The Tribuna of Palazzo Grimani: a 3D survey and virtual representation of the original statuary

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Abstract
This paper concerns the study of the Tribuna in Palazzo Grimani in Venice. This room was built in the second half of the sixteenth century to be a monumental container for Giovanni Grimani's antiquarian collection. *Unicum* in the artistic landscape of museums in Venice, the Tribuna is a remarkable room, both because it was the first private museum with a central plan in the lagoon, and because of its unique and complex architecture.
The room has been studied through a laser scanning survey, with the support of more traditional methods that initially helped verify, and subsequently test, the precision of the data obtained by the laser scanner. Our decision to utilise this technology was determined by its capability of acquiring information on the geometry of such a complex object in an accurate, fast and non-invasive way. This laser scanning survey produced a point cloud that was "coloured" with non-metric images orientated with the DLT algorithm. From this coloured cloud we obtained ortophotos on a 1:50 scale.
The analysis of the data obtained by this instrument allowed us to identify some interesting geometries probably used for the construction of this room. If the metric survey is a fundamental instrument to studying and acknowledging architectural structures, in this case it was indeed essential to reaching our goal. In fact, the main task of this work was the realisation of a proportional study that allowed us to identify the geometric rule used to build the room. This hypothesis was supported by the date of its construction: the sixteenth century developed a particular interest for geometric proportion in architecture. In the end, we add the possibility of constructing a digital model of the room and the statuary that was collocated inside it. This product would represent the original Tribuna as it was in the sixteenth century, before the statues were moved to the National Archeological Museum of Venice.

The last few years have marked an exponential growth in the use of electronic and computing technologies. This evolution of tools and methods has led to new ways of approaching surveys and as a consequence, the acquisition of data has changed and its elaboration has been made more precise. This diffusion of instrumental techniques for surveying, especially 3D scanning, allows us to observe complicated geometries, that would be impossible to study using traditional methods. In particular, these new techniques have shown their utility in the field of Cultural Heritage which so frequently demands detailed documentation under tight deadlines.The work discussed here concerns a survey of the Tribuna of Grimani's Palace in Venice, conducted by the Photogrammetry Laboratory of IUAV University, supported by the Soprintendenza per i Beni Architettonici e Paesaggistici di Venezia (Office for the Protection of Architectural, Natural, Historic, Artistic and Ethno-Anthropological Heritages in Venice and Its Lagoon) and it is the result of a dissertation titled "Digital technologies for knowledge: instrumental metric survey and geometrical analysis of the Tribuna in Palazzo Grimani in Venezia". The room was the appropriate field in which to use these instruments as its architectural complexity would have made it impossible to analyse through a traditional survey. Furthermore, the investigation needed considerable precision as the purpose was to study and identify some of the most important geometries and proportions that determined the

building's form at the time of its construction. In fact, the Tribuna was built in the second half of the sixteenth century as private museum for the exhibition of the antiquities collection of its owner. Giovanni Grimani, patriarch of Aquileia, was a lover of art, culture and classical architecture - all his passions were ultimately consolidated in the construction of this space, both in the forms of the room itself and because of what was contained in it; the collection of antiquities. During the last few decades, many studies have focused on the room's statue collection but none have analysed its architectural forms.

1. The Survey

The instrument used for this survey was a Leica HDS6000, a fast and compact phase-based scanning system: the scanning speed and the possibility of a higher scan density brought benefits in terms of productivity and in the variety of its applications. The tool, belonging to the class of phase-based laser, measures the gap between the wave emitted and the one received. Its most important characteristic is the possibility, through a rotating mirror, of having complete 360 degree vision around the vertical axes of the scanner, but also maintaining 270 degree horizontal vision. As a result we were able to obtain a large surface of the object in one shoot which made it easier to work on.

On the other hand, this instrument does not give the chance of acquiring RGB color features for each point, but only the three observations necessary to determinate the X, Y, Z coordinates of each point, together with information as to the surfaces' reflectance. This laser scanning survey produced a point cloud that was "coloured" with a self-made software which uses non-metric images orientated by the DLT algorithm.

