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L'ECO DELLE PIETRE: HISTORY, MODELING, AND GPR AS TOOLS IN RECONSTRUCTING THE CHOIR SCREEN AT STA. CHIARA IN NAPLES*

1. Introduction

Digital technologies are transforming historical research in multiple ways. As the authors of this essay demonstrate, digital technologies as research tools can bring to light evidence hitherto unavailable. Because technologies require various types of expertise, however, digital projects usually entail teamwork and collaboration, as is represented in this multi-authored and multi-lingual essay that describes the creation of a model of the choir screen at Sta. Chiara in Naples (Fig. 1).

In the seventy or more years since the end of World War II, many scholars have studied the architecture and decoration of this massive Franciscan church. Our article interrogates an aspect of the church that had only been hypothesized (Vitolo 2014), the choir screen destroyed at the end of the sixteenth century and for which there exists neither physical nor documentary evidence. Our research initiative began as a Master's thesis by Lucas Giles centered on two questions: would it be possible to utilize radar scanning to identify the location and dimensions of the choir screen of Sta. Chiara? And, if evidence of the foundations were found, would it be possible to develop a three-dimensional model? The answer to both questions was an emphatic "yes".

The identification of the location of the screen and our hypothesis of its appearance change our understanding of the church as a whole, its liturgy, ceremonial spaces, and burials. The questions prompted by our work are deep and complex, however, and require further research by scholars of medieval Naples and the mendicant orders.

Although now almost entirely lost, choir screens were once essential features of medieval church interiors, separating clergy from laity and creating a form of hierarchical zoning within religious space (Jung 2000, 2012). These monumental structures excluded laity from physical and visual participation in the liturgy at the high altar (Bruzelius 1992). On their front (usually west) face towards the public, they were the setting for secondary altars adorned with paintings and liturgical textiles, decorative programs that were bright with images. Altar screens were the setting for some of the most beautiful works of art of the high Middle Ages, which survive in decontextualized fragments

* This article is a collaborative effort with Caroline Bruzelius and Andrea Giordano as the authors of sections 1 and 2, Emanuela De Feo of section 3, Leopoldo Repola of section 4, Lucas Giles of section 5, Andrea Basso and Elisa Castagna of section 6, Caroline Bruzelius of section 7.

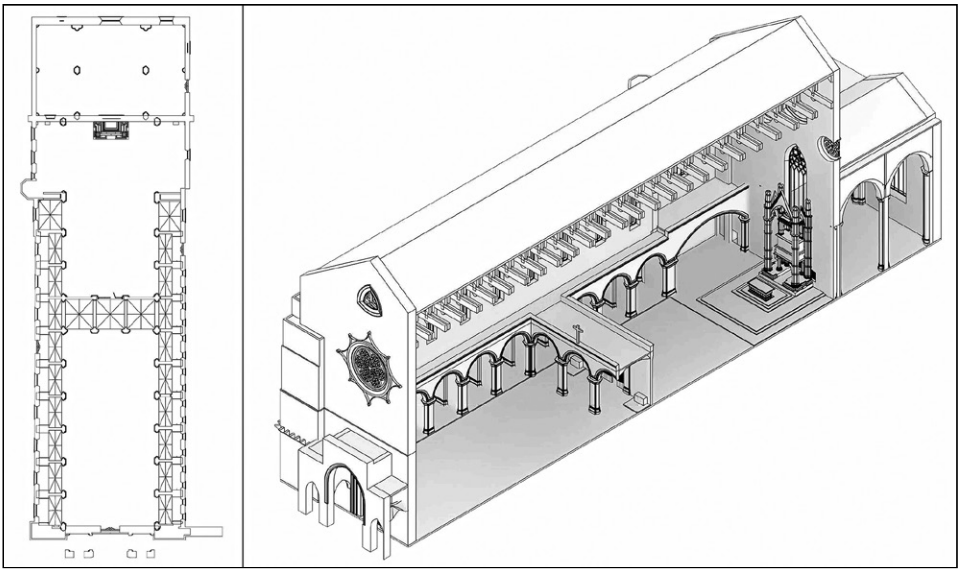

Fig. 1 – Views of the hypothetical screen, church plan (left) and axonometric view (right).

in museum settings. For most laymen, the altars of the choir screen were the primary locus of spiritual transactions as sites for the veneration of popular saints. In the mendicant orders, these were altars dedicated to the founders: Dominic, Francis, Claire, and saints of particularly intense devotion, such as Anthony. Association of their altars with the choir screen focused the attention of the public on the exemplary lives and intercessory powers of these new saints of *recent* memory, remarkable accomplishment, and profound spiritual potency. Choir screens were thus labile and sensitive indexes of popular piety, reflecting the social and economic realities of patronage and the co-dependence (in spiritual and financial terms) of friars with donors; this was an important area of connection between the laity and the religious community (Bruzelius 2014, 24, 30-31, 40, 57 and 135). In addition, the veneration of these new and immensely popular saints stimulated requests for burial near their altars, as attested in wills (Bruzelius 2014, 144-146, 151-152 and 157-158). In both life and death, however, noble and wealthy patrons, were often permitted *beyond* and *inside* the screen to the area reserved for the friars; the chapels of those donors (such as the Peruzzi, Bardi, or Strozzi families in Florence), benefitted from a privileged position by the liturgical choir. Indeed, at Sta. Chiara, the geo-radar scan revealed a longitudinal stretch of underground elements from the central door of the screen up to the main altar and the tomb of Robert, a "red carpet," as it were, of privileged burials towards the royal tombs.

2. The multiple choirs and the tramezzo of Sta. Chiara

Sta. Chiara in Naples, founded by Robert the Wise and Sancia of Mallorca in 1310, was a double convent of Clarissan nuns and Franciscan friars. There were two cloisters, one attached to the south (far) end of the church for the female community, and one to the right side of the nave for the friars. The nuns' cloister gave access to their strictly enclosed choir behind the main altar, a choir visible to the rest of the church only through three grated openings. After the death of Robert the Wise in 1343, the Bertini brothers of Florence created a double tomb that soared above the main altar; in the nuns' choir there was an additional effigy above the grated openings (D'Ovidio 2015). The effigies present the king in a Franciscan habit yet crowned; each was an incentive for intercession and remembrance from the two separate and *separated* religious communities that could hear, but not see, each other, doubling the power of intercessory prayer.

The object of our study, however, is the second division within the church: the choir screen that separated the lay public from the Franciscan community, a division destroyed in the late sixteenth century. By the time it was redecorated in the Baroque style, the church had long since been transformed into one enormous internal volume; the post-war reconstruction obliterated any possible surviving traces of the screen, with the exception of some relief panels depicting scenes from the life of Sta. Catherine.

Excavation might have provided a solution for identifying the foundations and perhaps architectural fragments. But this would have been expensive and disruptive. Indeed, it is precisely because the research team wanted to experiment with non-invasive technologies that we proposed using ground-penetrating radar (GPR) to identify the location and dimensions of the screen and develop a model of its appearance. We began with the hypothesis that the screen would logically have been located between a public entrance on the east (left) flank of the church and the entrance from the friars' cloister in the penultimate chapel towards the altar to the west (right) side. As will be seen in Repola's section (Section 4), the radar scans revealed substantial foundations of a transverse wall that extend across the full width of the nave, with two forward supports aligned with the piers of the lateral chapels one bay forward of the transverse wall. The second set of foundations are evidence of two forward piers: as will be seen below, the structure would therefore have consisted of three bays as deep as the side chapels.

