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3D Model Acquisition and Image Processing for the Virtual Musealization of the *Spezieria di Santa Maria della Scala*, Rome

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Abstract: This study was carried out within the project "Roma Hispana. Nuevas tecnologías aplicadas al estudio histórico, la musealización y la puesta en valor de Patrimonio Cultural español en Roma: la spezieria di Santa Maria della Scala" (Universitat de València Spain), which is funded by the Conselleria d'Innovació, Universitats, Ciència i Societat Digital of the Generalitat Valenciana (2020–2021) and authorized by the Sovrintendenza Speciale Archeologia Belle Arti e Paesaggio (Special Superintendence of Archeology, Fine Arts and Landscape) of Rome, Italy. The *spezieria di Santa Maria della Scala* was the oldest apothecary in Europe managed by the order of Discalced Carmelite friars. Operating between the second half of the seventeenth century and the mid-twentieth century, over time it acquired great prestige, becoming known as the Pharmacy of the Popes. The aims of the "Roma Hispana" project are to study, musealize and disseminate the material and immaterial cultural heritage of this historical *spezieria* by combining physicochemical and cultural studies, new 3D technologies, and artificial intelligence. As a case study, in this paper we report the application of a laser scanner prototype for 3D color imaging of the *spezieria*'s sales room and use a simpler photogrammetry method to collect analogous data in the small nearby storeroom coupled to the high-power capabilities of the ENEA parallel computer facility. Digital data were collected to enable a virtual tour that provides a fully navigable, faithful, high-resolution 3D color model to render this ancient Roman apothecary accessible and usable to interested members of the public and experts in the sector (art historians, restorers, etc.). We also describe the 3D technology used to obtain three-dimensional images of the cultural assets of these spaces (mostly drug containers) and its results. The ultimate aim of this study is to achieve the virtual musealization of the heritage complex.

Keywords: Roman *spezieria* at Santa Maria della Scala; cultural heritage; intangible culture; museum of the history of science and medicine; new 3D technologies

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1. Introduction

There is a place in Rome that has existed since the late 17th century, that was known and frequented by all social classes throughout the Modern Age, and that today, in a city that treasures more Cultural Heritage than it can sustainably manage, remains more invisible than visible-not only to the millions of tourists who, when visiting Rome, discover (or rediscover) it, but also to the local population. This heritage space, unique of its kind, is a conventual *spezieria* that initially supplied only the community of friars of the Order of Discalced Carmelites who lived there and built the Convent of Santa Maria della Scala in the heart of Roman Trastevere [1]. Shortly afterwards, the *Spezieria dei PP. Carmelitani Scalzi* *della Scala*, as it was known, opened to the public. Soon this historic *spezieria* would become known as the Pharmacy of the Popes, since all the drugs required by the supreme pontiffs and the papal court were prepared and dispensed there. This arrangement enabled the *spezieria* to continue its activity until the mid-20th century, when it closed permanently.

The interior of the *spezieria* of Santa Maria della Scala in Rome offers visitors a melting pot of Historical Heritage that distills millennia of intangible culture at first perceived only through the intense and confusing aromas emanating from the hundreds of containers preserving the substances and formulations that contain the medicinal knowledge and practice of numerous cultural periods. From the perspective of tangible heritage, on the other hand, visitors to the *spezieria* are introduced to the following spaces: the entrance, the sales room (Figure 1), a back room (Figure 2), the Galenic laboratory (Figure 3), an access corridor to the distillation room, the distillation room itself (here known as the *liquorificio;* Figure 4), and an old stone spiral staircase that descends to the cloister of the convent.

Figure 1. The sales room. Photo: Rafael Garay. © *Hispanic Rome Project*.

Figure 2. The back room. Photo: Rafael Garay. © *Hispanic Rome Project*.

Figure 3. Galenic laboratory. Photo: Rafael Garay. © *Hispanic Rome Project*.

The results of the numerous research projects conducted at the *spezieria* over the last seven years (2016–2022) by the Department of Art History of the Universitat de València confirm that the Roman *spezieria* of Santa Maria della Scala is an ancient and historical mosaic of pharmaceutical knowledge [1–6]. These results have been possible thanks to the support provided by various national and international funding sources and to the scientific collaboration of universities, research centers and laboratories in Spain, Italy, France, Portugal and Switzerland, all of which responded in a coordinated manner to the objectives outlined in the first phase of the project (2016–2019). These objectives were (1) to address the physicochemical characterization of the hundreds of drugs contained in the oldest containers at Santa Maria della Scala (which date from the late 17th century and early 18th century); (2) to conduct a historical and cultural study of the substances and recipes identified; (3) to study the geographical and temporal origin of these characterized medicinal treatments and explore their transmission and evolution through time; and (4) to complete the inventory and cataloguing of the personal property owned by this Roman *spezieria*.

Figure 4. Distillation room. Photo: Rafael Garay. © *Hispanic Rome Project*.