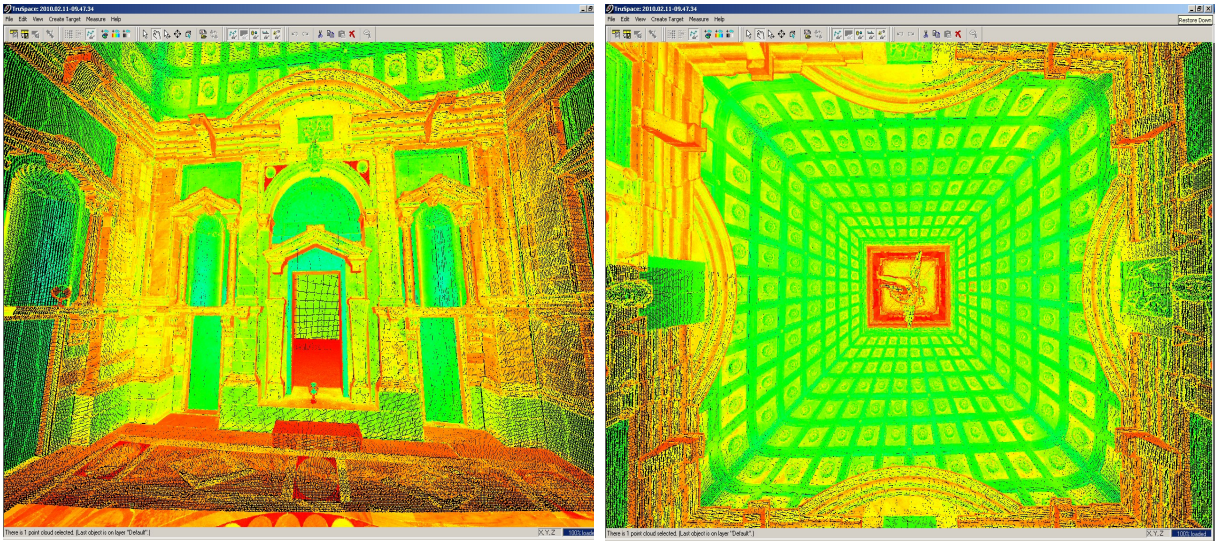

Image 1: The point cloud.

The Leica HDS6000 guarantees an accuracy in determining points of ±2 mm from a distance of 25m and ±4mm from a distance of 50m. This was perfect for the scale of the space - the Tribuna is an indoor room measuring 6 to 6.50m in length and 12m in height (including the lantern). To obtain complete numerical models of the four fronts, the plan and the vault, and minimise the areas without data, five scans were taken: a central one with high density (168 million points) and four at the four corners of the room with less density (42 million). The excess of data is essential in order to guarantee a homogeneous distribution of points and to cover the whole object. The resulting clouds were then registered together using scan targets, recognisable due to their high intensity.

