Reconnecting Past and Present with Old Photos. Reconstruction of the Church of the Stimmate in Palermo

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Abstract

Perspective restitution has rarely been used in researches aiming at the reconstruction of past monuments and urban contexts from old photos, due to the approximation that affected the process of restitution with pens and rulers. Digital drawing tools decidedly reduce the approximation and allow a straight 3D reconstruction of buildings displayed in a single photographic image. The chosen case study is the church of the Stimmate in Palermo, demolished at the end of the 19th century for the construction of the Massimo theater, the lyric theatre of Palermo. The church was decorated with valuable stucco sculptures that were saved from demolition and are now exhibited at the oratory of the Bianchi in Palermo.
Three low-quality photos show the stucco sculptures in their original arrangement around two facing niches of the nave, close to the entrance.
Perspective restitution and the survey of the sculptures allowed the 3D reconstruction of the niches with the stucco sculptures. Further images and surveys led to the reconstruction of the façade of the church with the annexed monastery and of a nearby city gate that was demolished at the same time.

Keywords: church of the Stimmate, Massimo theater, perspective restitution, 3D reconstruction, equirectangular images.

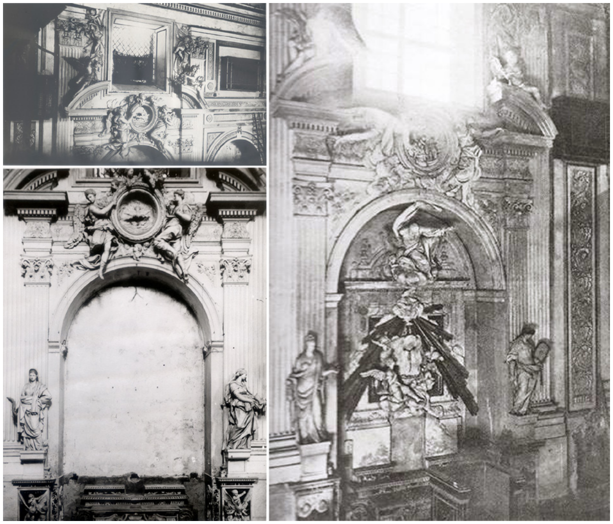
Introduction

Perspective restitution, driven with digital drawing tools, allows to model, straightly in 3D space, buildings that are displayed in a single photographic image. This technique therefore allows the reconstruction, from old photos of buildings and urban sites which were destroyed or modified by war events, natural disasters or urban renewal programs.
In 1864 the municipality of Palermo resolved to build an opera house; the new theater would be sited in an area at the northern edge of the walled town, close to Maqueda street, one of the main axes of the historic city center.
Along the axis of Maqueda street, the demolition program includes the homonymous urban gate, the church of the Stimmate and the annexed monastery.
The initiative of the municipality aimed at a twofold purpose: provide the city with an opera house, according to the use of the time; open the historic city center towards the northern urban expansion, through the partial demolition of the city walls.
The municipality promoted an international design competition; the jury, composed by Gottfried Semper and two eminent delegates of the municipality, in 1868 bestowed the victory to the proposal of Giovan Battista Filippo Basile. In 1874 Basile draws up a *piano di massima della ubicazione del nuovo Teatro* (rough plan to locate the new theater) that displays the location of the new theater in the extant urban context and the perimeter of the buildings that should be destroyed: together with the church of

the Stimmate, the annexed monastery and the urban gate Maqueda, the new theater demanded the demolition of the church of San Giuliano, of the annexed monastery, of many residential blocks.
Unluckily the *piano* does not display a graphic scale, nor we could access the original document; this is why, in order to extract the overall dimension of the church of the Stimmate, the *piano* has been scaled with reference to a 1984 map of the historic city center of Palermo and to the laser scanning survey of the area; the comparison showed the accuracy of Basile's survey (fig. 1).
The church of the Stimmate, built at the start of the XVII century, was, like most of the churches annexed to female monasteries, a hall church; the nave was delimited by walls with shallow niches and terminated in a rectangular apse. The facing niches placed near the entrance were decorated with stucco statues sculpted by Giacomo Serpotta, a prominent artist in the late-baroque Sicilian cultural context.
The memory of the original location of the statues in the church is kept by three low quality images, published in books that do not provide any suggestion supporting the retrieval of the original photos; it is known that these photos were taken in 1890, soon before the demolition of the church; the subject of the photos focus are the decorated niches and no other part of the nave is displayed (fig. 2).
The photos were probably commissioned to document the original position of stuccoes, before their removal and relocation in a hall of the archaeological museum of Palermo. In the 90s, the stuccoes were restored and moved to a large hall in the oratory of the Bianchi, a peripheral location of the regional Sicilian gallery of Palazzo Abatellis; the limited height of the hall prevented the exhibition of the sculptural groups according to their original arrangement.
The reconstruction of the façade of the church could not rely on better documentary sources; the façade appears in an anonymous painting dated from the early eighteenth century, which depicts several monuments of Palermo sited along the route of the religious procession of Santa Rosalia.
In the painting the façade of a church with the inscription 'Badia Delli Stimmati' shows the typical layout of a three naves church, therefore incompatible with the actual church of the Stimmate. Nonetheless, some elements could be reused, since they appear in the photo where the façade is displayed.

