

In addressing the digital recomposition of the partition, it is profitable to establish a critical comparison with other micro-architectures that, performing a similar liturgical function and typology, can offer an indispensable comparative framework for understanding the typological and functional variables that characterize these membranes. This includes their relationship with

liturgical space and ritual practice. However, it is important to recognize that local specificities, such as formal simplification dictated by the greater or lesser austerity of the monastic rule, are reflected in a lesser or greater visual link with the lay community.

Regarding the urban setting of Ferrara, many pilaster capitals located in various buildings and churches in the city were photographed and then subjected to photogrammetric analysis. Of these, the most noteworthy is the capital of the cantonment in Palazzo Turchi-Di Bagno, which was built in the 1590s and completed in the first decade of the 18th century. The canton contains eight scrupulously crafted versions of the Corinthian capital, each accompanied by various figurative elements at its centre. The calyx is nearly square, and two racemes and volutes rise from the capital's core. The angular leaves are detailed and accompanied by the customary straws, while the figures positioned centrally exhibit intricate workmanship. This includes the baskets with two types of weave and the drill marks that animate the wings of the dragons, which are analogous to some of the workmanship on the capitals of macro group A and the shafts of D. The bulk of the city's samples, according to a set of comparisons, show short and fairly thin proportions, possibly continuing a late-medieval tradition in the Po Valley area, regardless of the amount of figurative or symbolic updating towards the end of the fifteenth century. This assertion is further supported by the examination of the 15th-century capitals of the church of Sant'Andrea, the narthex of Sant'Antonio in Polesine, the second cloister of San Paolo, and the specimens supporting the public porticoes of Via Boccacanale di Santo Stefano and Via Spadari, which are no longer in situ but resting on the ground. The pilasters of the Carthusian screen may thus be said to incorporate 15th-century local figurative elements, although they are shaped differently than in the Ferrara panorama. Their form resembles that of the Venetian works of Codussi or the Lombardo workshops, like the façade of the Scuola Grande di San Marco, the Bernabò chapel in San Giovanni Crisostomo, Palazzo Vendramin Calergi, the church of Santa Maria dei Miracoli, or the marmoreal *Septo* of the Scuola Grande San Giovanni Evangelista.

All of these architectures, including those from the same period and circle of masters, consist of a vertically organized capital with volutes that open broadly at the connection between the down and collar. The presented assumption does not yet confirm the involvement of Venetian craftsmen in the Carthusian construction yard between the 15th and 16th centuries. However, the present study is a component of a first-stage research project and new digital technologies will support a comparative examination of shapes, dimensions, and stoneworking techniques. It is possible to assess the partition's function as both a functional component and a place of visual and spiritual mediation simply considering more intricate solutions used in various ecclesiastical contexts.

The *tramezzo* of the Basilica of San Miniato al Monte in Florence is an excellent example of how it should be done (fig. 9).

It fits seamlessly into the basilica layout in the front of the presbytery, with the precise function of delimiting and organizing the liturgical space between the high altar and the monastic choir. It effectively separates the area reserved for the clergy from the area accessible to the faithful, thus defining a sacred boundary that does not compromise the visual perception of the architectural whole. It develops as a low marble barrier, open in the centre, punctuated by quadrangular panels with a combination of geometric motifs and phytomorphic decorations, crowned by a tripartite entablature with a frieze in stone commesso.

Fig.9: The *tramezzo* in the Basilica of San Miniato al Monte, Florence. The microarchitecture is articulated through a horizontal rhythm of framed panels rather than by a fully developed architectural order. The absence of vertical members such as pilasters emphasizes a decorative scheme based on geometric and phytomorphic motifs, punctuated by a tripartite crowning entablature. This compositional approach privileges linear continuity over tectonic modulation, aligning with the preference yet anchored in the Romanesque language for visual clarity and symbolic legibility within the liturgical space.

Fig.10: The partition of the Basilica of Santa Maria Gloriosa dei Frari, Venice. Elevated on three steps, the screen marks a symbolic yet permeable boundary between nave and choir. Ten *candelabra* pilasters and eight framed reliefs reflect Franciscan ideals of proximity, culminating in a triumphal arch framing the sight toward the high altar.