The data from the radar scan had to be interpreted within correct measurements of the church, yet it had become clear that the dimensions of the post-war plans and sections were deeply flawed. We were fortunate in being able to collaborate with De Feo, who offered us the use of a precise laser scan (Fig. 2). With this evidence in hand, we were thus able to conclude that

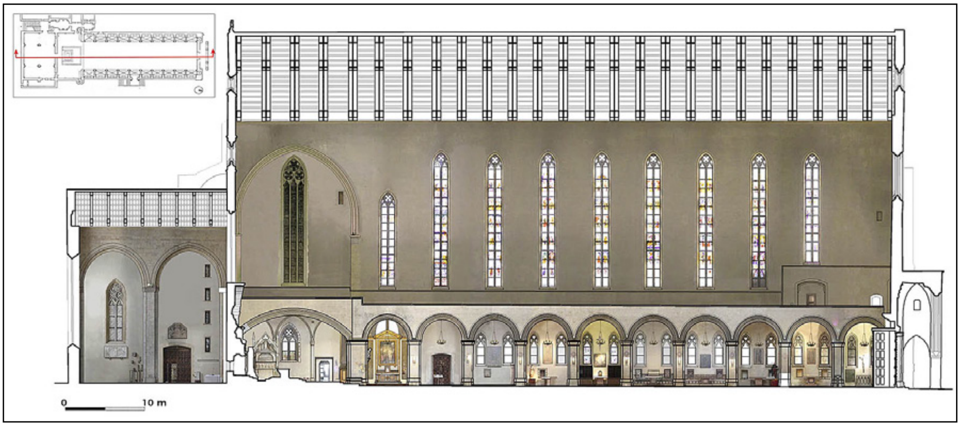

Fig. 2 – Longitudinal section of the church created using the initial laser scan data (De Feo).

the *tramezzo* reproduced the rhythm, depth and height of the side chapels, at upper level creating a transverse gallery that connected the wide tribunes over the nave chapels. The choir screen therefore united the lateral galleries across the immensely wide space of the nave, generating an "H" plan at the upper level (Fig. 1). A choir screen with three openings suggests of course that the central bay had a portal towards the friars' choir and tomb of Robert the Wise, and the side bays contained altars. As we shall see in the section authored by Giles (Section 5), the two altars were almost certainly dedicated to Francis (left side), and Claire (right side). The screen thus divided the nave of the church into two separate but interconnected sections, with a vast nave containing the altars of Claire and Francis, and an almost equally large precinct reserved for the friars as well as for royal and noble burials.

3. Una nuvola di punti per lo studio di Santa Chiara: un database di informazioni

Nell'ultimo decennio il rilievo tridimensionale ha visto il laser scanning quale metodologia indiscussa alla base di studi, ricerche e progetti di valorizzazione, recupero e restauro, specialmente nel settore dei beni culturali. L'ottima affidabilità del dato metrico acquisito e restituito dallo strumento, unita alla sua buona versatilità negli ambienti interni ed esterni hanno spesso compensato alcuni dei limiti più evidenti della metodologia e della tecnologia legati, ad esempio, al costo del sistema e alla complessità di gestione delle nuvole di punti. La possibilità di raggiungere un alto dettaglio nella restituzione grafica in situazioni di particolare complessità, di abbattere i tempi del rilevamento e della restituzione rispetto alle metodiche tradizionali, di acquisire contemporaneamente nuvole di punti e foto a colori e di integrare i risultati ottenuti con sistemi di modellazione 3D CAD e BIM hanno modificato e, sotto alcuni punti vista, migliorato la lettura e l'analisi critica dell'oggetto (Docci, Gaiani, Migliari 2001; Clini 2008; Apollonio 2010; Bianchini 2012; Bertocci, Parrinello 2015).

La complessità morfologica e le notevoli dimensioni della chiesa di Santa Chiara hanno rappresentato l'occasione per applicare una metodologia di rilievo già sperimentata con esiti positivi per lo studio della chiesa di Sant'Eligio al Mercato a Napoli (D'Auria, De Feo 2017), il primo edificio religioso angioino partenopeo. Il rilievo è stato finalizzato ad ottenere un riferimento metrico scientificamente affidabile per la successiva fase di modellazione parametrica dell'edificio e delle ipotesi ricostruttive del tramezzo e anche per creare un archivio digitale da cui poter attingere informazioni in qualsiasi momento.

La tecnologia utilizzata dagli attuali laser scanner, operando in modo quasi automatico, consente di acquisire dati metrici e colorimetrici di oggetti sotto forma di nuvole di punti tridimensionali: ogni punto della superficie colpito dal raggio laser emesso dallo strumento viene tradotto in un punto digitale identificato numericamente da una terna di coordinate spaziali riferite al sistema di riferimento del laser scanner; il contestuale impiego di sensori ottici di immagine (CCD o CMOS), generalmente integrati nello strumento, fornisce al punto anche l'informazione cromatica, consistente in un'altra terna rappresentativa dei valori RGB. Una sola scansione non è sufficiente a rilevare l'intero edificio e risulta necessario fare stazione in vari punti di presa per eliminare possibili coni d'ombra, dovuti sia a limiti legati al campo visivo dello strumento sia alla presenza di oggetti interposti tra questo e le superfici da rilevare, sia alla eventuale complessità della geometria del manufatto. Per ottenere un corretto modello 3D è necessario, quindi, che ogni scansione rilevi almeno il 30% di superficie comune tra nuvole consecutive al fine di agevolare il loro allineamento in fase di post-processamento. Quest'ultima viene condotta con specifici software che, in modo controllato, individuano punti omologhi tra le varie scansioni oltre che elementi caratterizzati da geometrie note, come target piani o sferici.

Per il rilievo morfologico dell'intera chiesa è stato utilizzato un laser scanner Faro Focus 3D X 130 che, in condizioni ambientali ottimali, garantisce un range di scansione tra i 60 cm e i 130 m, una velocità di misurazione fino a 976.000 punti al secondo e un errore di linearità compreso tra i -2 e i +2 mm. Al fine di agevolare le successive fasi di elaborazione dati (registrazione delle nuvole), sono stati utilizzati target sferici (sei, collocati di volta in volta su superfici orizzontali) disposti a quote differenti e in zone intervisibili in più acquisizioni. Sono state eseguite in tutto 74 scansioni, 26 all'esterno e 48 all'interno della chiesa (Fig. 3), con risoluzioni variabili a seconda della