Fig. 1. The Piano of Basile dated 1890.

Fig. 2. Period photos of the niches with stucco sculptures, taken in 1890, soon before the demolition.



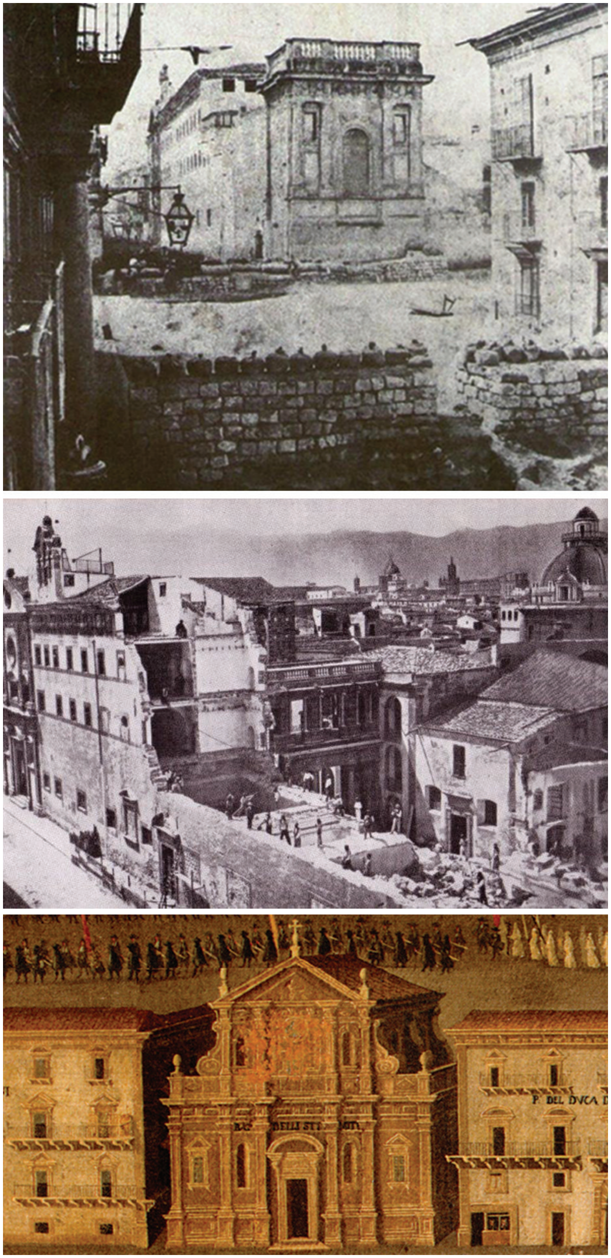


Fig. 3. The documentary sources used for the reconstruction of the façade and the urban context. From top: a photo of Maqueda gate dated 1860; a photo that displays the demolition of the monastery and, foreshortened, the façade of the church; a detail from Il Quadro.

The photo, taken from the roof of a building facing Maqueda street, focuses the demolition of the monastery; the half part of the façade of the church appears foreshortened at the left edge of the image (fig. 3).
Due to the unavailability of adequate documentation, surveys and drawings, the photos are the sole resources that witness the arrangement and the architectural quality of the church and its surroundings before the construction of the theater.
That's why the church of the Stimmate is an excellent case study to test the potential of digital perspective restitution for the reconstruction of buildings and urban sites from period photos.
The first step of the reconstruction process aimed at the virtual re-location of the surveyed sculptures in their original arrangement around the niches at the sides of the nave.