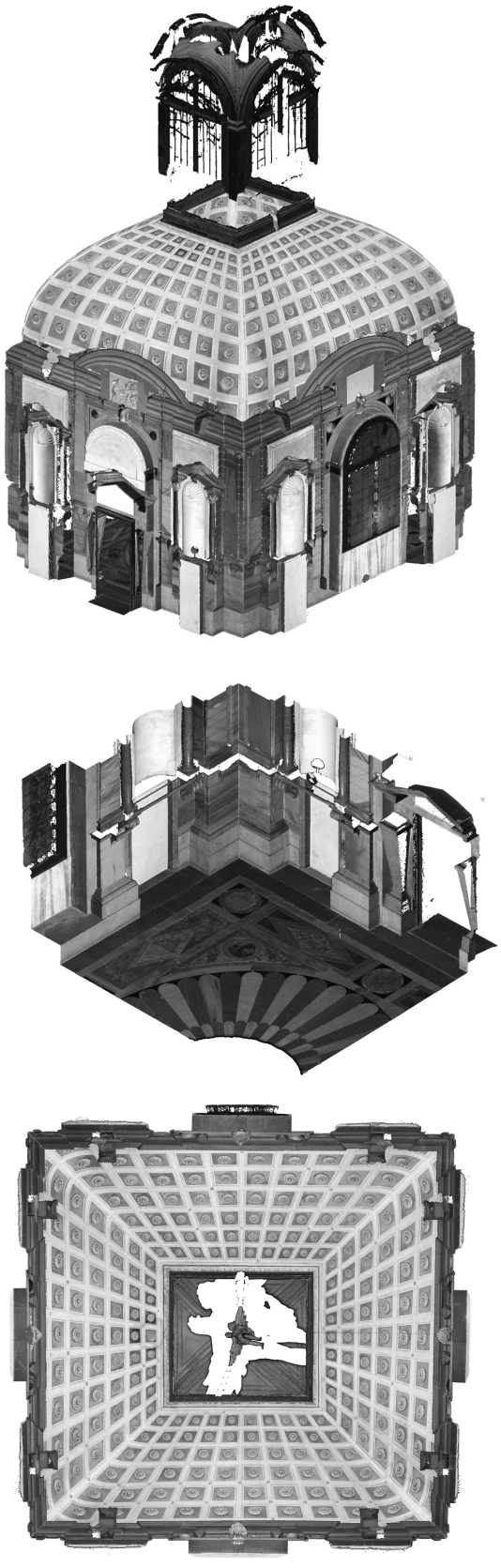

Image 2: The cloud in Pointools.

For each scanning session, an angular step needs to be set, which defines the point resolution on the object. In this case, the angular step corresponded to a variable grid on the object of more or less 1mm (the variability is determined by the distance of the object from the instrument). This allowed us to obtain a good definition of even the smallest details; advantageous given the rooms architectural complexity. Moreover, the analysis we wanted to conduct on the data obtained from the survey necessitated millimetric precision, because the proportional study likewise had to affect the smallest details.

At the end of the acquisition, the point cloud requires internal processing, in order to eliminate noise and non useful zones, and, if it is necessary, to decimate the data. After this first step of data processing (registration, alignment and filtering) the result is a numeric model, which, even if complete, requires further elaborations to obtain final products comparable to those acquired by traditional survey methodologies. Through specific software programmes the redundant data offers the possibility of extracting a high number of horizontal and vertical profiles. Furthermore, it is possible to proceed with digitising directly on the point cloud, which allows us to produce drawings comparable to a photogrammetric restitution, both from the metric perspective and from the representative one.

Here, the georeferenced point cloud was imported into Pointools, a software which allows the management of a large quantity of points and very heavy files. Through this software we created orthogonal views of the Tribuna, similar to orthophotos, in which every pixel corresponded to 2mm. In surveys, the use of orthophotos and photoplans has become common practice as they can be used not just for metric analysis, but also for material analysis. In fact, orthophotos are geometrically corrected images with a uniform scale and a photographic content: we pass from the central perspective of the acquisition, to an orthogonal projection, so that every element in the picture is correctly measurable. If we use Pointools, the final product corresponds to an orthophoto, but it is an orthogonal projection of the point cloud.

Image 3: Intensity orthophoto (left), RGB orthophoto (right).

Subsequently, the orthogonal views of the four fronts of the Tribuna, together with the pavement and the vault, were imported and digitised in CAD, in order to transform the almost continuous data produced by the laser scanner into a discrete one: a drawing.
Again through Pointools, we extracted some profiles from the point cloud, which were digitised in CAD using another software, PointCloud. This software allows the visualisation and analysis of millions of 3D points in AutoCAD. In this way, we obtained the plan and the central cross-sections with views of the four fronts. Moreover, both sections and fronts were georeferenced in a single reference system, determined by the instrument.

