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X-Ray Computed Tomography In Situ: An Opportunity for Museums and Restoration Laboratories

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Abstract: X-ray Computed Tomography (X-ray CT) is a sophisticated non-destructive imaging technique to investigate structures and materials of complex objects, and its application can answer many conservation and restoration questions. However, for Cultural Heritage investigations, medical CT scanners are not optimized for many case-studies: These instruments are designed for the human body, are not flexible and are difficult to use in situ. To overcome these limitations and to safely investigate works of art on site—in a restoration laboratory or in a museum—the X-ray Tomography Laboratory of the University of Bologna designed several CT systems. Here we present two of these facilities and the results of important measurement campaigns performed in situ. The first instrument, light and flexible, is designed to investigate medium-size objects with a resolution of a few tens of microns and was used for the CT analysis of several Japanese theater masks belonging to the collection of the "L. Pigorini" Museum (Rome). The second is designed to analyze larger objects, up to 200 cm and was used to investigate the collection of the so-called *"Statue Vestite"* (devotional dressed statues) of the Diocesan Museum of Massa.

Keywords: X-ray computed tomography; cultural heritage investigations; in situ analysis; Japanese theater mask; Statue Vestite

1. Introduction

X-ray Computed Tomography (X-ray CT) is a powerful non-invasive and non-destructive technique capable of revealing crucial information about the construction techniques, conservation state, and materials of works of art. Exploiting the high penetration power of X-rays, CT investigates the entire volume of the objects, revealing internal hidden details. Here we describe two of the transportable X-ray tomographic facilities especially designed and developed by our research group to investigate Cultural Heritage objects. Additionally, the capabilities of these instruments will be presented through the important results of two recent measurement campaigns: the investigation of a Japanese Theater mask collection of the L. Pigorini Museum in Rome (currently Museum of Civilities), and the analysis of the so-called *Statue Vestite* collection (devotional dressed statues) of the Diocesan Museum in Massa (Massa, Tuscany, Center Italy).

Nowadays, a large number of scientific investigations of works of art can be achieved in situ, avoiding risky transports. Examples are the imaging of superficial layers, being varnish, pigments or preparatory layers, using techniques, such as infrared reflectography [1], ultraviolet fluorescence [2] or

the more sophisticated multi and hyperspectral imaging [3,4]. Frequently, these techniques are safely performed on site with custom instruments, achieving excellent results [5,6]. Similarly, single point chemical investigations or the most advanced chemical mapping could be performed on site with instruments such as used in [7,8] or [9–11].

Contrariwise, investigation of the internal structure of Cultural Heritage objects with processes such as X-ray tomography is not widespread. This is mostly due to the technical challenge of the construction of a flexible, precise, and light instrumentation movable to on site.

Other approaches are feasible, such as the use of Synchrotron light sources with the availability of highly resolved tomographic imaging and several other sophisticated X-ray analyses [12], but they are unavailable in situ, and the use of medical CT [13], industrial CT [14], or custom facilities [15] installed in specialized laboratories inside Museums and restoration labs. This last approach greatly reduces the artwork transportation risk and makes X-ray tomography available as routine analysis, but only main institutions have these technologically advanced labs. The developing of systems which are transportable in situ avoids these difficulties, making the technique available for all museums.

Despite the technological challenges cited above, CT systems are nowadays available in situ [16–18].

The instruments presented, to provide the maximum flexibility in terms of portability and object dimensions, are designed with the main components—source, object sample stage, and detector—un-bonded and independent. Using this configuration, conversely to the medical systems, the projections are acquired over 360° rotating the objects. To perform CT of artworks larger than the detector dimensions, the so-called tile-scanning technique is used: Two orthogonal translation axes are used to move the detector on an X-Y plane and Z-translation to move the source. Thanks to the extreme flexibility of the facilities, measurement campaigns in situ are easily achievable.

Here we will present the results of two important campaigns performed in situ in the frame of the MATEGIAPPI and STA.VE projects supported by the IPERION_CH National Call [19]. For the first project, we present the CT investigation of the collection of ancient Japanese theater mask of the L. Pigorini Museum in Rome (currently part of Museum of Civilities, Rome, Italy) [20], achieved at "The Superior Institute for Conservation and Restoration (ISCR)" (Istituto Superiore per la Conservazione e il Restauro). For the STA.VE project, we performed an X-ray tomography campaign on a selection of five statues, part of the collection of the Diocesan Museum of Massa (Massa, Italy) [21,22].

The Japanese masks of the L. Pigorini Museum represent an exceptional miscellany: Recently donated to the museum, this collection covers the main theater forms and a period of more than three centuries, from XVII to the XIX century.