State of the art

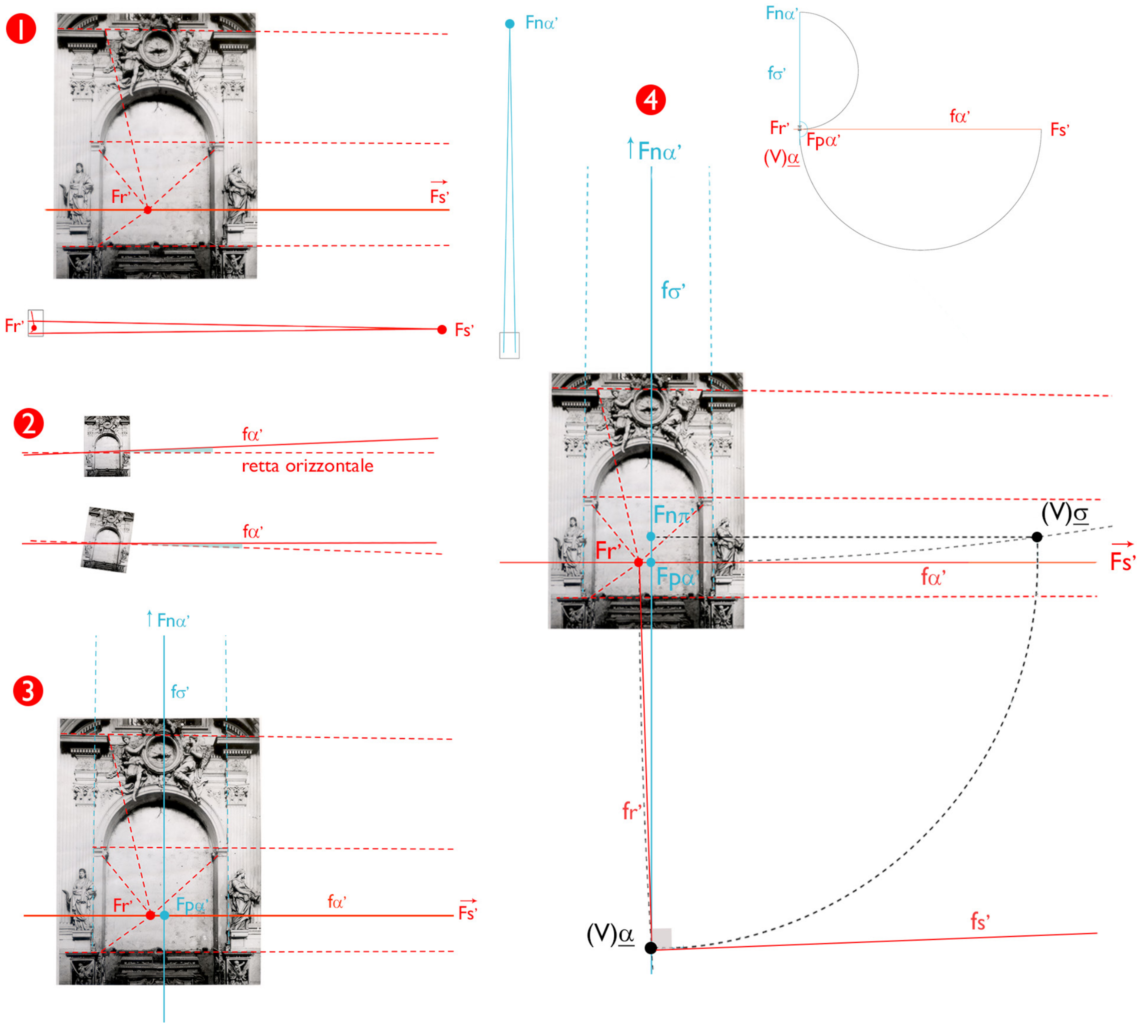
Perspective restitution is the inverse solution of perspective and hence belongs by right to the corpus of descriptive geometry. Perspective restitution from photos belongs, at the same time, to photogrammetry, since its output is the dimensional restitution of the portrayed buildings.
Nonetheless, due to the approximation that affected perspective restitution with pens and rulers, the technique was rarely used both as a surveying tool [Docci 1994, p. 253] and for the reconstruction of demolished buildings from old photos.
The limited size of printed photos and the occurrence of vanishing points located at a great distance from the image, made internal orientation difficult and approximate; the outputs of perspective restitution were 2D figures that were revolved onto the pictorial plane, thus missing the potential of a direct link between the point of view, the image and the object.
These limitations account for the marginal role played by perspective restitution in processes aiming at the conjectural reconstruction of building and urban sites.
New digital drawing tools offer today the opportunity to enhance this old technique, improving its accuracy and effectiveness.