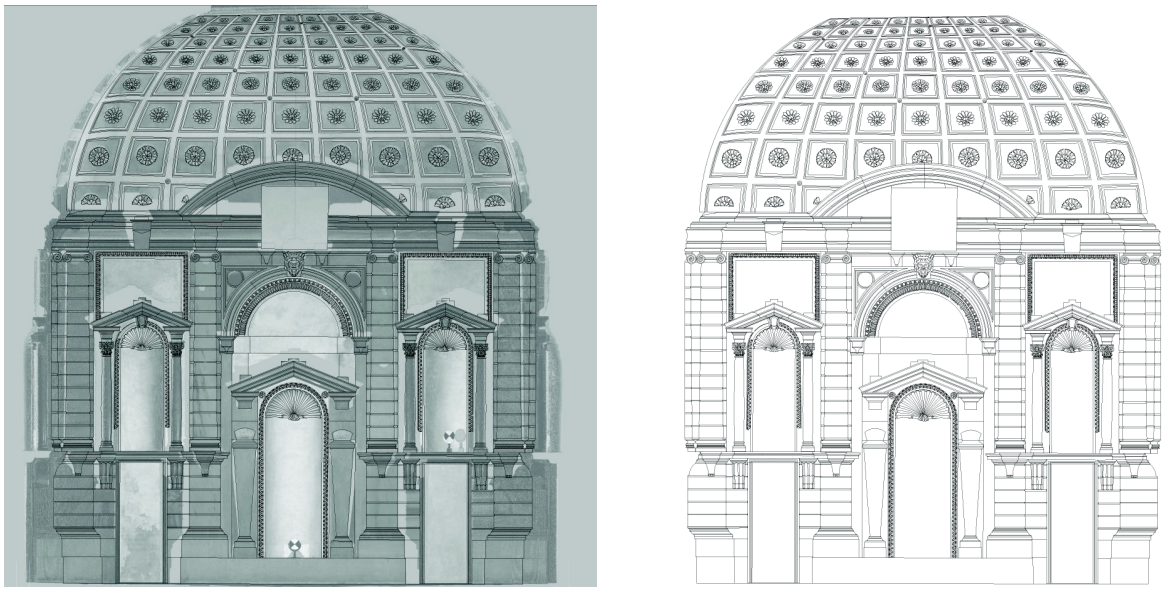

Image 4: Digitised front on the orthophoto (left), one of the digitised fronts (right).

In the end, the data was verified against results acquired using other methodologies: at an early stage we produced some direct surveys and sketches which provided a point of comparison for the digitisation, especially for the mouldings that would have been hardly recognisable from the laser scanner due to their forms and dimensions. Subsequently, the results have been tested with a further survey using a total station, in order to verify the accuracy of the data obtained.