The art of Japanese Theater developed from the VI century from several agricultural communities and evolved separately for centuries generating the still-performed four main theater forms, each of them with different scopes and masks. The contemporary theater is based on realistic drama and played without the use of mask or painting. Contrariwise, the most ancient *Nõ* drama is associated with feudalism and acted in archaic language, and the center of the action is the characteristic carved masks. Traditionally made of wood and painted, the masks are used to represent the most common archetypes of an old man, a maiden, a god, or an animal. Another important theater form is the *Bunraku* puppet theater, characterized by high dolls with wooden masks and operated by three men. The puppet masks are generally painted and could have movable parts, such as the eyes or mouth, to appear more natural. Another popular form, the *Kabuki* dance–drama theater, grew out of the *Bunraku* tradition in the XVIII century. In the *Kabuki,* the actors have elaborated make-up to resemble the *Bunraku* puppets [23].

In addition to the theater forms, several types of traditional dances exist, often mixed with the theater forms, such as the Shinto rituals *Kagura* [24] and the *Bugaku* court dances. As for previous theater forms, also in traditional dances, wooden masks play an essential role.

In each of these art forms, masks play a central role, and the important traditional art of mask carving is still handed down today [25]. Generally carved from a block of Hinoki wood (Japanese cypress), a series of chisels are used to finely sculpt the front and the back of the mask. At the end of this process, holes for eyes, nose, and mouth are made.

The mask is then painted on the back with a dark protective layer of Urushi lacquer (made from the sap of Japanese Urushi tree) and on the front with many thin layers of Gofun, a fine white powder made from ground oyster shells, mixed with Nikawa, a natural glue. The finished painting is made with traditional colors: red, made from natural minerals, yellow from natural soil, and black, using Chinese ink [25]. Occasionally, some masks could have movable parts with metal inserts, such as eyes or lower jaw, to mimic and highlight facial expressions.

The MATEGIAPPI project aimed to conduct a comprehensive scientific investigation of the L. Pigorini Japanese mask collection: from the documentation to the material characterization, from the investigation of possible previous restorations to the study of the conservative state of the objects.

Within this framework and to investigate in detail the construction technique of the Pigorini's mask collection, an X-ray CT investigation has been performed in situ. In Figure 1a, the 3D CT rendering of all the acquired masks is shown. In the next paragraph, two of them will be analyzed in detail: a "Karasu Tengu" mask (*Kagura* rituals, XIX century) and a "Ran-Ryô" mask (*Bugaku* court dances, unknown date).

(**a**) (**b**)

Figure 1. Computed Tomography (CT) volume rendering (in false colors) of the Japanese theater mask collection of the L. Pigorini Museum (**a**) and of the *Statue Vestite* collection of the Diocesan Museum of Massa (Massa, Italy) (**b**).

The second measurement campaign was performed on part of the collection of *Statue Vestite* (dressed statues) of the Diocesan Museum of Massa.

These Italian artifacts of medieval origin are usually located in churches or private chapels as venerated objects and are still nowadays carried in procession during the Christian holidays. As the name suggests, these wooden statues are *dressed* in rich and delicate costumes, donated by noble ladies as votive offerings. Being covered, the wooden bodies of the *Statue Vestite* are only outlined, often without any anatomical detail. Contrariwise, the uncovered parts, such as visage, chest, arms, and feet, are carefully modeled in plaster and finely painted. An interesting detail of this collection is the use of the so-called "*Stucco di Lucca*" to model these details. This particular *stucco* is a mixture of plaster, papier-mache, and other various materials [26–30].

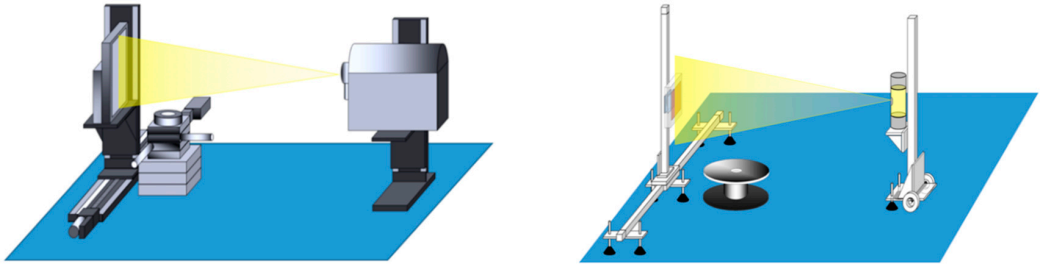
Despite the wide dispersion of these artifacts, even outside of Tuscany, and their historical interest and the peculiar conservation and restoration problems related to material-mix used to mold them, these statues have only been investigated episodically and rarely with a scientific approach [27,30].