Manuals of descriptive geometry almost ignore perspective restitution; a small but precious book published at the end of the '70s focused perspective restitution with traditional tools, providing a good gallery of examples and restitution strategies that could be used in the restitution from photos as well [Fano 1979].

Fig. 4. Sculptures above the niche on the left side in the nave of the church of the Stimmate: photo and laser scanning survey.

At the end of the '90s scholars in computer engineering experimented automated processes for line extraction, vanishing point identification, intrinsic and absolute orientation through the combination [Van den Heuel 1998] of line-photogrammetric measurement and geometric constraints, i.e. coplanarity, parallelism, orthogonality and so on. The purpose of most studies was the automated restitution of a 3D textured model from a single image. At a later stage tentative software packages were developed and discussed in publications [Arslan 2014], but no evidence of their use in further researches has resulted.
Architects and scholars in architectural representation perceived that digital drawing could enhance perspective restitution. A book dedicated at this subject [Paris 2000] reports, for the first time, a detailed gallery of methods and strategies for perspective restitution discussed in historic treatises on perspective. The second part of the book focuses the use of digital drawing tools for the restitution of fronts and plans from photographs.
The feasibility of a convenient combination between descriptive geometry and digital drawing leads to the proposal of a solution [Fallavolita et al. 2013] that uses 3D modeling tools for the internal orientation of a photographic image and for the restitution of demolished buildings.
Later studies use descriptive geometry to calculate photos orientation [Dzwierzynska 2017], but no use of 3D tools is proposed or discussed [Ramon-Constanti, Gomez 2020], thus missing the opportunity, provided by digital tools, to build up 3D models straightly from a single photo.
Digital perspective restitution can restitute even the furthest vanishing points; absolute orientation is calculated in 3D space; 3D models can be built using interpretation lines and planes; the correspondence between 3D reconstructions and their photographic image can be visually checked posing a virtual camera on the point of view.
Perspective restitution, like any photogrammetric technique, cannot restitute measures, but only angles and proportions; in order to build measurable 3D models, it is mandatory to scale the perspective model; to this purpose it is enough the measure of a segment displayed in the image.
Such information can be extracted when existing and surveyable elements are displayed in the photo; if such elements are surveyed with laser scanning or SfM photogrammetric tools, the quality of the intrinsic and absolute orientation of the image can be checked by the comparison between the point cloud or the mesh model of the object and its photographic image.

Fig. 5. Interior orientation of the photo of the niche.