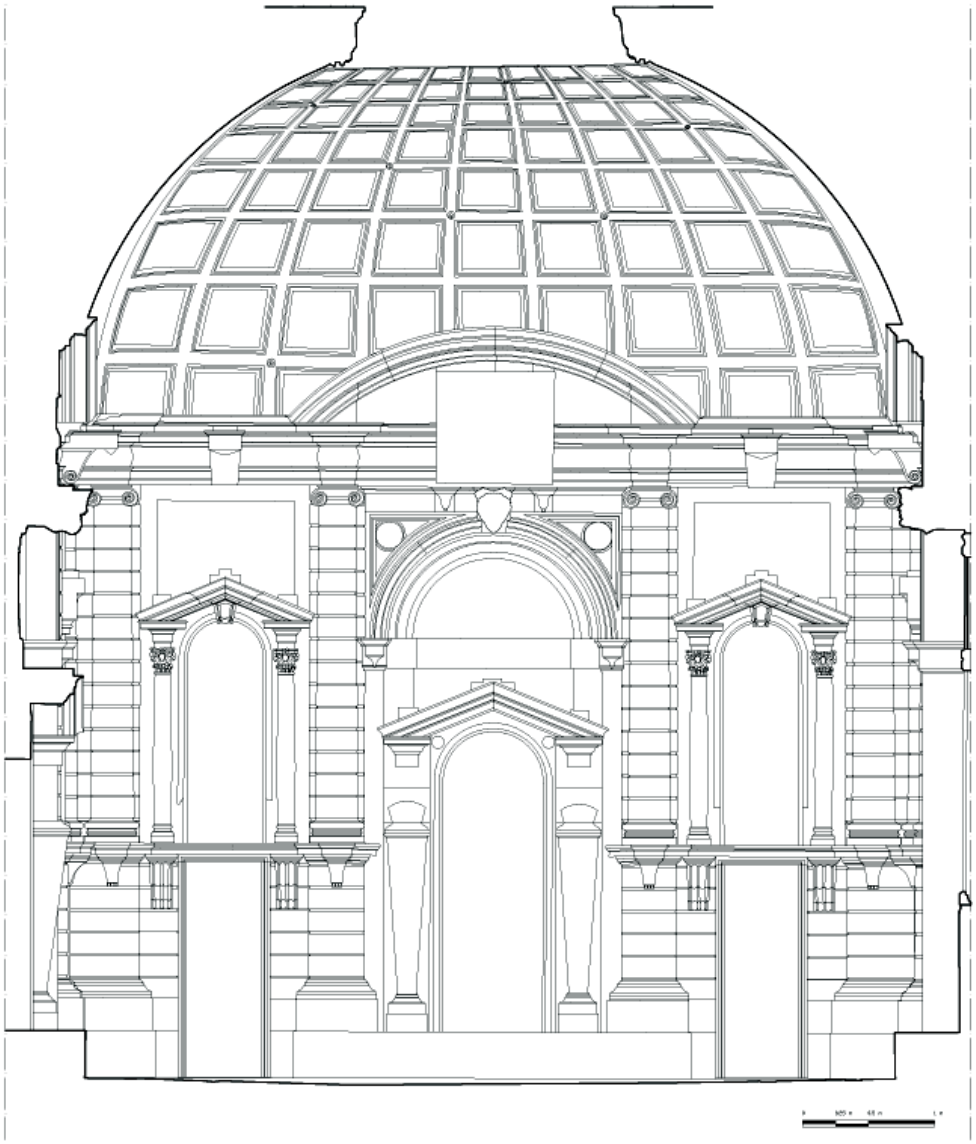

Image 5: Cross-section with view on one of the digitised fronts without the decoration.

2. The proportional analysis

Using the data collected via the operations just described, the room was then geometrically analysed. The ultimate purpose was to determinate the design idea that lay at the foundation of the general structure of the Tribuna. This hypothesis was supported by the period of the room's construction, a time of high interest in proportions, and by Giovanni Grimani's passion and knowledge of ancient and Renaissance art, his unlimited economic chances and his friendship with notable personalities of his time.

Giovanni Grimani, patriarch of Aquileia, is well-known because he came from a family composed of aristocratic artistic patrons, but most of all because of his testament, with which he founded the current National Archeological Museum of Venice. When he died, in 1593, his whole collection was donated to the Republic. Two hundred statues coming from his palace were placed in the "Antisala" of the Libreria Marciana and they formed the first public museum, transforming his private collection into a collective heritage.
Before this date, though, Giovanni Grimani's collection was displayed in his palace in Santa Maria Formosa, specifically in its Tribuna. This unique room among the Venetian's architectural landscape was built specifically in order to house the most beautiful pieces of his collection of antiquities.
The room was set at the corner of two new wings built during the 1560s, when Giovanni was the sole owner of the palace. It is a central plan room, whose four walls present substantially the same structure: vertically, they are clearly divided into three parts by the marble ashlar pilasters, while the entablature in the red marble of Verona emphasises a horizontal division into two parts – the cloister vault and the part of the wall decorated with pilasters and niches. Originally, three of the four walls had three semi-circular niches each, two small lateral ones and a big central one. There was no window on the western side, nor the door on the eastern one; the room was only accessible from the northern side, and the only light that illuminated it came from the lantern on the cloister vault. The room is not a square, nor a trapezium, probably because of the general trend of both the external and the internal perimeter of the palace.
The analysis of the proportions was based on a study of the classical order, the individuation of the module and the detection of rules used to determine the dimensions of its singular parts, along with its possible irregularities. As a general rule, the model used in the Tribuna was Vitruvian, though, the architect allowed himself some freedom. In fact, the classical order is ionic, but it is slightly different from the one usually used in the Renaissance. To determine the dimensions of the pilasters the architect of the Tribuna used the classical Vitruvian ratio of 1:9, introducing though a rather unusual change in the lower scape's dimensions. Even if tradition determined this measure to be the fundamental base for the proportions of the whole classical order, in this case the lower scape is slightly bigger than the module (it is a module plus 1/12). This peculiarity seems to be determined by the method used to taper the pilaster: that 1/12 surplus on the canonical measure of the lower scape is subtracted from the measure of the top of the column's shaft. In fact, this corresponds to a module minus 1/12. The width of a module is found exactly in the middle of the pilaster (with base and capital). The reason for this irregularity must be established in the attempt to counteract the dominant verticality of the elements in the room.
The base does not respect the taste of the period, which conventionally privileged attic bases: it is half a module high and the internal division of its mouldings corresponds exactly to the Vitruvian ionic base described in book IV of "De Architectura". The same can be said about the capitals, at least for what concerns the dimensions of the abacus and the volute's height. In fact, these last ones are very peculiar. Due to their structure, a spiral that comes out of the main plan while it gets near to the center, they are reminiscent of a theory developed by Giuseppe Porta il Salviati, printed at least ten years before the Tribuna's construction.
The entablature too has its irregularities. In fact, it is an ionic entablature, but its architrave has just two faces, again most likely to eclipse the predominant verticality of the room. In this way the height of the whole entablature corresponds to one fifth of the pilaster, together with base and capital, as Palladio theorized in his "Quattro Libri Dell'Architettura". Even if the architrave and the frieze's construction seems to be modeled on Vitruvius, the cornice is very different. As a consequence of this, we could say that for the entablature a real model may have been used, not just a rule or a book.