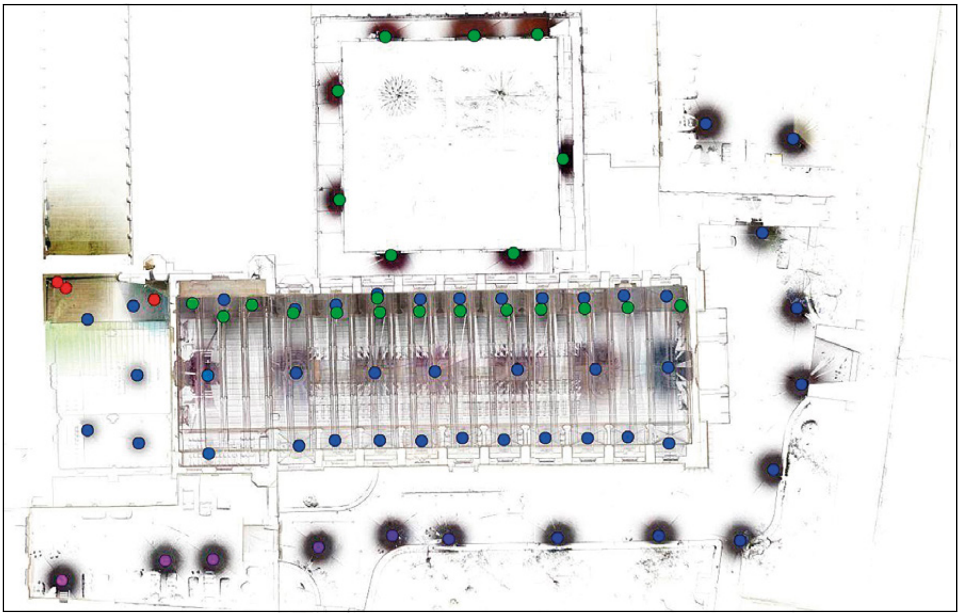

Fig. 3 – Indicazione planimetrica delle stazioni laser.

Fig. 4 – Modello a nuvola di punti del complesso religioso.

distanza del laser dalle superfici, in media pari a un punto battuto ogni 6 mm circa ad una distanza della sorgente emittente di 10 m dall'oggetto. Il modello infografico tridimensionale dell'intera chiesa (Fig. 4) è stato generato gestendo e applicando procedure software e algoritmi informatici di allineamento e

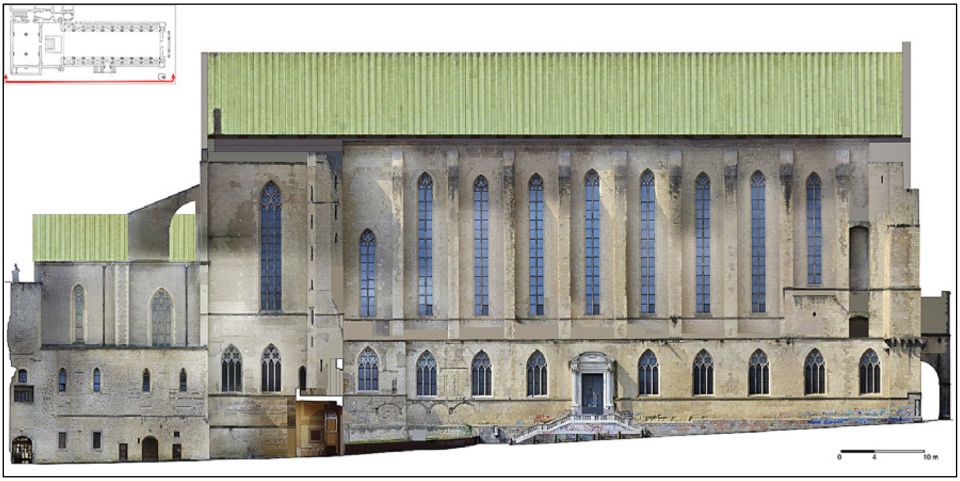

Fig. 5 – Ortoimmagine del fianco orientale.

filtraggio ormai consolidati e affidabili. La nuvola ottenuta, opportunamente decimata dei punti ridondanti e delle informazioni non utili ai fini della ricerca, è caratterizzata inoltre dai valori cromatici RGB acquisiti dal contestuale impiego del sensore ottico durante le scansioni. Tale parametro costituisce un importante arricchimento fornito dal modello 3D, soprattutto in ordine alla comprensione dei materiali che caratterizzano le superfici della chiesa.

La nuvola di punti, di volta in volta opportunamente trattata, ha consentito di visualizzare piante a più quote, sezioni trasversali e longitudinali, elevati interni ed esterni, dettagli architettonici e di effettuare misurazioni (lineari, superficiali e volumetriche) con elevata precisione (Fig. 5). In questo modo è stato possibile compiere una prima analisi critica direttamente sulla replica tridimensionale dell'edificio. L'accurato rilievo ha consentito di dare ragione anche dell'irregolarità costruttiva dell'edificio, che non deve essere considerata il "degrado" di un'idea progettuale dovuto all'imprecisione dell'accidentale realtà del cantiere, ma una peculiarità degli edifici medievali. La geometrizzazione e la rettificazione che si applicano di consueto nella rappresentazione grafica di strutture prive o quasi di pareti rettilinee o di rigorose simmetrie, infatti, possono essere fuorvianti per lo studio degli edifici storici. L'esatta digitalizzazione formale dell'architettura si rivela indispensabile per far emergere informazioni altrimenti non deducibili, come variazioni anche minute di allineamenti e di spessori murari, anomalie esistenti, o presunte tali, e aspetti cromatici delle superfici (Carbonara 2012). La loro individuazione e interpretazione sono fondamentali per l'analisi dell'architettura, della sua storia e della sua evoluzione. L'avanzamento rispetto alla tradizionale metodologia di ricerca è notevole sia per accuratezza del dato finale, sia per quantità e qualità di informazioni a disposizione.

4. The echoes of the stones: the geo-radar process

The remarkable potential of digital technologies is evident as an entire process of knowledge-making and knowledge-diffusion, from the initial steps of structuring data to the methodological concepts entailed in developing public-facing components. Through the transformational potential of digital tools, learning and the creation of historical narratives can take on forms that far surpass the traditional roles of pure research. In addition, this transformational potential extends to methods of archiving data as well as the re-use of the data for future projects. In an era in which the digital has blurred the distinctions between the real (physical) and the virtual (imaginative) worlds, it has become essential to differentiate between acts of perception, the quality of information (data), and methods of interpretation and representation. The qualitative variations between context and actual object of study have fused the processes of perception and representation as part of cognition. Digital technologies surpass the limits of traditional perception and permit the use of contextual information to extend far beyond the limits of conception, generating different levels of critical interpretation that are valid for various types of users.

With these premises as a point of departure, the relation between diagnostic tools, parametric software and systems of representation is now the foundation for our research method. To ensure an accurate and critically supported process in the production of our data, this requires co-ordination between all aspects of our research. In this project, evidence from Ground Penetrating Radar (GPR) was correlated with a laser survey, allowing us to locate the GPR evidence and providing precise co-ordination between the GPR data and the new measurements of the church.