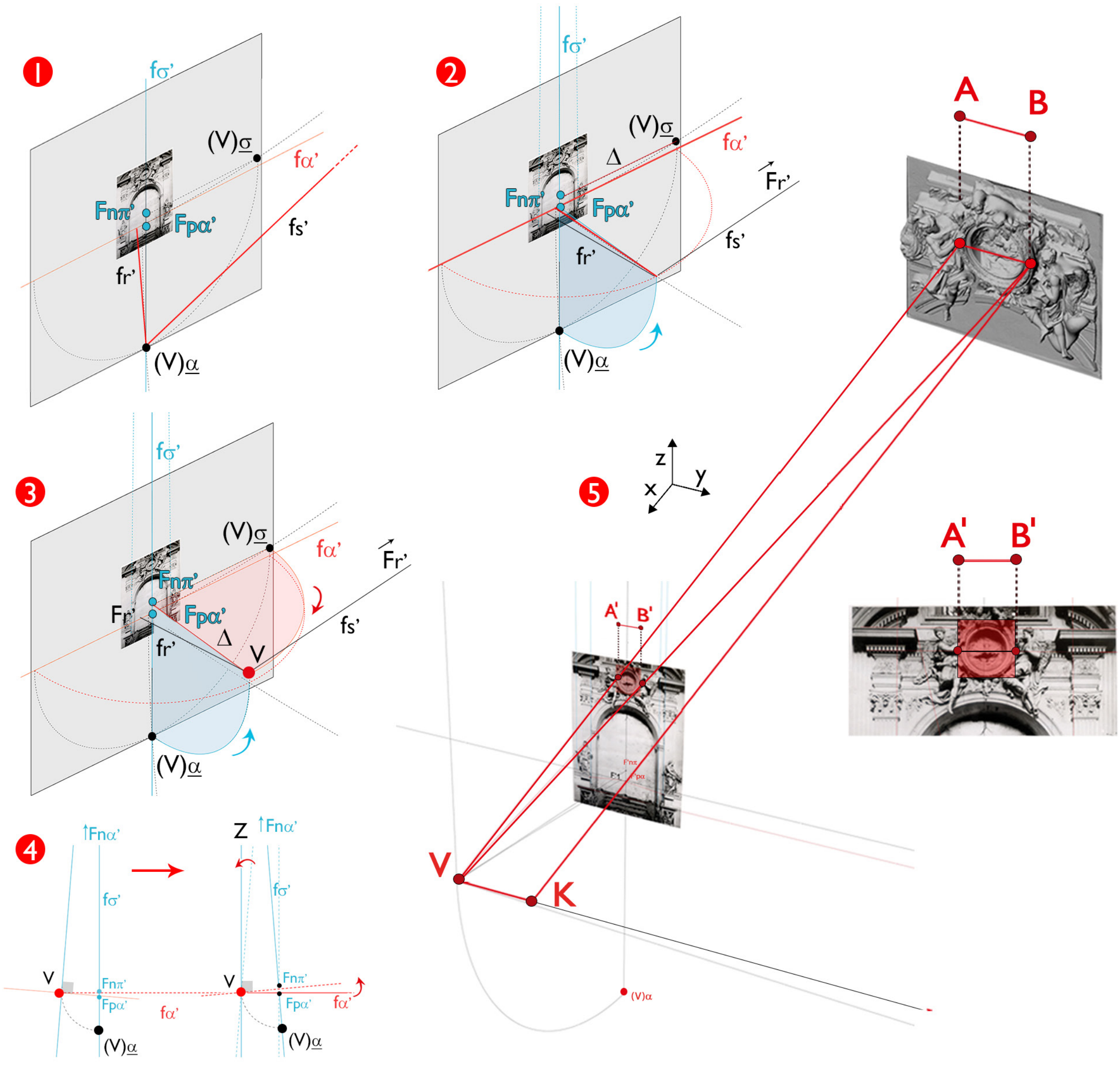


When no extant building appears in the image, period maps can provide angular information for intrinsic orientation and dimensional data for absolute orientation.
In this study both methods have been used.

The restitution process

The process aiming at the relocation of Serpotta's stuccoes in their original arrangement inside the church of the Stimmate started with the laser scanning survey of the statues in their present location at the oratory of the Bianchi (fig. 4) and ended, through perspective restitution, with the construction of a hybrid model that combines NURBS surfaces of architectural elements and meshes of the statues.
The second step aimed at the reconstruction of the church façade and of its surroundings, up to Maqueda gate; in this step perspective restitution was compared with metric information extracted from the plan of Basile.
In this study stuccoes are the only 'measurable' parts of the demolished church and therefore perspective restitution assumed these models as reference elements; mesh models were all rotated around z-axis, to make their backwards parallel to xz or -xz planes in the digital scene; this way x-axis acted as the longitudinal axis of symmetry of the reconstructed church [1].
It is well known that the orientation of a photo is split into intrinsic and absolute orientation.
Intrinsic orientation calculates the position of the point of view V through the graphic construction of the principal point and the principal distance; when the image displays elements of a 3D scene linked by mutual constraints, intrinsic orientation refers the direction of the 'principal' ray to the perspective restitution framework.
Absolute orientation refers the point of view and the direction of the principal ray to a 3D context documented in surveyed data or maps; furthermore, it scales the perspective model and thus allows the restitution of measurable geometric features.
The first step in intrinsic orientation usually aims at detecting two vanishing points of horizontal lines and at drawing the horizon line through them. The vanishing point of vertical lines eases the intrinsic orientation solution [2].
In perspective restitution from photos the horizon line fα' is never horizontal and the VP of vertical lines Fnα' is never at infinite. These conditions, usual in drawn perspectives, would occur in photographic image if both the shooting axe and the base of the camera were perfectly horizontal; no need to say that these conditions never occur.
As a consequence, the principal point Fnπ' of a photographic image never belongs to the horizon line fα' [3].
Since photographers in the period from the second half of the XIX to the first half of the XX century aimed at keeping the lens axis almost horizontal, or used mechanical devices to reduce aberrations, in old photos Fnα' is often very far from the image frame.
The restitution process started with the photo of the niche on the left side of the nave; the intrinsic orientation of this image can be summarized as follows: the VPs Fr' and Fs' are detected at the intersection of horizontal edges respectively parallel (Fs') and perpendicular (Fr') to the back of the niche; the line through Fr' and Fs' is the horizon line fα' (fig. 5.1); the photographic image and the lines are rotated to make fα' horizontal (fig. 5.2).
Fnα' is drawn at the intersection of the lines that extend the vertical edges of the pillars flanking the niche; the vertical line perpendicular to fα' that passes through Fnα' is fσ', i.e. the intersection between π and σ, the interpretation plane parallel to σ; Fpα' is the intersection between f'α and fσ' (fig. 5.3).
Lines that vanish in Fr' and Fs' intersect at right angle; the point of view V will therefore belong to the half-circle through Fr' and Fs', that belongs to $\underline{\alpha}$. If we consider the revolution that moves $\underline{\alpha}$ to π, the point (V)$\underline{\alpha}$, i.e. the point of view V revolved onto π by $\underline{\alpha}$, will be on the picture plane at the intersection between the half-circle through Fr' and Fs' and the line fσ'.
Since lines that vanish in Fpα' and Fnα' are perpendicular, V belongs to the half-circle through Fpα' and Fnα'; this circle belongs to $\underline{\sigma}$. If we consider the revolution that moves $\underline{\sigma}$ to π, the point (V)$\underline{\sigma}$, i.e. the point of view V revolved onto π by $\underline{\sigma}$, will be on the picture plane on the half-circle through Fpα' and Fnα'.
The arc of the circle centered in Fpα' through (V)$\underline{\alpha}$ intersects this half-circle in (V)$\underline{\sigma}$.
The horizontal line through (V)$\underline{\sigma}$, i.e. the revolution of the principal ray onto π, intersects fσ' at right angle in the principal point Fnπ'; the segment (V)$\underline{\sigma}$-Fnπ' measures the principal distance (fig. 5.4).
The angle delimited by the principal ray and the line from (V)$\underline{\sigma}$ to Fpα' measures the inclination of the axis of the lens of the camera.