The STA.Ve project focused on a comprehensive examination of these artifacts: from the chemical analysis of the *Stucco di Lucca* to the investigation of its complex stratification and, more generally, to the evaluation of the conservation state of the statues.

Within this framework and to investigate the construction techniques of these peculiar objects, an X-ray CT investigation on a selection of five statues was performed in situ. Figure 1b shows the 3D tomographic rendering of the investigated statues. In the next paragraph, we will analyze in detail the X-ray CT results of one of them, the "Madonna del Rosario" statue.

2. Materials and Methods

Considering the substantial difference between the two collections, the analysis was performed in situ with two different systems, illustrated in Figure 2.



(**a**) (**b**)

Figure 2. Schemes of the CT systems designed by the X-ray Imaging Lab for in situ analysis of medium-size objects (up to 50 by 50 cm) (**a**) and of large-size objects (up to 150 by 150 cm) (**b**).

Figure 2a shows the system used for the Japanese mask investigation, designed for medium-size objects. Thanks to the small dimensions of the system, it can be easily placed on a desk and thanks to its components, the system is optimal to perform a highly-resolved investigation of not too high-density materials, such as the wooden Japanese mask here described. Indeed, the facility enables high-resolution 3D imaging, up to 50 µm of voxel size, of objects up to 50 by 50 cm.

The system is equipped with a microfocus X-ray tube (Kevex mod. PXS10, maximum voltage of 130 KV and maximum current of 0.5 mA), a large-surface indirect conversion flat panel detector (Varian PS2520 D with a CsI:TI scintillator, 1536 × 1920 pixel and 127 µm pixel size) and a rotational stage (Physik Instrumente PI, mod. M-038.PD1). To perform the tile-scan and reach a 50 by 50 cm^2 field of view, the detector is placed on an X-Y stage system (linear stages PI, mod. M-413.3PD) and the X-ray tube on a Z-stage (PI, mod. M-521.DD). Considering the object dimensions and the resolution desired for these investigations, the source-object distance was fixed at 800 mm and the source-detector distance at 1030 mm. In this configuration, it was possible to perform the tile-scanning of the masks in a small number of frames: only two for the "Karasu Tengu" mask (dimensions: 22 × 18 × 17 cm) and four for the Ran-Ryô mask (dimensions: 33 × 29 × 17 cm). Both masks were analyzed using 100 kV, 160 µA, 2 fps (frame per second) and 900 projections over 360°, obtaining a voxel size of 100 µm.

In Figure 2b, the system designed for large-size objects is shown. Thanks to its flexibility, combined with the two broad translational stages and the fast acquisition process—each tomographic frame requires only 3 minutes—the facility is optimal to perform CT of large objects, such as the *Statue Vestite* collection here illustrated. Indeed, the facility enables medium high-resolution 3D imaging, up to 100 µm voxel size, of objects up to 150 by 150 cm.

The system is equipped with an X-ray tube (Yxlon, Smart EVO 200D, 30–200 kV and maximum current of 6 mA), a fast flat panel detector (Hamamatsu C10900D with a CsI:TI scintillator, 1216 × 1232 pixel and 100 µm pixel size) and a heavy load rotational stage (stage PI, mod. PRS200). To perform the tile-scan acquisition, the detector is placed on a custom X-Y stage system and the X-ray tube on a custom Z-stage. Considering the large object dimensions and the resolution required, for these analyses, the source-object distance was set at 253 mm and the source-detector distance at 2650 mm. Due to the dimensions of the statue (39 × 38 × 141 cm) several frames were necessary to acquire the entire object. The acquisition was performed using 120 kV, 2 mA, 5 fps, and 900 projections over 360°. To obtain a voxel size of 167 µm, a binned acquisition mode (2 × 2) was used.

For maximum flexibility and transportability, both systems are designed without shielding. The radiation safety is guaranteed by a no-go zone defined based on the criteria established by a qualified expert in radiation protection. The X-ray CT investigations are performed in rooms not accessible to the public and, during the X-ray activities, the access to the area is interdicted to everyone (including authorized operators).

The tomography reconstruction is performed using the cone-beam algorithm of Feldkamp, Davis, and Kress (FDK) developed in house [31]. The use of high-performance computing (HPC) techniques allows the fast processing of large dataset as with the 65 GB of the statue here analyzed. In the case

of tile-scanning, the frames are stitched taking into account the opportune geometrical parameters. The 3D rendering and the image display are then performed using the two open-source software Slicer and ImageJ.