Georadar is a non-invasive methodology used in geophysics for the study of the upper level of subsoil, and is based on the analysis of electromagnetic wave reflections generated by the resistance to invisible, sub-pavement elements. This technology uses short and continuous high frequency electromagnetic pulses generated by an antenna located near the surface. When the electromagnetic impulse intercepts the layer between two surface materials with different physical characteristics, one part of the incident energy is reflected and one part continues into a second layer. The portion of waves reflected off the first layer, returns to the surface and is detected by the receiving antenna. Conversely, the portion of energy which passes through this first layer, produces additional reflections on surfaces found deeper underground, thus providing a representation of a sequence of layers. This

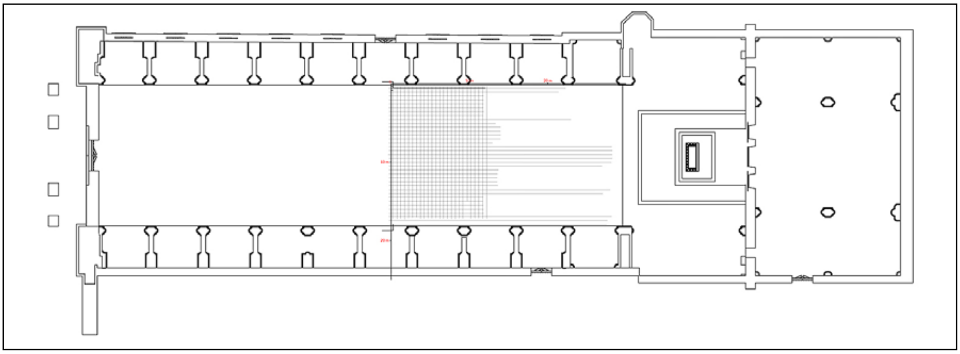

Fig. 6 – Location of acquisition paths.

method creates a sectional plan of the subsoil, with depth ranging from a few centimeters to several meters depending on the nature of the materials (subsoil, walls, objects) and the frequency of the antennas used. In the case of Sta. Chiara, an IDI HI-MOD instrument was employed, using K2FastWave software and a 200 MHz and 600 MHz frequency antenna, which obtained a depth investigation of 17.4 m and 8.5 m respectively. Significant preparatory work took place prior to the scanning process, such as the creation of a grid on the floor of the basilica. This corresponded with the survey area and was composed of a series of orthogonal lines arranged along the longitudinal and transversal axis of the nave at a distance of 50 cm apart. The point of origin of the acquisition path was identified according to the intersection between the nave and the side chapels in correspondence with the side entrance of the church. The sequence of scanning was conducted according to these parallel lines, firstly along the longitudinal axis (L axis) and then along the transversal axis (T axis). We recorded 24 transversal pathways across the entire width of the nave, and 36 longitudinal pathways within the area between the 6th and 8th chapels of the church (Fig. 6).

For the 14 longitudinal paths at the corridors between the stalls beyond the survey area, prospection was continued up to the steps of the presbytery, to check for additional evidence in the subsoil in front of the chapels near the altar. Radargram processing procedures were made using IDS Launch GRED HD software, which indicated discontinuities present under the pavement through geometric shapes in space, better characterized by the application of noise elimination filters. Subsequently, on each radargram, these were indicated as red lines, in correspondence with the diffraction plans of the signal. Proportional to the intensity of the return signal, and corresponding to more discontinuous plans, we used lines of different thickness, in order to better visualize possible underground elements within the sections. The

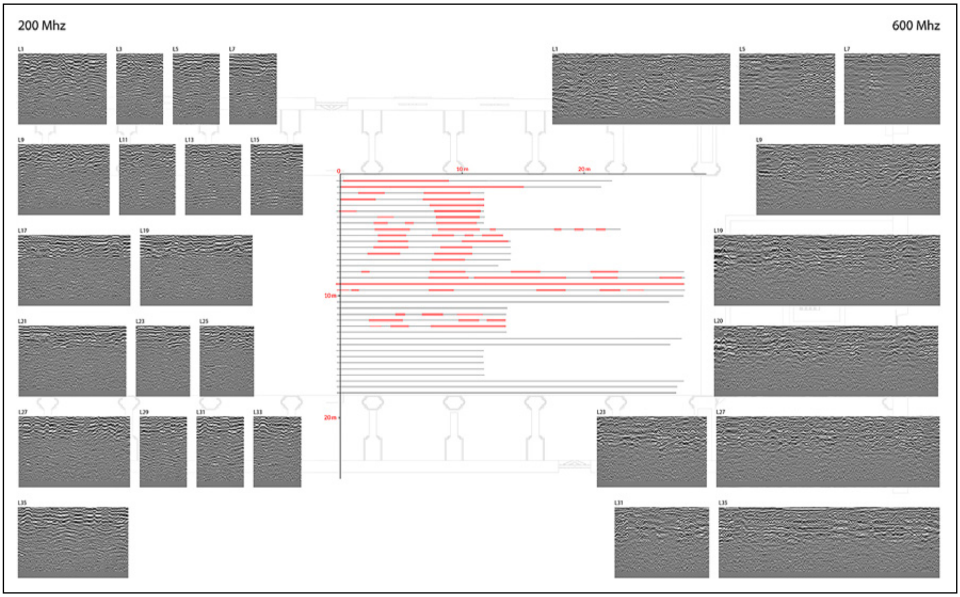

Fig. 7 – Representative framework of some radargrams.

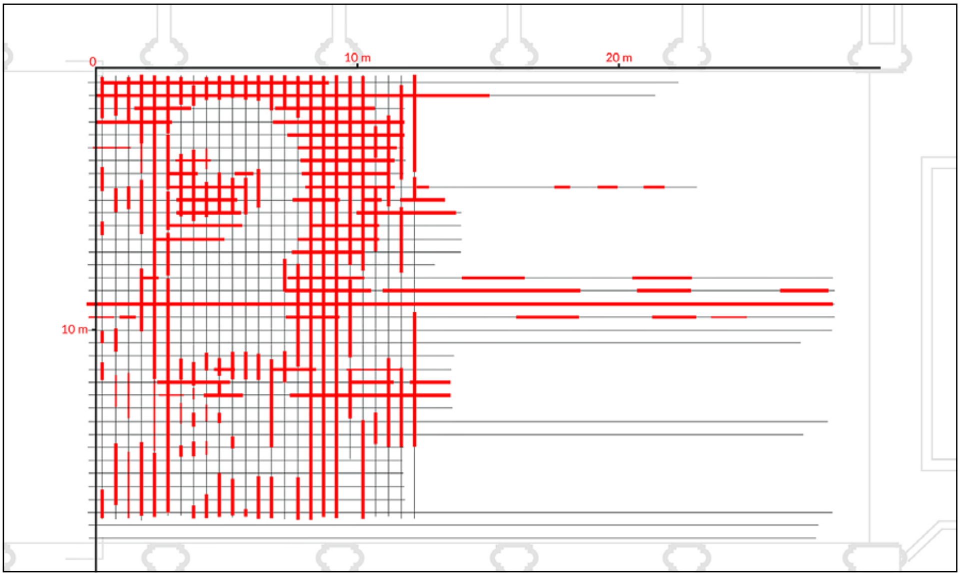

Fig. 8 – Map of the targets.

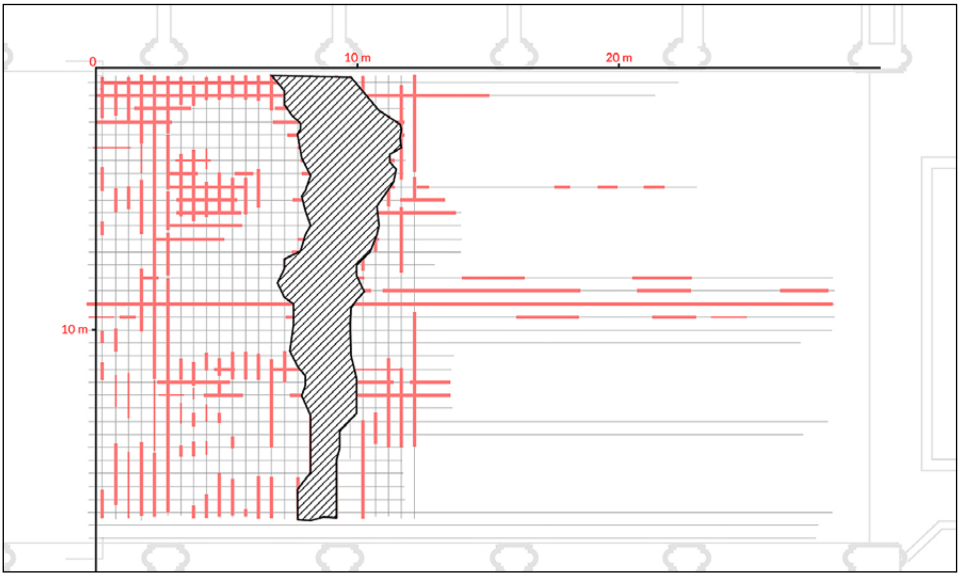

Fig. 9 – Map of areas with greater number of targets.