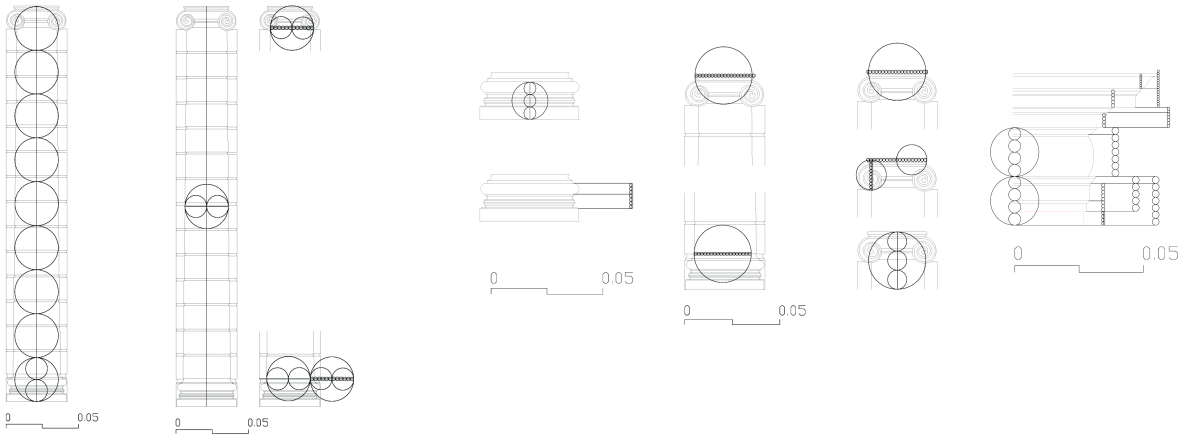

Image 6: Dimension of a pilaster and its tapering, proportions of a base, a capital and an entablature.

3. Conclusions

In conclusion, this analysis has demonstrated the Tribuna as being a great application field for the methodology of laser scanning, which allows to study in detail and in a short time a very complex structure. Moreover, this proportional analysis could not have anything else but the survey as a point of departure. In fact, the survey's discipline studies the architectural form through geometries which have an essential role in the designing, construction and comprehension processes of a building. When the architect elaborates the project, he uses geometry; when the builder translates that idea into something real, he too has to use well-defined geometrical categories. As a consequence, anyone who studies a building has to attempt to interpret it using the same geometrical logic. The survey gives us data and information to proceed with this interpretation.

Finally, from the laser scanning we can obtain tridimensional models which could have a number of different uses, all of them very useful for a detailed documentation of the object. In this case, for example, we could recreate the original set up of the exhibition of his collection; these could be appreciated on a computer screen from every possible angle, allowing us to observe even the smallest details. Moreover, digital models could be used to recreate the original illumination of the room and its sculpture. In fact, the concentration of light coming from above the statues was very important for Giovanni, and was an important detail appreciated by visitors.