The Basilica of Santa Maria Gloriosa dei Frari in Venice is a perfect example of how a partition met liturgical and spiritual needs (fig. 10). The separation between the nave, intended for the faithful, and the choir, intended for the community of friars, is less rigid, although the choir symbolically separates the presbytery from the space for the faithful; however, its central location and the arrangement of the open stalls suggest a compromise between monastic privacy and the visibility of the liturgy. The composition, elevated on three steps, is distinguished by ten candelabra pilasters, exhibiting pronounced naturalistic elements in the manifestation of intertwined racemes and capitals adorned with oak leaves and allusions to Christological symbolism, which envelop eight mirrors embellished with reliefs of patriarchs and prophets. The framework is crowned by a tripartite entablature interrupted at the centre, directing the gaze towards the high altar as the liturgical focal point. The crowning, reminiscent of a triumphal arch, is adorned in the second register with pilasters clamping the arch ring. Another type of micro-architecture that plays the role of separating and, at the same time, defining the liturgical space is represented by the partition of the peribolos around the presbyterial area of the Basilica of St. Anthony, which, following the rearrangement carried out by Camillo Boito between 1893-1899, is distinguished by a crowning entablature supported by pilasters that delineate bipartite mirrors. In the context of the Ferrara episode, the fragments reused in the decoration of the Barattelli antechamber are distinguished by their characteristic adaptation to wall use. The capital is designed to visually and physically adhere to the wall surface to set up a pilaster, thereby reducing the rear relief to little more than a denture and concentrating the decoration only on the front.

The comparative analysis with the transennae of San Miniato al Monte in Florence, Santa Maria Gloriosa dei Frari in Venice, and the peribolos partition in the Basilica of St. Anthony in Padua reveals both formal affinities and significant deviations in compositional strategy and liturgical intent. Proportionally, all three examples exhibit a measured articulation of vertical and horizontal elements; however, the Ferrara fragments suggest a more attenuated development in elevation, with slimmer pilasters and a reduced entablature height. This divergence may reflect a conscious adherence to a more austere Carthusian aesthetic, in contrast to the monumental registers and decorative exuberance found in the Venetian and Paduan contexts.

In terms of architectural grammar, the reconstructed partition aligns with the proportional logic codified by Leon Battista Alberti, particularly in the use of the module (modulus) derived from the base of the pilaster to govern the vertical development of the architectural order. The calculated ratio of base, shaft, and entablature adheres to a scalar system consistent with early modern treatises, even in the absence of direct textual documentation for the Carthusian structure. This internal coherence reinforces the plausibility of the digital hypothesis, distinguishing it from purely conjectural reconstructions.

Liturgically, the Ferrara screen reflects a monastic paradigm of spatial separation similar to that observed in San Miniato and the Frari, where partitions serve not only a functional delimitation but also a symbolic mediation between clerical and lay zones. However, unlike the more permeable solutions in Venice or the scenographic elaboration in Padua, the presumed configuration of the Ferrara partition, reinforced by its narrow central opening and simplified articulation, emphasises contemplative isolation and hierarchical division in keeping with Carthusian ritual discipline. The liturgical screen thus

emerges not merely as an architectural device but as a manifestation of the monastic rule, shaping the spatial perception of the sacred through proportion, material articulation, and controlled visibility.

3.2. Analytical classification and morphological decoding of the fragments

To bridge the descriptive richness of architectural detail with the interpretive goals of digital anastylosis, it is necessary to isolate the analytical reading of the architectural fragments. The empirical findings obtained from the studied elements, particularly the pilasters, capitals, and candelabra shafts, are critically important since they form the bedrock of the comprehensive analytical dataset. These data, structured through abaci, typological matrices, and 3D comparative renderings, enable a stratified classification system that guides the reconstruction phase while preserving the distinct features of each object. This classification process is instrumental in mitigating speculative interpretations and reinforces the validity of the reconstruction through morphological coherence. As previously mentioned, to conduct this comparative analysis, the digitally acquired texture was deliberately and thoughtfully removed, as surface patinas and degradation phenomena would have compromised the accuracy and reliability of the morphological comparison.

The capital's composition is characterized by a quadrangular abacus, with sides that connect to the mirroring surface protruding from the front, resulting in a trapezoidal section that ensures a more immediate transition to the wall. The cavetto of the abacus houses a small floral decoration in the form of a barely stylized rosette in the center. The kalathos of the capitals are of an inverted trapezoidal shape, flattened at the back, indicating that the element was designed to be applied to a flat surface and perceived primarily from the front.

A single register of acanthus leaves emerges from the base of the kalathos and curves slightly upwards with undulating margins and terminations that curl below the volutes. The development of the leaves is flattened better to suit the lower relief of the pilasters modeling. The volutes at the capital's corners are connected to the abacus with a more pronounced and less three-dimensional curvature, again emphasizing the frontal view. On the primary surfaces, the rim of the volutes extends towards the center of the kalathos, where it is picked up by a ribbon together with symbolic elements.