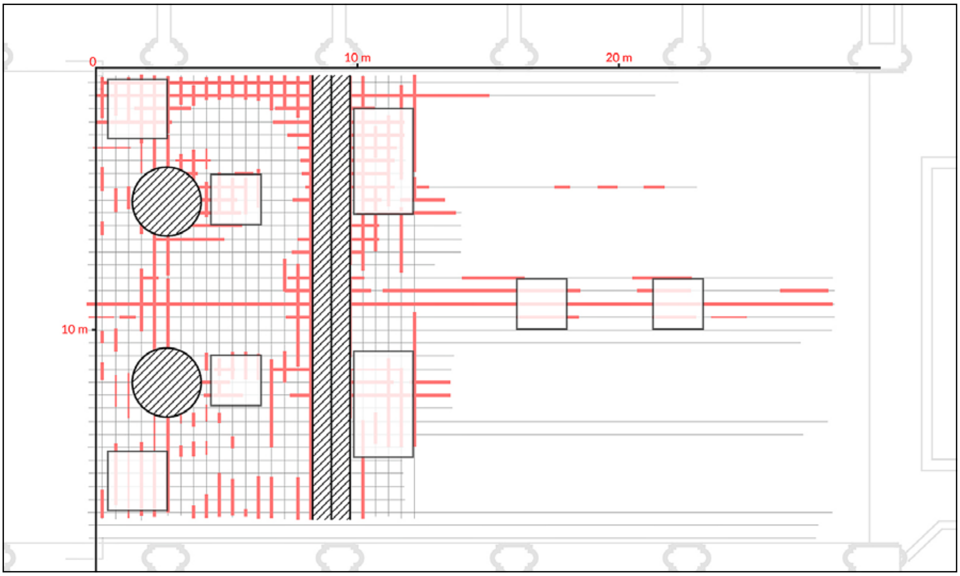

Fig. 10 – Characterization of areas with a greater number of targets.

122 radargrams, relative to their position in relation to the zero point of the grid, are displayed three-dimensionally in 3D Viewer-GRED HD in order to verify the coherence of possible masses through simultaneous interpolation of multiple sections (Fig. 7).

All the lines were then represented on plan and referred to the geometric survey of the church, producing a representative target map of the possible underground elements (Fig. 8).

Finally, based on the occurrences and proximity of targets in some areas, the return signals and the ripples of radargrams, were verified.

Using a map of targets on a CAD-drawn plan, we highlighted the areas with a higher and more intense concentration of underground disruptions (Fig. 9). With this evidence, the historians, working closely with the architects, were able to generate the hypothetical reconstruction (Fig. 10).

5. Making visible the "invisible": the reconstruction of the choir screen

The radar scans conducted in June 2016 covered a 16×6 m rectangular area between the mid-point of the 6th and 8th bays of the nave. As previously outlined by Repola (Section 4), a grid was formed on the surface of the pavement, providing a scanning path for the geo-radar instrument. These data points were then processed and subsequently mapped out on a plan of the basilica (Fig. 11): the black lines represent areas of concentrated material, most likely stone, which are located roughly 0.5 m underground. The grey lines represent sections where no noteworthy data points were deciphered.

The most significant form is discernible between the 7th and 8th bays of the church (disruption 1 – highlighted in dark grey). This is evidence of a substantial foundation that traverses the width of the nave, and roughly intersects with the base of the adjoining side chapels. Its diameter also closely resembles the width of the chapel pilasters (1 m). This provided compelling evidence for the presence of a considerable structure located above this traversing wall foundation. The second notable feature is the pair of disruptions in front of the traversing wall (disruption 2 - highlighted in light grey), significant both in form and positioning. The foundations not only stop between the 6th and 7th bays of the church, but also intersect the transverse wall at two equidistant points. This suggested some key findings about the screen:

1) it was probably a transversal wall which split the nave in two;
2) it was divided into three bays;
3) it was a deep structure – as deep as the side chapels;
4) it probably included two side chapels and a central opening towards the altar;
5) and it probably incorporated a vaulting system.

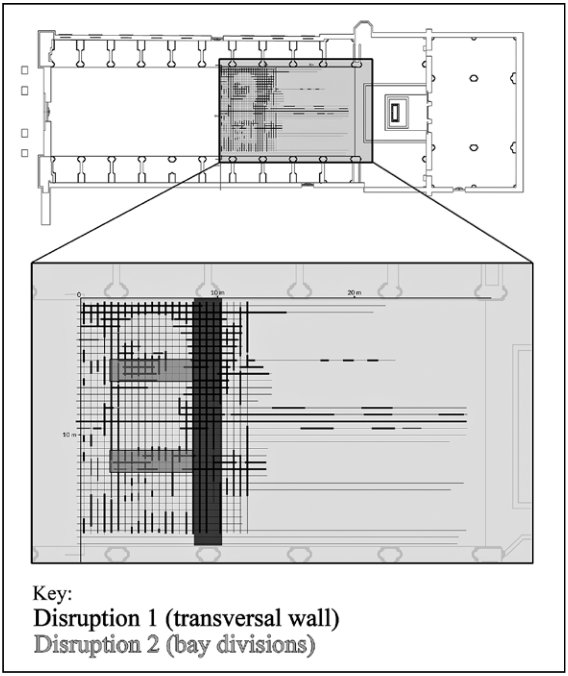

Fig. 11 – GPR data plotted on a church plan.

Based on this evidence, we created a preliminary hypothesis consisting of a deep, three-bay structure located between the 7th and 8th bays of the church (Fig. 1), a position that correlated with the two significant entrances into the church:

1) the door from the Franciscan cloister in the 9th bay of the western flank (positioned two bays behind the hypothetical screen);
2) the lay side entrance to the church in the 6th bay on the eastern flank (positioned a bay in front of the hypothetical screen).

Additional evidence visible in the church supported the creation of our hypothetical model. Thanks to the point cloud model, we acquired accurate measurements of the building that revealed a correlation between the dimensions of side chapels (around 6 m) and the width of the nave (around 18 m). This supports a hypothesis of a three-bay structure, as indicated by the geo-radar data. It also suggests that the nave chapels were consistent with the design of the screen, both structurally and visually. The resulting effect would have created a visual continuity within the church, with the pattern of arches producing a seamless transition between the choir screen and the side flanks of the nave.