Most importantly, as stated above, the majority of the statuary collocated inside the Tribuna and the palace is now exhibited in the National Archaeological Museum in Venice, so we are unaware of its original arrangement. During the past few decades many studies have focused on this problem and we can now say that the conclusion has almost been reached. Through the use of modern technology we can assist this process: we can represent virtually the original statuary inside the 3D model of the Tribuna. Digital models of the statues can be produced in a very short time just by taking pictures and using a software that from a number of images recreates the third dimension, providing depth information. As a consequence, a 3D model can be formulated. The final result could even allow us to compare the aesthetic effects of the different reconstructions and decide what the most probable one was due to the scale of the statues and the spaces in the room, overcoming a limitation which too frequently inhibits the reconstruction hypothesis; that being proposed just through drawings and pictures, does not consider the third dimension.

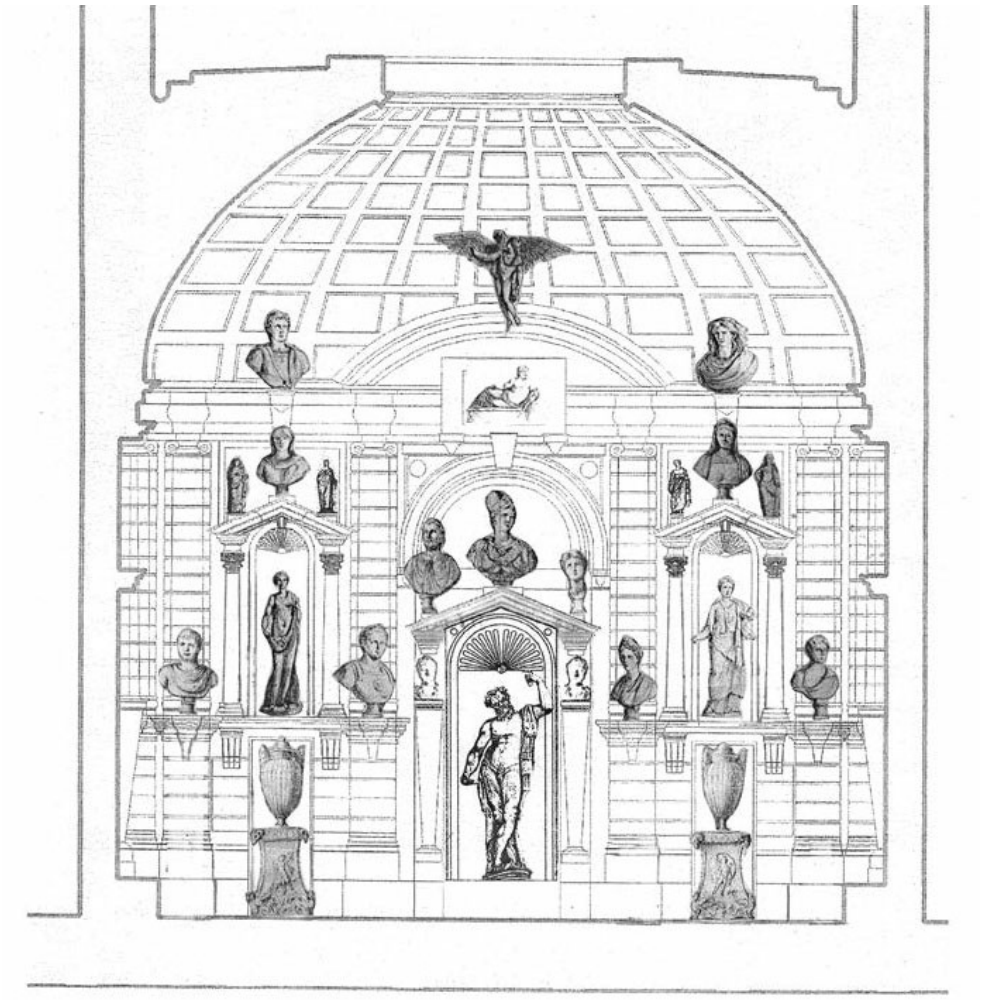

Image 7: Reconstruction of one of the fronts of the Tribuna with its statues (after FAVARETTO-DE PAOLI 2010).

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