Fig. 6. Absolute orientation of the photo of the niche.

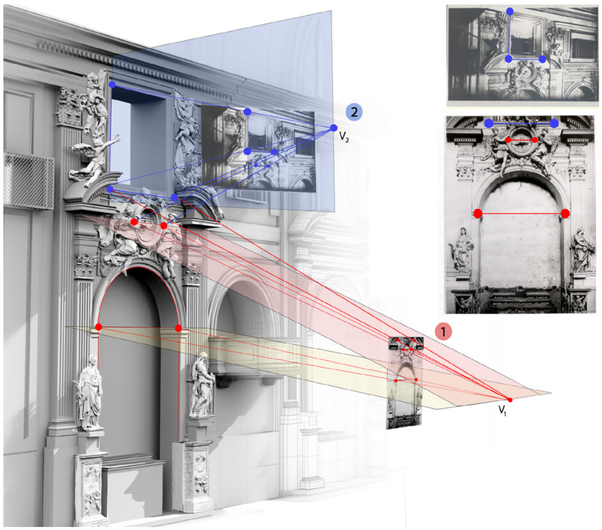


The point of view V is finally drawn in 3D on the principal ray at the principal distance. The lines through V, Fr', Fs' and Fnα' are finally drawn (fig. 6.1, 6.2, 6.3).
The intrinsic orientation is thus processed.
It is worth noting that, if the entire image is available, the principal point Fnπ' is at the intersection of the diagonals of the frame. When the image is taken from a book, or when it could be supposed that particular devices to reduce aberration were used, the position of the principal point should be calculated.
The absolute orientation has been developed in three steps: the first step is the rotation of the entire perspective model around a line through V that is parallel to fα'; the rotation angle makes the line through V and Fnα' parallel to z-axis; as a consequence, the rotation makes α horizontal (6.4).
The second step is the rotation of the perspective model around z-axis, to make the horizontal line through V and Fs' parallel to x-axis (6.5); it is worth remembering that the mesh model of the sculptures had been rotated to make the backward plane parallel to xz.
The third step scales the perspective model with reference to a known dimension. The diameter parallel to x-axis of the tondo portrayed in the image is drawn on the mesh model; its ends are named A and B; a segment VK=AB is finally drawn on the line from V to Fs' (6.5).

Fig. 7. Visual evaluation of the correspondence between the photographic image of sculptures and their 3D mesh model.