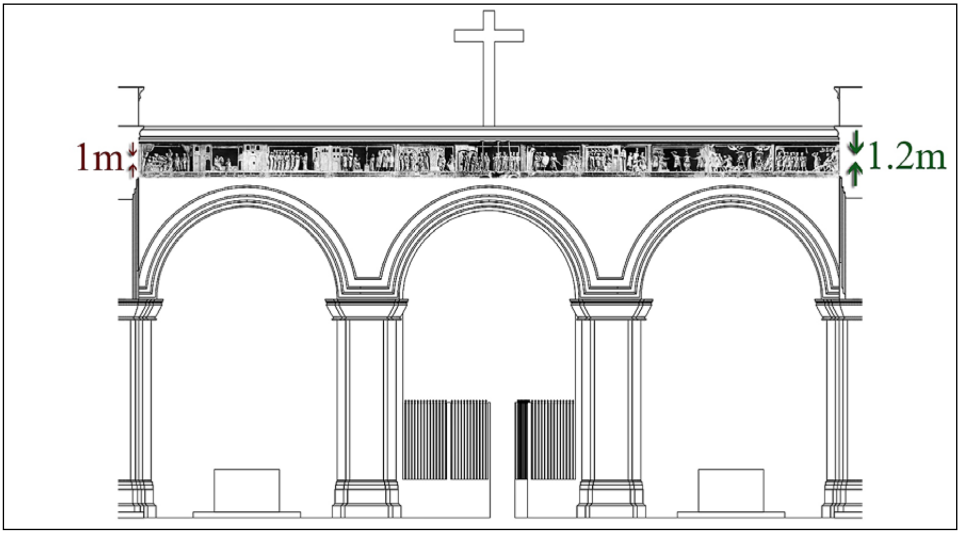

Fig. 12 – Hypothetical screen, measurements of Sta. Catherine reliefs (1 m) and apex of screen (1,2 m).

The GPR, laser, and modelling evidence indicate that the screen would have been an enormous masonry structure, measuring 10 m high to reach the level of the tribune. It would have incorporated two chapel spaces that probably contained important altars dedicated to Saints Francis and Claire (the founding saints of the Franciscan order). These chapels are currently located at the 7^{th} bay of the nave, a puzzling position because of their distance from the high altar. Our proposed choir screen provides a strong historical explanation for why the altars are located here: they were once positioned in the two side chapels of the screen for the veneration of the lay public, and rotated 90 degrees when the screen was destroyed.

The scale of the screen would have integrated well with the enormous, barn-like nave of Sta. Chiara. It would also have supported a wide upper tribune to bridge the gallery spaces over the side chapels. In the present configuration of the church these are completely separate from one another, accessible only through independent stairwells at opposite ends of the nave. However, in our model, a screen as tall and approximately as wide as the lateral chapels, provided access across the nave at gallery level, a space perhaps used for sermons, preaching and theatrical liturgical performances.

The proposed height also provides a possible location for the relief panels depicting scenes from the life of Sta. Catherine (Fig. 12). The height of the screen could have incorporated the 1 m tall horizontal relief between the apex of the arches and upper cornice. The relief (located either on the

Fig. 13 – Counter-facade prior to 1943 church bombing showing Sta. Catherine reliefs on a structure similar to the hypothetical screen.

lay or clerical side) would thus have become the crowning component of the screen; a magnificent decorative feature that differentiated the screen and its arches from the rest of the church.

Our hypothesis that the relief was positioned in the upper part of the screen is possibly confirmed by pre-war photographs that show the reliefs on a gallery attached to the counter façade, an architectural structure similar to our model (Fig. 13). This structure was used as a liturgical choir for the Franciscans after the destruction of the original choir screen in the Counter-Reformation. The similarities of these structures is compelling: in addition to the mirrored location of the Sta. Catherine reliefs, the balcony incorporated three bays of comparable dimensions and vaults supported by two free standing piers.

Fig. 14 – View of hypothetical screen (left), hypothetical screen as a visual frame for Robert of Anjou's tomb (right).

The creation of a model of the screen within the church transforms the spatial dynamic of the interior space (Fig. 14). It interrupts the rhythm of the nave chapels and becomes a focal point of the interior. The height of the vaulted chapels and high springing arches neither inhibit the visual thrust towards the high altar nor impede a view of the monumental tomb of Robert of Anjou behind the altar. To the contrary, the alternating open and closed arches enhance the dramatic visual effect of the tomb by focusing attention on the open central axis. The screen therefore acts simultaneously as both a facilitator and as an inhibitor of visual access, an effect that incites a desire for what lies beyond by governing and controlling the visual contact with the sacred.

In addition to its visual impact, the screen probably had a significant liturgical function, acting as a critical site for promoting lay spirituality. While the GPR data revealed traces of fragments of tombs under the pavement, altar dedications, especially by prominent lay patrons, attest to the importance of this area within the church. Most notable are the chapels associated with important individuals and noble families (Rullo 2014, 377). For instance, the tomb of Gagliardo Primario (d. 1348), the master mason attributed with overseeing the construction of Sta. Chiara, was located in the 6th bay on the south side. On the opposite side was the chapel shared by the Gianvilla and

Sanseverino families, noted for their devotion to the Franciscan order and for their close ties to the Angevin family (Bruzelius 2004, 177-180).

Equally significant is the presence of a coat of arms attributed to the Mansella family on the first two panels of the Sta. Catherine reliefs. These are located within a series of circular shapes in the lower region of the panels and serve as a boundary for the accompanying text for each episode. Similar circles (now, however, devoid of any heraldry) are visible along the length of the entire set of twelve panels, although it is not clear whether they contained the Mansella coat of arms or those of other families. This heraldry also correlates to the location of the Mansella chapel in the first bay beyond the screen on the left side, as well as documentary evidence of Tommaso Mansella's tomb being located in the church.

GPR technology has enabled the recovery of a crucial element of this monumental church. The evidence changes our perception of how the building would have functioned and been experienced in its original context. The geo-radar data permitted the creation of a hypothetical 3D model of the screen, making tangible its profound visual and liturgical impact. This "rediscovery" now offers the opportunity to explore new aspects at Sta. Chiara as well as re-examine pre-existing research in a new light.

6. Dall'indagine storica alla creazione di un modello tridimensionale interoperabile

La ricostruzione del passato da parte degli storici si è sempre basata su fonti materiali, scritte, orali; negli ultimi anni però, con lo sviluppo delle nuove tecnologie, sono subentrati ulteriori strumenti in grado di fornire delle risposte ai molti quesiti che la storia pone. La sfida è stata prendere in considerazione strumenti informatici e tecnologici e andare alla ricerca di un'interoperabilità tra di essi che permettesse di dialogare con la ricerca storica all'interno dell'arco temporale di tre mesi.