3. Results

3.1. Japanese Theater Masks Analysis

3.1.1. *Karasu Tengu*—Kagura Rituals—XIX Century

In Japanese traditions, Tengu are spirits generally represented as bird-men with the characteristic prominent beak. Due to its ambiguous morality, they could be represented both as evil and as good spirits. Different kinds of Tengu exist, and the Karasu Tengu is one of the less powerful forms of them, and are generally ascetics or monks living in remote mountain regions and forests.

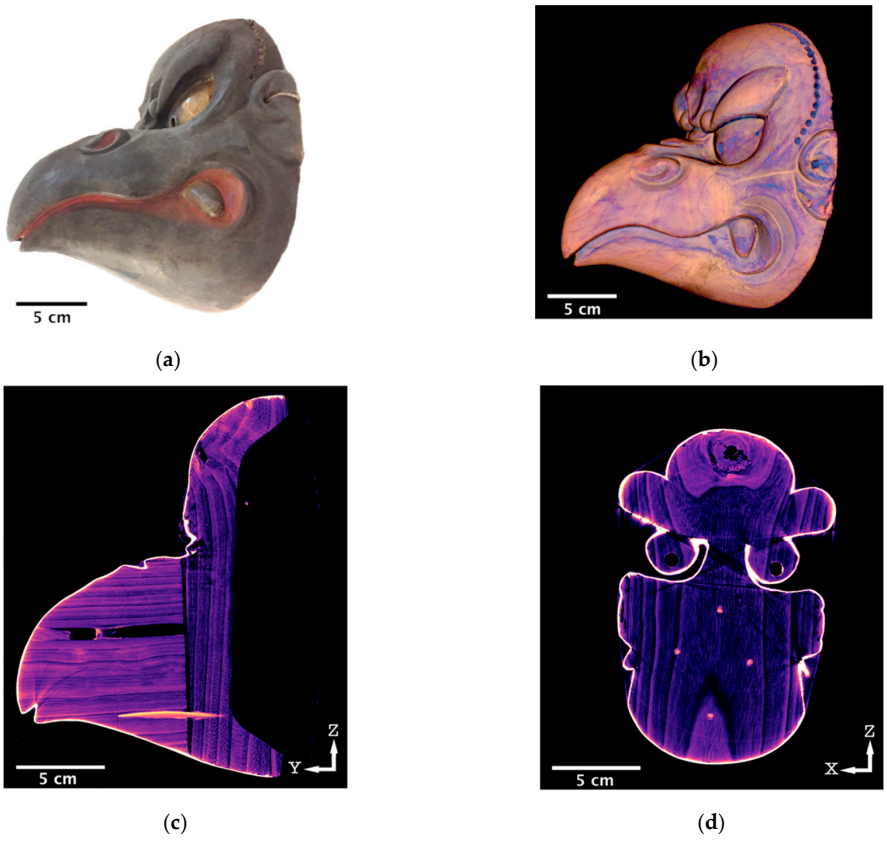


Figure 3. CT investigation of a Karasu Tengu mask—Kagura rituals—XIX century. Top: photograph of the mask (**a**) and CT rendering (in false colors) of the entire volume (**b**). Bottom: two tomographic slices (in false colors) showing the junction between the nose and the visage and the mallow removal (**c**), and the wood knot on the forehead (**d**).

The Karasu Tengu mask here presented (Figure 3a) is a traditional carved wooden mask, without metal inserts and with the conventional prominent beak. As shown in Figure 3b, the 3D tomographic rendering confirms the presence of a quite homogeneous preparatory layer. Nevertheless, the tomographic slices revealed several unexpected details. As shown in Figure 3c, the mask is shaped with two wooden blocks, apparently of the same wood type: one for the main part of the visage and one for the beak. The two blocks are positioned with the fiber direction perpendicular one to the other and joined using four wooden nails and a glue layer. Another interesting detail is the use of wooden blocks with defects or potentially fragile areas. Indeed, as shown in Figure 3d, the area of the forehead

is characterized by a large wood-knot. Moreover, the wood block chosen to shape the beak is the central part of the trunk, the most fragile due to the presence of mallow. To prevent its degradation, as generally done in Western sculptures, the mallow has been removed, and the hole has been covered with a wooden stopper (Figure 3c).

3.1.2. *Ran Ryô*—Bugaku Dances

The Ran-Ryô is one of the main characters of the traditional Japanese court dances called *Bugaku*. There are several interpretations of this dance. The most common explains it as a celebration of battle victories of the Chinese Prince Lanling (Ranryoo) [32]. According to the legend, he was an intelligent and brave warrior but so handsome that he could not inspire terror in his enemies. For this reason, he had to wear a scary mask to scare his enemies.

The Ran-Ryô mask is generally wooden carved with movable parts, such as lower jaw and, as in this case, movable and metallic eyes as shown in Figure 4a.