The shafts of the pilasters, measuring approximately 27 cm in width (equivalent to 8 ounces), feature a candelabra decoration and are distinguished by a rectangular section with an increase in height proportional to its width, resulting in an overall height, inclusive of the base and capital, that is six times the width of the pilaster observed at the imoscape. The bases adhere to the Attic compositional scheme, characterized by a plinth and spiral, modeled by a lower torus, scotia between laths, and an upper torus of reduced dimensions. This results in a sequence of moldings with a restrained three-dimensional development, yielding a slightly flattened element to facilitate its placement against a wall. The uniformity of the Baratelli antechamber fragments and the erratic elements housed in the lapidary of Casa Romei in Ferrara imply the arrangement of a partition structured according to a ten-pilaster system surmounted by an entablature.

In order to undertake a virtual reconstruction of the initial configuration of the partition prior to 1597 through a process of digital anastylosis, it is necessary to reconstitute the sequence of the pilasters, incorporating an upper entablature. However, given the paucity of trabeation fragments that can be traced back to the entablature of the partition, it is indispensable to dimension its articulation on the basis of a careful analysis of the existing fragments, the proportions of the architectural order and direct comparisons with typologically similar examples.

In particular, the partition of the Frari church in Venice represents a useful reference due to the articulation of the partition in pilasters with entablatures and ornamental superstructures. Although the partition of the Certosa in Ferrara may have differed in the sobriety of its formal layout and the absence of elaborate superstructures, the comparison allows us to establish plausible proportions and principles of composition for the dimensioning of the entablature.

The existing pilasters show proportions and decorations that can be traced back to the Italic Corinthian order, as codified in the treatises by Alberti. By measuring the overall height of the pilasters, including their capitals and bases, it was possible to determine the module at the base of the original composition. The module m, equivalent to

half the width of the shaft of the pilaster surveyed at the imoscape, was identified as the generating element for dimensioning and proportioning the missing entablature. The hypothesis of an architraved cornice, in which the entablature is devoid of a frieze, was excluded. It was assumed that the entablature could be grammatically articulated into three main components, the proportions of which are derived directly from the module of the pilaster. The height of the latter was estimated to be four modules. The dimensions of the moldings that constitute the bases were traced back to the sub-modules that are useful for reconstructing the entablature's missing parts by following the moldings' proportions and sequence. The reconstruction in simplified forms of the entablature was limited to the definition of the dimension of the development in height supported by the proportional ratios without pushing the simulation further, which would be arbitrary if it exceeded the boundaries of interpretation. The resulting digital model of the partition, adopting the hypothesis of the ten pilasters frontally aligned towards the nave, returns a plausible layout of the partition with which, eschewing arbitrary solutions, to emphasize the value of the surviving fragments by integrating them into an architectural system consistent with the liturgical context of the Charthouse of Ferrara.

3.3. From data to interpretation: digital anastylosis and the choir screen simulated reconstruction

The transition from the empirical data to the recompositional hypothesis represents a critical turning point in the methodological path of this research. While the data derived from 3D scanning and typological comparison establish the groundwork, the interpretation emerges as a dialogue between what is measurable and what is hypothetically reconstructible. This passage from metric survey to virtual projection is not linear: it involves choices that are rigorously constrained by the architectural syntagma, intended as the ordered sequence of formal elements whose spatial and functional relationships define a coherent compositional structure, and by its stylistic grammar, comprehended as the set of codified rules, conventions, and proportional systems governing the articulation of those elements within a given historical and typological framework. These constraints, together with the canonical principles of proportion and the