In particolare la scelta di utilizzare un software BIM di modellazione parametrica, in questo caso Revit, ha permesso di analizzare in tempi brevi le varie ipotesi relative alla forma e alla dimensione dell'ipotetico tramezzo e ha dato la possibilità di esplorare il mondo della realtà aumentata e virtuale, al fine di trovare maggiori conferme della ricerca svolta e di avere uno strumento di conoscenza fruibile a un pubblico più vasto. Sovrapponendo i dati della chiesa di Santa Chiara provenienti da laser scanner, si è potuto ricostruire all'interno di un software di modellazione BIM il manufatto con le dimensioni corrette, e non basate su vecchi rilievi. Si è scelto di optare per questo strumento poiché permette la creazione di oggetti parametrici facilmente modificabili attraverso la definizione dei parametri ad essi associati al fine di adattarsi al meglio alle fasi dello sviluppo della ricerca storica. Inoltre è stato possibile

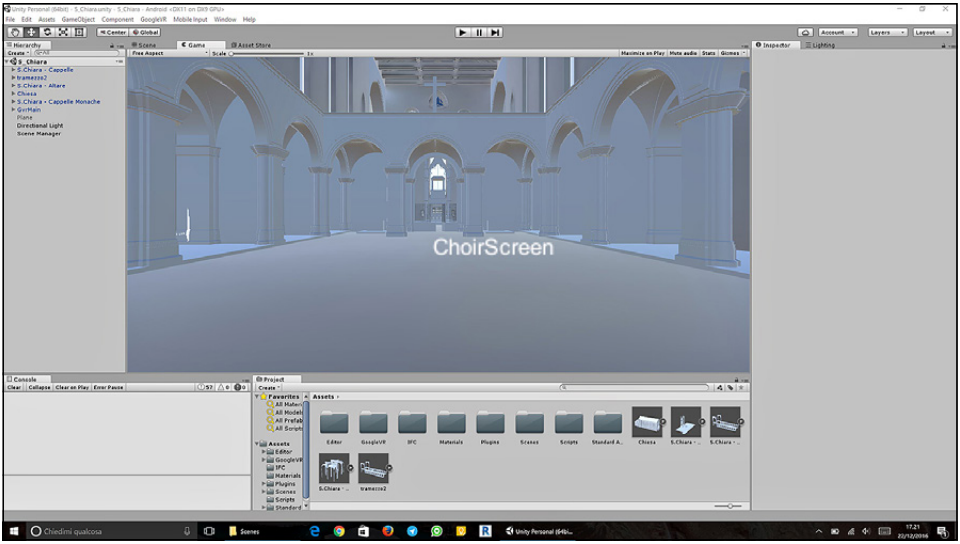

Fig. 15 – Il modello della chiesa di Santa Chiara inserita all'interno del motore grafico Unity con la sua interfaccia.

mantenere un costante controllo della modellazione dello spazio attraverso l'utilizzo di viste 3D all'interno del modello. L'uso di uno strumento BIM ha permesso anche di elaborare un catalogo di tipologie dei vari elementi come monofore, bifore e trifore, grazie alla possibilità di modellare i diversi tipi attribuendo loro caratteristiche geometriche e non.

La modellazione attraverso software BIM della chiesa di Santa Chiara e del suo ipotetico tramezzo è stata effettuata di pari passo con il progredire della ricerca storica sul manufatto, ma non si è limitata a sviluppare un modello che potesse corroborare le ipotesi storiche. Infatti, fin dall'inizio, e da qui la scelta di questo tipo di software, l'intenzione è stata quella di importare il modello all'interno dell'ambiente della realtà virtuale. La possibilità di esportare dati grafici e informazioni non geometriche in un motore grafico come Unity (Fig. 15) è stata fondamentale per avere un modello interattivo della chiesa di Santa Chiara. Oltre alla possibilità di prendere visione degli spazi architettonici attraverso l'uso di mouse e tastiera, si è potuto osservare il manufatto con o senza l'ipotetico tramezzo e interagire con gli elementi architettonici per conoscere le informazioni ad essi associati nella fase di modellazione.

La fase finale del progetto consiste nel trasferimento dell'applicazione creata in Unity a partire dal modello BIM all'interno del DiVE, uno spazio immersivo virtuale presente nei laboratori della Duke University che fa uso della tecnologia CAVE (Cave Automatic Virtual Environiment). Tale tecnologia è costituita da

Fig. 16 – Il modello della chiesa di Santa Chiara all'interno del DiVE presso i laboratori della Duke University.

proiettori puntati sulle sei pareti che vanno a comporre una stanza a forma di cubo, una sorta di cinema 3D dove è possibile muoversi al suo interno (Fig. 16).

Proprio al fine di garantire una maggiore fruibilità del modello sviluppato e nell'idea di far conoscere questo progetto anche a tutti quei visitatori che ogni giorno affollano la chiesa di Santa Chiara, si è voluto cercare di riproporre in scala ridotta l'esperienza immersiva. Nello specifico è stata sviluppata un'applicazione per smartphone Android che, attraverso un semplice ed economico dispositivo come il Cardboard, un visore di cartoncino rigido dotato di due lenti focali e un magnete, combinato a un cellulare, permettesse di far arrivare l'esperienza della realtà virtuale a più soggetti, indossandolo semplicemente come un paio di occhiali. A partire dal modello tridimensionale importato nell'ambiente Unity è possibile trasformare il proprio progetto in VR-ready attraverso l'utilizzo di un pacchetto preconfezionato scaricabile dal sito di Google Cardboard. La codifica all'interno di Unity permette all'applicazione di riconoscere i movimenti della testa in modo che la vista all'interno del visore possa seguire i movimenti dell'utilizzatore. È stata poi aggiunta la possibilità di interagire direttamente con il modello che permette, attraverso l'utilizzo del tasto capacitivo, di passare dalla vista con l'ipotesi del tramezzo di Santa Chiara a quella della chiesa odierna.

Lo studio delle possibili applicazioni delle nuove tecnologie a servizio dell'indagine ha portato successivamente allo sviluppo di una applicazione, sempre per Android, che facesse uso della realtà aumentata. Sempre partendo dall'ambiente Unity e integrando all'interno del software il pacchetto VUFORIA, è stato possibile creare un'applicazione che permettesse, attraverso l'utilizzo della fotocamera dello smartphone, di riconoscere l'immagine della pianta di Santa Chiara e di sovrapporre a tale immagine il modello tridimensionale della chiesa: in questo modo, ruotando e spostando lo smartphone attorno all'immagine, è possibile esplorare il modello nello spazio reale attraverso il filtro dello schermo del cellulare. Il risultato ottenuto è prova di come sia possibile avere una modello che unisca dati geometrici provenienti da laser scanner con dati storici basati su ipotesi di forme e dimensioni di elementi non più esistenti e come esso possa essere strumento di valorizzazione di un manufatto storico attraverso la realtà virtuale e aumentata. L'uso di un software BIM ha permesso in una prima fase di aiutare gli storici nella elaborazione di informazioni tecniche e di dati scientifici, e in una seconda fase ha permesso, grazie all'interoperabilità di questo strumento BIM, la visualizzazione del manufatto con l'ipotetico tramezzo all'interno della realtà virtuale per verificare se le ipotesi avanzate potessero essere conformi o meno con l'esistente.

Il lavoro svolto è in realtà un progetto in continuo divenire, che ha come fine ultimo quello della divulgazione della ricerca storica anche attraverso mezzi non convenzionali quali sono appunto la realtà aumentata e la realtà virtuale. In conclusione la scelta iniziale di preferire un software BIM ad altri di semplice modellazione è proprio dovuta al fatto che la sua natura parametrica e la sua interoperabilità permette di sviluppare al meglio un progetto come questo che è e sarà oggetto di continue revisioni ed evoluzioni, attraverso un processo dinamico che si dirama in molteplici direzioni.