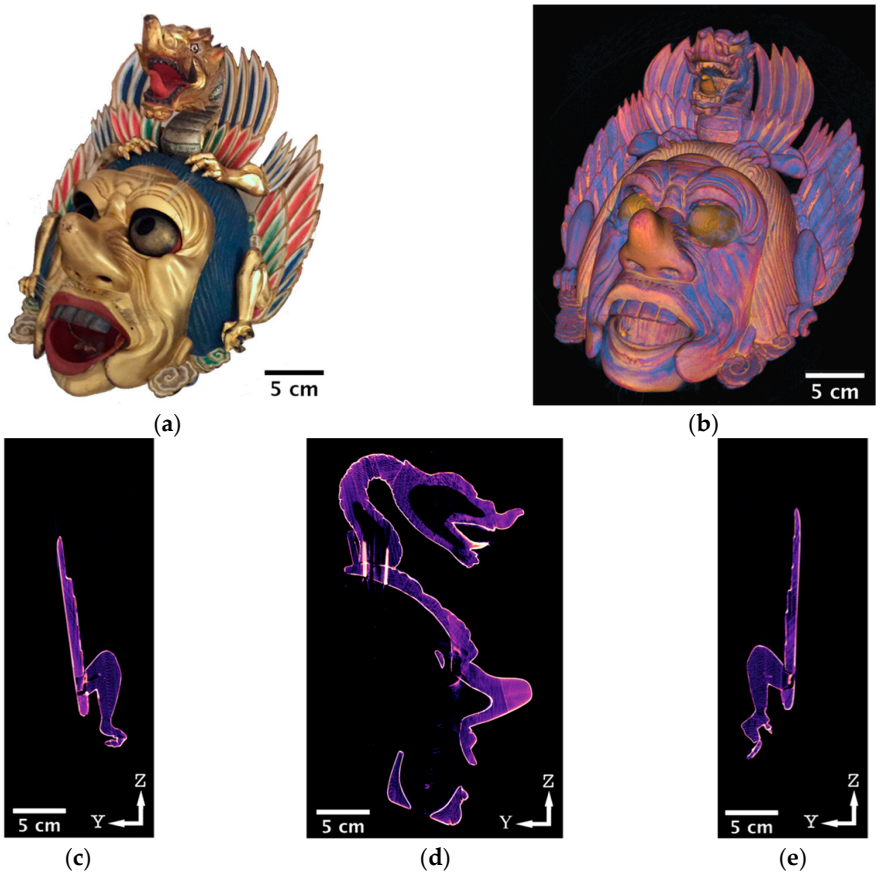


Figure 4. CT investigation of a Ran Ryô mask—*Bugaku* court dances—unknown date. Top: photograph of the mask (**a**) and CT rendering (in false colors) of the entire volume (**b**). Bottom: tomographic slices (in false colors) showing the complex construction of the mask and junctions between the nose, the visage, and the dragon (**d**). On the left (**c**) and on the right (**e**) details of dragon wings.

Analogously to the Karasu-Tengu mask, the CT investigation reveals a quite homogeneous preparatory layer. As shown in Figure 4b, exceptions are the red areas of the dragon wings, related to the use of absorbing pigments or to a higher thickness of the ground layer.

In addition, for the Ran-Ryô, the nose is realized with a wooden block positioned with the wood fibers perpendicular to those of the visage, as shown in Figure 4d.

Despite these similarities, the analysis of the tomography slices reveals a completely different internal structure. Indeed, contrary to the two main blocks of the Karasu-Tengu, the mask is composed

of a multitude of small wooden parts, held together thanks to the use of wooden joints and glues, as evident in the construction of the wings and of the Dragon (Figure 4c,d). Moreover, metal nails have been used to reinforce the junction of the Dragon with the main part of the mask (Figure 4d).

3.2. The Statue Vestite CT Analysis—Diocesan Museum of Massa

Madonna del Rosario, XVII Century

The statue, generally located in the Church of S. Remigio (Fosdinovo, Massa, Italy), is a typical example of devotional dressed statues. The main body is carved in wood while the upper parts—head, shoulders, and chest—are molded in *Stucco di Lucca*, apparently made with a mixture of materials, such as canvas, plaster, and papier-mache.