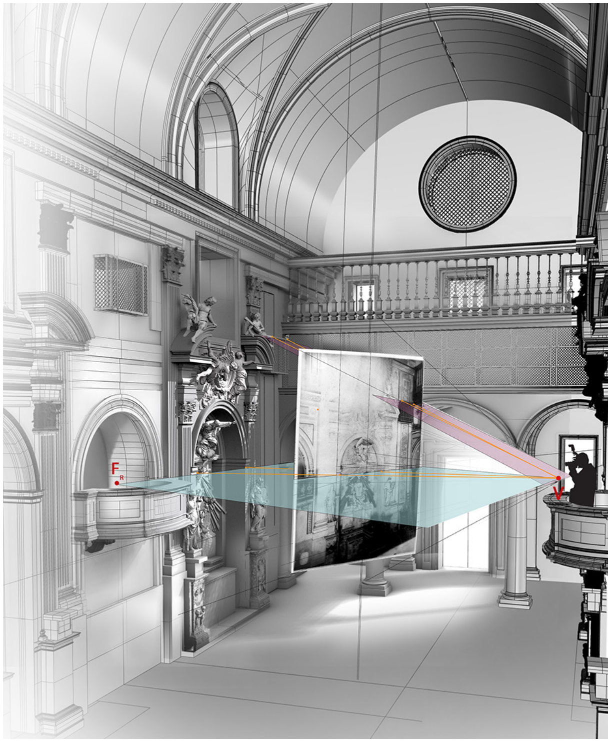
Points A' and B' are marked on the image at the ends of the diameter of the tondo that vanishes in Fs' and the interpretation lines through A' and B' are drawn; a line through K that is parallel to the interpretation line through A' intersects in B the interpretation line through B'; the line parallel to x axis through B intersects in A the interpretation line through A'; the entire perspective model is finally moved to match the restituted segment AB to the segment AB in the mesh model.
The quality of orientation has been visually evaluated by posing on V a virtual camera with focal length equal to the principle distance. The possibility to manage the opacity of the picture plane allows the verification of the match between the photographic image of sculptures and their 3D mesh mode (fig. 7).
The image is now fully oriented and perspective restitution can be started.
The 3D restitution of a vertical edge on the wall of the nave provides a good example to illustrate the method that led to the reconstruction of all 3D models presented in this paper: a vertical plane corresponding at the back of the mesh has been modeled; an interpretation plane through the vertical line from V to Fnα' and the image of a point C' on the vertical edge g' is modeled as well; the

Fig. 8. The photos of the niche are oriented by means of an element that is visible in both images.



3D restitution of the edge, i.e. the line g, is the intersection between these planes; the intersection between the interpretation plane and the image plane has to match g'.
Perspective restitution can be developed in line, using dimensions and directions restituted from a photo, for the orientation of other photos where the same features are entirely or partially displayed; the restitution of the higher part of the niche was completed through the restitution of a photo taken from an elevate position, that displays the higher part of the nave with one of the windows that enlightened the church.
The two photos were referred by the horizontal line at the base of the window, visible in both images (fig. 8).
The facing niche, displayed in the third image of the interior, was reconstructed by symmetry, arguing the invariancy of the dimensions of the niche.

Fig. 9. The orientation of the image is verified by the position of V in the reconstruction model.



A final check, made possible by the 3D approach to perspective restitution, focuses the position of the camera inside the reconstruction scene; if that position proves incongruent, e.g. if V results below the floor or outside the church, the orientation should be reconsidered. The orientation of the third image, that portrays the niche on the right side of the nave from an elevated position, restituted point V on one of the chancels inside the church (fig. 9).

Fig. 10. The niches in the nave.

The conjectural reconstruction of the nave was developed with reference to the overall dimensions provided by the piano of Basile and to the dimensional and proportional comparison with coeval similar churches in Palermo (fig. 10).
The third part of the restitution process aimed at the reconstruction of the façade of the church, with the annexed monastery, and of the Maqueda gate.
The reconstruction of the front of the church started from a photo that displays Maqueda gate with the barricades erected during the protests of 1860, portrayed by Eugène Sevaistre from outside the walls; the photo displays, behind Maqueda gate, the front of the monastery foreshortened. The column of a palace that survived the demolitions of the area supported the absolute orientation of the image and the reconstruction of Maqueda gate and of a part of the front of the monastery. The same front, partly ruined, appears in a photo that documents the demolition of the monastery; at the left edge of the photo the front of the church is partly displayed and highly foreshortened. The shared part of the front of the monastery allowed to link these photos and thus start the reconstruction of the façade of the church and its urban context; the comparison between the outputs of perspective restitution and the piano of Basile allowed a more accurate control and proved an adequate correspondence, with discrepancies close to 10 cm.
The last step of the research aimed at the alignment of equirectangular images taken on site, with the corresponding images digitally extracted from the reconstruction model.
The alignment allows the synchronous visualization of the extant layout of a site and the reconstruction of a previous layout, thus making the understanding of the urban transformations accessible to a wide audience.
The alignment demands: the accurate calculation of the pose of images and the alignment between the reconstructive model and the site.
This alignment has been supported by the superimposition of the piano of Basile and the map dated 1984.
The position of equirectangular images of the site [4] was calculated with SfM photogrammetric tools, through the implementation of a photogrammetric model that aligns standard 35 mm and fish-eye photos.
At the same time the area was partially surveyed with a laser scan and the registered clouds were referred to the 1984 map.