7. Conclusion: technology as a form of historical reasoning

The development of models and visualizations is an important component of the intellectual process. In our study, the creation of a model based on evidence derived from geo-radar and a laser scan generated a convincing hypothesis for the choir screen of Sta. Chiara. The model, in turn, stimulates numerous reflections, some of which emerged most powerfully when it was experienced in a virtual full-scale immersion environment. At this point the research team became aware of several topics for further reflection and research:

1) the wide central gallery of the choir screen united the two sides of the church, creating a new raised area for liturgical and state ceremony;
2) the central opening of the choir screen served as "visual funnel" that focused attention on the tomb of Robert the Wise at the far end of the church;
3) the experience of the dimensions of Robert's tomb in relation to the choir screen suggests that the height of the tomb was perhaps conceived in relation to the pre-existing *tramezzo*;
4) the choir screen may have been incorporated into state ceremonies, such as coronations. Thus the reader may be able to imagine that prior to its partial destruction in 1943, the image of King Robert enthroned with orb and scepter in the highest part of the tomb existed in a dialectical relationship to the choir screen and as the locus of the scenography of royal ritual and possibly coronation (Figs. 1, 14).

Although the model, as well as any conclusions, remain of course hypothetical, and may change with the discovery of new evidence (if such can be found), identification of the location and the hypothetical reconstruction present important additions to knowledge about this major building. The 3D model not only permits preliminary reflections on the spatial, liturgical and social organization of the interior of the church, but also serves as an experimental setting for fragments of sculpture, including the Sta. Catherine relief. The research team hopes that the model may become a point of departure for further discussion, debate, and experimentation, as well as a stimulus for new research by others.

It is important to conclude with a few brief statements on the benefits of new technologies and Digital Humanities. In our project, technology generated new knowledge (the geo-radar and laser scans) that allowed the development of a 3D model and permitted, indeed *incited*, new reflections on the spatial organization of the church, a topic that includes the sites of special veneration, and possible new research on patronage and burials.

There are, in addition, several distinct benefits to the application of modern visualization technology to historical questions. Models are of course used in many disciplines (medicine, economics, finance, and engineering, to name only a few) to achieve insights that would not otherwise be possible. The benefits of models apply every bit as much to art history and to the other humanities, as they enable us to imagine a contingent, or possible, past, one that no longer exists, one that may have conditioned the position and character of what does remain.

The use of technology requires the collaboration of experts in a variety of disciplines, and with different types of expertise, from that of the historian. In the case of our project, no single individual working alone could have accomplished what was achieved as a team. This kind of work, deeply embedded within disciplinary expertise, yet at the same time using technology to expand research questions, is the wave of the future for certain kinds of problems. Technology and its benefits drive us to work together, and this will in time change notions of authorship and individual research.

Finally, technology used in the history of art and material culture can engage the public through the creation of publicly accessible websites and Apps. In a world that often seems to ignore the humanistic disciplines, public-facing digital projects in the forms of models, animations, and apps, offers new means of public involvement in historical research.

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Caroline Bruzelius
Department of Art, Art History & Visual Studies
Duke University, North Carolina
c.bruzelius@duke.edu

Andrea Giordano, Andrea Basso, Elisa Castagna
Dipartimento di Ingegneria civile, edile e ambientale
Università degli Studi di Padova
andrea.giordano@unipd.it, andrea.basso.13@studenti.unipd.it,
elisa.castagna.1@studenti.unipd.it

Lucas Giles
Cambridge University, UK
lcogiles@gmail.com

Leopoldo Repola
Scienza Nuova - CEM
Università degli Studi Suor Orsola Benincasa, Napoli
repolaleopoldo@gmail.com

Emanuela De Feo
Dipartimento di ingegneria civile
Università degli Studi di Salerno
edefeo@unisa.it

REFERENCES

Apollonio F.I. 2010, *La modellazione digitale*, in G. Braghieri (ed.), *Architettura 38. Aldo Rossi. Due progetti*, Bologna, CLUEB, 13-17.

Bertocci S., Parrinello S. 2015, *Digital Survey and Documentation of the Archaeological and Architectural Sities*, Firenze, Edifir.

Bianchini C. 2012, *Rilievo e metodo scientifico*, in L. Carlevaris, M. Filippa (eds.), *Elogio della teoria. Identità delle discipline del disegno e del rilievo*, Roma, Gangemi Editore, 391-400.

Bruzelius C. 1992, *Hearing is believing: Clarissan architecture, ca. 1213-1340*, «Gesta», 31, 2, 83-91.

Bruzelius C. 2004, *The Stones of Naples: Church Building in Angevin Italy 1266-1343,* New Haven-London, Yale University Press.

Bruzelius C. 2014, *Preaching, Building, and Burying. Friars in the Medieval City*, New Haven-London, Yale University Press.

Carbonara G. 2012, *Disegno e documentazione per il restauro: un impegno interdisciplinare*, «Disegnare CON», 5, 10, 9-20.

Clini P. 2008, *Il rilievo dell'architettura, metodi, tecniche ed esperienze*, Firenze, Alinea Editrice.

D'Auria S., De Feo E. 2017, *La chiesa di Sant'Eligio al Mercato a Napoli. Storia, indagini documentarie, rilievi, analisi critica*, Salerno, CUA.

Docci M., Gaiani M., Migliari R. 2001, *Una nuova cultura per il rilevamento*, «Disegnare Idee Immagini», 23, 37-46.

D'Ovido S. 2015, *Osservazioni sulla struttura e l'iconografia della tomba di re Roberto d'Angiò in Santa Chiara a Napoli*, «Hortus Artius Medievalum», 21, 275-312.

Jung J.E. 2000, *Beyond the barrier: The unifying role of the choir screen in Gothic churches*, «The Art Bulletin», 82, 4, 622-657.

Jung J.E. 2012, *The Gothic Screen: Space, Sculpture, and Community in the Cathedrals of France and Germany, ca. 1200-1400*, Cambridge, Cambridge University Press.

Rullo A. 2014, *Patronato laico e chiese mendicanti a Napoli: i casi di S. Chiara e S. Lorenzo Maggiore*, in F. Aceto, S. D'Ovidio, E. Scirocco (eds.), *La Chiesa e il Convento di Santa Chiara. Commitenza artistica vita religiosa e progettualità politica nella Napoli di Roberto d'Angiò e Sancia di Maiorca. Atti del Convegno (Napoli 2012)*, Battipaglia, Carlone & Laveglia, 361-384.

Vitolo P. 2014, «Ecce rex vester». *Christiformitas e spazio liturgico*, in F. Aceto, S. D'Ovidio, E. Scirocco (eds.), *La Chiesa e il Convento di Santa Chiara. Commitenza artistica vita religiosa e progettualità politica nella Napoli di Roberto d'Angiò e Sancia di Maiorca. Atti del Convegno (Napoli 2012)*, Battipaglia, Carlone & Laveglia, 227-274.

ABSTRACT

This essay describes the use of Ground-Penetrating Radar (GPR) to establish the location and dimensions of the destroyed choir screen at the church of Sta. Chiara in Naples. On the basis of this new evidence, inserted within a laser scan of the church that provides its exact dimensions, the authors have been able to reconstruct a hypothetical model of the screen's original appearance. The model, if correct, suggests that the choir screen not only contained altars to Saints Francis and Claire (now present in the flanking side chapels), but also that it supported an upper gallery that connected the wide tribunes on either side of the nave. It is hoped that this hypothetical model will stimulate new research on the décor, liturgy, and ceremonial functions of this important Neapolitan church.