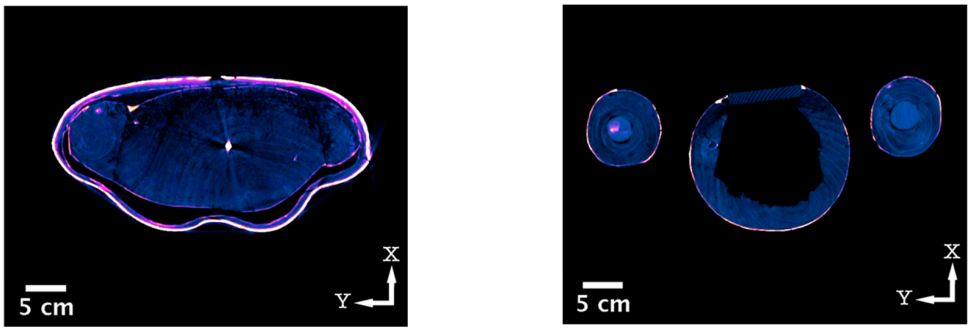
The incomplete documentation about the statue's origin [26], combined with the clear evidence of several interventions, give rise to a peculiar local tradition that identifies the Madonna del Rosario as a re-adaptation of a more ancient angel statue. In particular, an Annunciation's Angel that, together with a Madonna, constituted a XV century wooden pair of statues named Madonna dell'Annunziata. Several historical documents support this hypothesis, but while it is possible to find documentation regarding the decades following for the Madonna's creation, all traces of the Angel were lost after the year 1628. Moreover, there is no information about The Madonna del Rosario's origin and the first indirect mention of the object was found on a receipt of rich and detailed clothes for a statue dated 1676. Stronger indications of the modification can be found in the structure of the statue itself, where several modifications appear evident, as described in detail in the following paragraphs.

In addition to that (supposed) main change, verified historical documentation reports several interventions on the statue. The first one, commissioned in 1692, consists of just in a new silver vest. The second and the third ones, both in 1693, were more invasive adducing wide and important alterations of the wooden parts of the statue, in particular on the hips area and probably adding the two wooden bars still present today. Presumably, the intervention was aimed to enlarge the hips to adapt the statue silhouette to what was in vogue at the end of the XVII century. Another important modification occurred in 1743, when the statue was completely repainted and, in the same year, three metal screws and two metal bars were added to the arms and to the wooden platform.

The CT investigation revealed the extensive use of plaster, primarily as a preparation layer and as filler, the latter most probably related to the several interventions mentioned above (Figure 5b). As emphasized by restorers, the *Stucco di Lucca* parts, such as the head and hands, are removable and the tomography highlighted how these parts fit with the main wooden body (Figure 6a,b).

(**a**) (**b**)

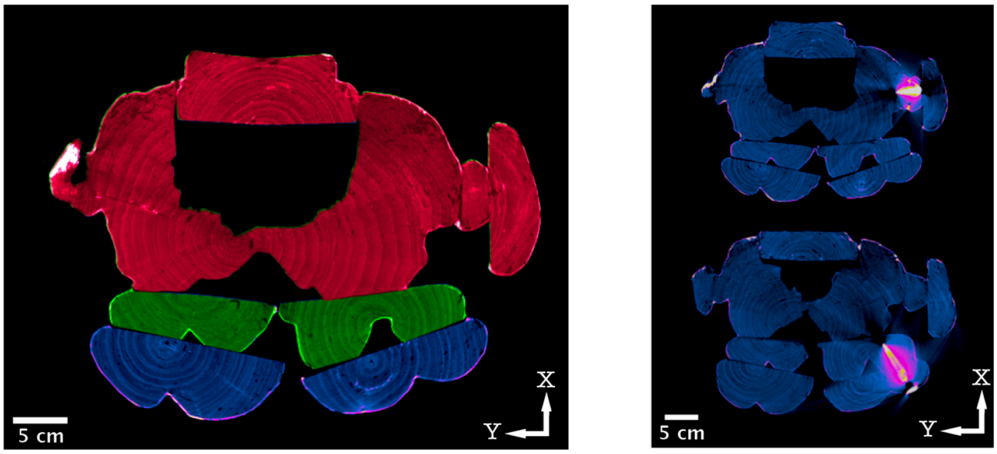
Figure 5. CT investigation of the Madonna del Rosario, XVII century. Photograph of the statue (**a**) and CT rendering in false colors of the entire volume (**b**).



(**a**) (**b**)

Figure 6. X-ray tomographic slices revealed how the *Stucco di Lucca* parts are joined with the wooden statue. Details in false colors of the junction between the head and the torso (**a**) and between the hands and the arms (**b**).

The X-ray investigation of the statue skirt (Figure 7a) clearly revealed the modifications and three main overlays are recognizable: the main, and presumably original, body (in red) has been cut and refined to create a flat base for a second layer (in green). The current statue shape has been achieved with the same technique, and a supplementary layer (in blue) has been added. The analysis at different heights revealed the use of massive metal nails to connect the several parts (Figure 7b).



(**a**) (**b**)

Figure 7. False colors reconstruction of the different Madonna del Rosario versions (**a**) and details of the junction nails used to connect the several parts (**b**).