The coordinates of the points, extracted from laser scans, allowed to scale and refer the photogrammetric model to the 1984 map and, consequently, to the piano of Basile. In the reconstruction model, the equirectangular images were used to texture spheres centered in the points extracted from the oriented photogrammetric model.
A virtual camera placed in the center of a sphere allows to navigate the equirectangular image of the site; if the opacity of the sphere is reduced, the reconstruction model appears, thus allowing a direct visual comparison between the current state of the site and its past arrangement (fig. 11).

Conclusions

The study led to the reconstruction of buildings and an urban site that no longer exists, by means of old photographic images. Intrinsic orientation was calculated according to the principles of descriptive geometry, whereas the absolute orientation was calculated with the aid of historic maps and of digital surveys of elements displayed in the images. The reconstructive model of two niches of the church of the Stimmate, displayed in photographic images, allowed to reposition the sculptures that escaped the demolition of the church and are today exhibited in a museum. The reconstructive model at urban scale supports the understanding of the urban transformations.
Perspective restitution is obviously an approximate process, but the study showed that digital tools can significantly reduce the errors of pre-digital restitutions and allow a visual check of the correspondence between the photo and the reconstructed model.
The final part of the research work focused the use of equirectangular images for the visualization of virtual reconstructions of buildings and sites that no longer exist; the alignment between equirectangular images of the site and the corresponding projections of the reconstruction model, was calculated with SfM photogrammetric tools.
Further researches should be oriented at the development of a tool that allows the comparison between equirectangular images on portable devices (smartphone or tablets) and to experiment the visualization of the church of Stimmate in the visiting tour inside inside the hall of the oratory of the Bianchi, where the sculptures are exhibited.

Fig. 11. Reconstruction of the façades and of the urban site.

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Notes

[1] Scans have been taken with a shift-based laser scanner Leica HDS7000 and have been registered with Autodesk Recap Pro. Perspective restitution, 3D modeling and texturing have been processed with McNeel Rhinoceros 6.0. Further point cloud processing (sampling, rotation, normal computation, mesh extraction) has been developed with the free software CloudCompare.

[2] When the vanishing points of two horizontal lines at right angles and the vanishing point of vertical lines are available on the picture plane, the principal point is the orthocenter of the triangle formed by these three VPs. The position of V in 3D space can be calculated at the intersection of three spheres; each sphere is centered on the middle point of one side of the triangle and its diameter is equal to the length of that side.

[3] In this study the following notation will be used: V is the point of view; π is the picture plane; α is the horizontal reference plane; $t\alpha$ is the 'ground line', i.e. the intersection between α and π; $Fn\pi'$ is the principal point, i.e. the VP of lines that are perpendicular (normal) to the picture plane π; $\underline{\alpha}$ is the interpretation plane parallel to α; $f\alpha'$ is the horizon line, i.e. the intersection between π and α; $Fn\alpha'$ is the VP of vertical lines, perpendicular (normal) to α; σ is a plane that is orthogonal to $t\alpha$ and $f\alpha'$; σ is the interpretation plane parallel to σ; $f\sigma'$, the intersection between π and $\underline{\sigma}$ passes through $Fn\alpha'$ and is perpendicular to $f\alpha'$; $Fp\alpha'$, the intersection of $f\sigma'$ and $f\alpha'$, is the VP of lines generated by the intersection of planes parallel to σ and α. The proposed notation refers to the illuminating lessons on perspective held by prof. Michele Inzerillo at the University of Palermo up to 2015.

[4] Equirectangular images were generated with PtGUI from 7 photo sets taken with a reflex camera mounting fish-eye lens, fixed to a Nodal Ninja arm.

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