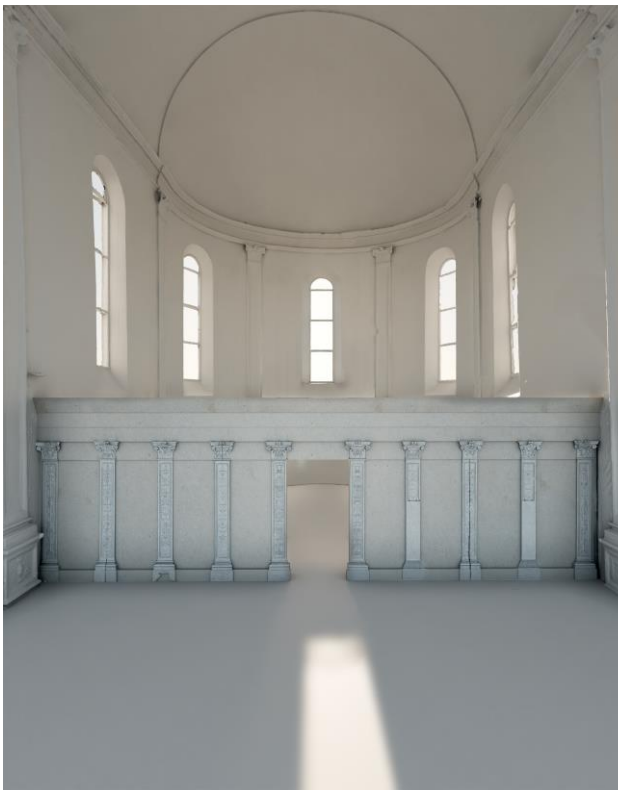

Fig.11: The digital anastylosis of the choir screen. In this perspective, aligned with the visual axis toward the *Sancta Sanctorum*, the digital reconstruction repositions the pilasters arranged in sequence according to the hypothesised original layout. The fragments are textured with a material simulating Istrian stone, consistent with the lithological characteristics of the fragments. The surrounding spatial context of the Carthusian church, as well as the entablature and the intercolumniation between pilasters, is rendered neutrally using a clay-style shader to emphasise the reconstructed elements. The entire model is developed and rendered within Blender 4.2 environment.

intended liturgical function of the architectural apparatus, inform the plausibility and internal consistency of the reconstructive hypothesis. It is here that digital anastylosis achieves a delicate balance. It moves beyond being a mere modelling tool and operates as a heuristic application, testing the plausibility of various reconstructions within epistemologically transparent boundaries. This interpretative leap, guided by the principle of non-invasive reversibility, ensures that each hypothesis remains falsifiable and open to further refinement through interdisciplinary dialogue and technological reassessment. During the digital anastylosis process, a meticulously structured system of para data was implemented. This was not just to ensure the traceability, transparency, and scientific accountability of each interpretative step but also to provide a robust and reliable basis

for our findings. The para-data framework functioned as a reflexive apparatus, capturing the methodological rationale, interpretative uncertainties, and alternative pathways explored throughout the virtual recomposition of the liturgical partition. This approach proved particularly critical in addressing the formal ambiguities posed by the presence of ten pilasters, whose number raises significant compositional questions in the absence of complete historical documentation or surviving elevation drawings.

To critically engage with these uncertainties, three hypothetical configurations were developed, each informed by the presumed spatial arrangement of the screen before the modifications introduced in 1597. These variants tested different distributions of the pilasters in relation to axial symmetry, modular spacing, and the possible inclusion of a central opening. The reconstructions were grounded in geometric analysis and typological comparison, drawing on analogues from contemporary ecclesiastical contexts and monastic liturgical practices, as well as proportional frameworks derived from the Alberti's treaty. This process, where each dimension, mould, and volume derive from the module m extracted from the pilaster width, transforms the virtual reconstruction into a philological act. It strikes a reassuring balance between objectivity and conjecture. The value of the fragment, in this sense, is no longer merely residual but generative: it becomes the syntax from which the entire lost composition can be re-imagined. This adaptable approach, which allowed to consider a wide range of possibilities, ensured that no potential solution was overlooked. At each stage, para data were meticulously recorded in the form of annotated decision trees, mesh alignment logs, and interpretative commentaries, ensuring the transparency and trustworthiness of our research.

4. Conclusions

This study showcased the potential of digital anastylosis when supported by combining material evidence, historical sources, and advanced modelling techniques. It serves not only as a restitution tool but as a catalyst for deeper architectural understanding. High-resolution three-dimensional surveys and typological and proportional analysis helped build consistent screen partition configuration theories.

This method addresses the interpretative challenges posed by fragmentation, enabling a more structured and evidence-based reconstructive process.

A key contribution of this research lies in the use of digital anastylosis to test structural assembly hypotheses. The analysis of connections among individual components revealed traces of original construction logic, interlocking techniques, and potential distributions, aligning the simulated configuration with plausible historical practices. The virtual modelling environment also permitted the testing of alternative recomposition scenarios, offering a dynamic framework for assessing formal, spatial, and liturgical implications.

Moreover, digital anastylosis has proven particularly valuable in documenting the relational logic between fragments, providing a robust interpretive foundation for practical applications in heritage enhancement, digital museology, and educational contexts. Rather than merely serving as a visualisation device, it becomes a critical epistemic instrument that helps reframe the architectural fragment as a vector of spatial memory and historical identity.

Looking ahead, the methodological framework established here opens up promising directions for integrating Artificial Intelligence into architectural recomposition processes. This is especially significant in cases where the material record is highly eroded, dispersed, or entirely lost. AI-driven pattern recognition, predictive modelling, and generative algorithms could assist in extrapolating missing geometries, simulating tectonic compatibilities, or suggesting historically coherent configurations based on training datasets from similar architectural contexts. Such integration could significantly enhance the potential of digital anastylosis in reconstructing architectural ensembles that have undergone radical transformation or survive only as erratic fragments.

In conclusion, this experience confirms that architectural fragments should not be viewed solely as a loss but as an opportunity to experiment with new critical tools for reconstructive reasoning, fostering both the advancement of knowledge and the cultural reactivation of our built cultural heritage.

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