Moreover, X-rays reveal in each layer the presence of a finishing plaster coating, clearly intended to be visible, but currently covered.

4. Conclusions

The investigation campaigns performed proved the possibility of totally safe in situ X-ray tomography investigations. Indeed, the design of flexible and transportable facilities, optimized for Cultural Heritage investigations, allow to perform studies on a wide range of objects, from medium size wooden Japanese masks of the Pigorini Museum in Rome to the (almost) natural-size *Statue Vestite* of the Diocesan Museum in Massa. Moreover, the joined competences of the restorers and of the scientists, allow to discover details about the construction techniques of less-known objects such as the Karasu Tengu mask or the peculiar restoration/modification history of the Madonna del Rosario.

Finally, these experiences could be great opportunities for outreach. Excellent examples are the two events organized by the Diocesan Museum of Massa for the general public: a temporary exposition titled "Statue vestite, lavori in corso: dalla devozione alla ricerca scientifica"(Dressed Statues, work in progress: from devotion to scientific research) and a scientific conference. For both, the response of the public was above expectations.

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Conflicts of Interest: The authors declare no conflict of interest.

References

1. Walmsley, E.; Metzger, C.; Delaney, J.K.; Fletcher, C. Improved visualization of underdrawings with solid-state detectors operating in the infrared. *Stud. Conserv.* **1994**, *39*, 217–231.
2. Pelagotti, A.; Del Mastio, A.; De Rosa, A.; Piva, A. Multispectral imaging of paintings. *IEEE Signal. Process. Mag.* **2008**, *25*, 27–36. [CrossRef]

3. Bacci, M.; Casini, A.; Cucci, C.; Picollo, M.; Radicati, B.; Vervat, M. Non-invasive spectroscopic measurements on the Il ritratto della figliastra by Giovanni Fattori: Identification of pigments and colourimetric analysis. *J. Cult. Herit.* **2003**, *4*, 329–336. [CrossRef]
4. Fischer, C.; Kakoulli, I. Multispectral and hyperspectral imaging technologies in conservation: Current research and potential applications. *Stud. Conserv.* **2006**, *51* (Suppl. 1), 3–16. [CrossRef]
5. Adriaens, A. Non-destructive analysis and testing of museum objects: An overview of 5 years of research. *Spectrochim. Acta Part. B At. Spectrosc.* **2005**, *60*, 1503–1516. [CrossRef]
6. Artioli, G.; Angelini, I. *Scientific Methods and Cultural Heritage: An Introduction to the Application of Materials Science to Archaeometry and Conservation Science*; Oxford University Press: Oxford, UK, 2010.
7. Leona, M.; Casadio, F.; Bacci, M.; Picollo, M. Identification of the pre-columbian pigment Maya blue on works of art by noninvasive UV-Vis and Raman spectroscopic techniques. *J. Am. Inst. Conserv.* **2004**, *43*, 39–54. [CrossRef]
8. Gianoncelli, A.; Castaing, J.; Ortega, L.; Dooryhee, E.; Salomon, J.; Walter, P.; Hodeau, J.L.; Bordet, P. A portable instrument for in situ determination of the chemical and phase compositions of cultural heritage objects. *X Ray Spectrom. Int. J.* **2008**, *37*, 418–423. [CrossRef]
9. Edwards, H.G.; Munshi, T. Diagnostic Raman spectroscopy for the forensic detection of biomaterials and the preservation of cultural heritage. *Anal. Bioanal. Chem.* **2005**, *382*, 1398–1406. [CrossRef] [PubMed]
10. Van der Snickt, G.; Miliani, C.; Janssens, K.; Brunetti, B.G.; Romani, A.; Rosi, F.; Walter, P.; Castaing, J.; De Nolf, W.; Klaassen, L.; et al. Material analyses of 'Christ with singing and music-making angels', a late 15th-C panel painting attributed to Hans Memling and assistants: Part, I. Non-invasive in situ investigations. *J. Anal. At. Spectrom.* **2011**, *26*, 2216–2229. [CrossRef]
11. Ruberto, C.; Mazzinghi, A.; Massi, M.; Castelli, L.; Czelusniak, C.; Palla, L.; Gelli, N.; Bettuzzi, M.; Impallaria, A.; Brancaccio, R.; et al. Imaging study of Raffaello's "La Muta" by a portable XRF spectrometer. *Microchem. J.* **2016**, *126*, 63–69.
12. Sodini, N.; Dreossi, D.; Giordano, A.; Kaiser, J.; Zanini, F.; Zikmund, T. Comparison of different experimental approaches in the tomographic analysis of ancient violins. *J. Cult. Herit.* **2017**, *27*, S88–S92. [CrossRef]
13. Yamato, M.; Pyenson, N.D. Early development and orientation of the acoustic funnel provides insight into the evolution of sound reception pathways in cetaceans. *PLoS ONE* **2015**, *10*, e0118582. [CrossRef] [PubMed]
14. Natural History Museum, London, UK. Available online: https://www.nhm.ac.uk/ (accessed on 1 July 2019).
15. Re, A.; Albertin, F.; Avataneo, C.; Brancaccio, R.; Corsi, J.; Cotto, G.; de Blasi, S.; Dughera, G.; Durisi, E.; Ferrarese, W.; et al. X-ray tomography of large wooden artworks: The case study of Doppio Corpo by Pietro Piffetti. *Herit. Sci.* **2014**, *2*, 19. [CrossRef]
16. Morigi, M.P.; Casali, F.; Bettuzzi, M.; Brancaccio, R.; d'Errico, V. Application of X-ray computed tomography to cultural heritage diagnostics. *Appl. Phys. A* **2010**, *100*, 653–661. [CrossRef]
17. Bettuzzi, M.; Casali, F.; Morigi, M.P.; Brancaccio, R.; Carson, D.; Chiari, G.; Maish, J. Computed tomography of a medium size Roman bronze statue of Cupid. *Appl. Phys. A* **2015**, *118*, 1161–1169. [CrossRef]
18. Peccenini, E.; Albertin, F.; Bettuzzi, M.; Brancaccio, R.; Casali, F.; Morigi, M.P.; Petrucci, F. Advanced imaging systems for diagnostic investigations applied to cultural heritage. *J. Phys. Conf. Ser.* **2014**, *566*, 012022. [CrossRef]
19. National Access Call of the Infrastructure IPERIONCH.it (Now E-RIHS). Available online: http://www.e-rihs.it/ (accessed on 1 July 2019).
20. Museo Etnografico Pigorini—part of Museo delle Civiltà. Available online: http://www.museocivilta.beniculturali.it. (accessed on 1 July 2019).
21. Museo Diocesano di Massa. Available online: https://www.museimassacarrara.it/musei/museo-diocesano-di-massa (accessed on 1 July 2019).
22. Gioli, A. *STA.VE—Statue Vestite*; In Collaboration with Diocesan Massa Museum; Project of University of Pisa—Departments of Civilisations and Forms of Knowledge: Pisa, Itay, 2017.
23. McCormick, J.P. Japan: The mask and the mask-like face. *J. Aesthet. Art Crit.* **1956**, *15*, 198–204. [CrossRef]
24. Immoos, T. The birth of the Japanese theater. *Monumenta Nipponica* **1969**, *24*, 403–414. [CrossRef]
25. PittsRiver Museum. Available online: https://pittrivers-photo.blogspot.com/2017/07/carving-noh-mask.html (accessed on 1 July 2019).
26. Gioli, A. *Statue Vestite, la Vita Delle Opere 3, Statue Vestite della Lunigiana*; Documentary in Collaboration with a Diocesan Massa Museum, Università di Pisa: Pisa, Italy, 2016.

27. Gioli, A.; Scaravella, E.; Sisti, B.; Salvadorini, A.; Kazantjis, D.; Lazzari, S. *Progetto STA.VE. Statue Vestite Polimateriche: Diagnostica, Studio e Conservazione della Madonna del Rosario di Fosdinovo*; Lo Stato dell'Arte 16; Congresso nazionale IGIIC: Trento, Italy, 2018.
28. Collareta, M. *Vestire le Statue. Arte, Devozione e Committenza Nella Toscana Nord-Occidentale*; Pisa University Press: Pisa, Italy, 2016.
29. Galassi, C. *Sculture "da Vestire": Nero Alberti da Sansepolcro e la Produzione di Manichini Lignei in una Bottega del Cinquecento*; Mondadori Electra: Milano, Italy, 2005.
30. Galassi, C. La tecnica delle sculture polimateriche della bottega di Nero Alberti da Sansepolcro: Indagini diagnostiche e analisi delle fonti. In *Bollettino d'Arte*; De Luca Editori d'Arte: Roma, Italy, 2011; Volume 1, pp. 95–114.
31. Brancaccio, R.; Bettuzzi, M.; Casali, F.; Morigi, M.P.; Levi, G.; Gallo, A.; Marchetti, G.; Schneberk, D. Real-time reconstruction for 3-D CT applied to large objects of cultural heritage. *IEEE Trans. Nucl. Sci.* **2011**, *58*, 1864–1871. [CrossRef]
32. Lovrick, P.; Wang, N.S. *Chinese Opera: Images and Stories*; UBC Press: Vancouver, BC, Canada, 2011.