Between 2016 and 2017, the physicochemical protocol employed for drug characterization was optimized (Objective 1). This protocol consisted of a combination of microscopic techniques (Optical Microscopy/LM; Scanning Electron Microscopy-X-ray Microanalysis/SEM-EDX), diffractometry (X-ray Diffraction/XRD), spectroscopic techniques (Fourier Transform Infrared Spectroscopy/FT-IT; Raman Spectroscopy; and Nuclear Magnetic Resonance/NMR) and chromatographic techniques, isolated or in tandem (Gas Chromatography-Spectrometry of Mass/GC-MS, Pyrolysis-GC-MS, High-Performance Liquid Chromatography/HPLC). Finally, and always with the aim of improving the detection of organic compounds [4,6], work was conducted with Diffuse Reflectance (DR) and in-phase magnetic micro-extraction online "solid in tube" (Magnetic-IT-SPME) combined with capillary liquid chromatography-diode array detection (CapLC-DAD). The results obtained were analyzed from a historical and cultural perspective between 2019 and 2021 (Objectives 2,3). This analysis enabled the implementation of the project's second phase (2019–2023), which focuses on the conservation and musealization of the tangible and intangible cultural heritage of the *spezieria* at Santa Maria della Scala. Specifically, the objectives of this second phase are: (1) to develop an International Thesaurus and Semantic Web that will bring together this compendium of immaterial culture centered on the drugs present at this historical *spezieria* and facilitate its conservation, knowledge and accessibility through intelligent searches that enable users to find each compound and/or complex formulation from its original nomenclature (Greek, Latin, Hebrew or Arabic) or as recorded in English, Italian and Spanish; (2) to commence the virtual musealization of the site and its cultural assets in order to preserve its tangible cultural heritage in digital format and render visits accessible to those unable to reach the site, e.g., visitors with reduced mobility (the *spezieria* is located on the first floor of the Carmelite convent; (3) to work on an intelligent software model for risk prediction, in museums displaying the history of science and medicine, characterized by the custody of hybrid heritage collections (ceramic containers, glass containers, metal scientific instruments, herbariums as well as sources such as writings, canvases, mural paintings and historical furniture, etc.) in which the degradation factors act differently on each support/work of art. The aim is to implement this model as a pilot experience at the *spezieria di Santa Maria della Scala* with a view to replicating it at other museums to enhance the value of other identical or similar collections. This objective is supported by the inventory and cataloging of the cultural assets of the *spezieria* (first phase of the project/2015–2019; Objective 4).

In this article we describe the work being conducted by the "Hispanic Rome" project with new 3D technologies to enable the virtual musealization of the *spezieria* (second phase/2019–2023; Objective 2). This work, which should be completed in 2023, is being developed in parallel to the creation of the International Thesaurus and the Semantic Web, which will enable users not only to explore the interior spaces of this historic building and its cultural assets online but also to access the site's huge legacy of intangible culture relating to the transmission of medicinal knowledge from antiquity to the contemporary era.

2. Materials & Methods

The aim of the methodology described below is to create the *Virtual Museum: spezieria di Santa Maria della Scala, Rome* and enable its application to all rooms of the *spezieria* and their entire range of cultural assets. The results we present here are those collected so far from the sales room and the back room of the *spezieria*.

2.1. ENEA Digital Acquisition Systems

The Red Green Blue Imaging Topological Radar (RGB-ITR) shown in Figure 5 is a prototype instrument produced at the ENEA FSN-TECFIS-DIM laboratory in Frascati (Rome) belonging to the class of non-invasive, remote, Amplitude-Modulated (AM) 3D color laser scanners based on an active range-finding laser-radar technique. It has recently found various applications in the field of cultural heritage as a tool for fruition, cataloguing, valorization, digital storage, monitoring, diagnostics and support for the restoration of artworks both inside monumental buildings and at archaeologic sites [7–9].

Figure 5. RGB-ITR during the field campaign of May 2021 conducted in the sales room of the *spezieria di Santa Maria della Scala*.

The system presents a monostatic optical layout and a modular design made by an active and a passive module. Its working range is from 2.5 m to 35 m. In all its operating range, the RGB-ITR is able to function without the use of scaffolding or reflective target. The yellow boxes (Figure 5, background) constitute the active module, which comprises the system electronics (detectors, lasers, lock-in amplifiers and motors controller). The black object on the tripod (Figure 5, foreground) constitutes the passive module (optical head), which comprises the system optics (lenses, mirrors, optical mixer, etc.). Both modules are physically separated and optically connected by means of optical fibers with a core of 4 µm (single mode) for the launching stage and roughly 1 mm (multimode) for the receiving stage. This enables the system to also be used in barely accessible or even hostile environments without compromising its performance [10]. A laptop is used for remote handling of the scanning and data-acquisition phases. The laser probe of the RGB-ITR is modulated at two frequencies (double-AM technique), whose values are selected far apart from each other [11]. It is therefore possible to obtain submillimetric accuracy in distance measurement analogous to the xy resolution fixed by the scanner for targets located at distances up to 10 m. For longer target distances (10 m to 35 m), the distance-related accuracy/resolution of the RGB-ITR decreases to a few millimeters.

RGB-ITR enables the simultaneous acquisition of distance (i.e., structural) and color (i.e., reflectivity, RGB triplets) data from a real scene for any sample point (pixel). Combining the collected information opens up new scenarios for remote, differential, point-by-point colorimetry and structural analysis, especially in the field of cultural heritage [12]. The instrument uses three pigtailed, continuous-wave (CW) AM laser sources at optical wavelengths of 440 nm (blue, modulation frequency 1–10 MHz), 517 nm (green, modulation frequency 3 MHz) and 660 nm (red, modulation frequency 190 MHz). The three laser beams are combined into a single ray of white light (spot size 0.5 mm at 10 m and 1.2 mm at 19 m, overall optical power of roughly 5 mW) by means of a Wavelength Division Multiplexer (WDM) connected to the optical head by a single-mode optical fiber. The laser beam is then focused on the target by means of a 40 mm-focal-length, diffraction-limited, achromatic lens (Melles-Griot LAL-011), while a motorized, two-degrees-of-freedom rotating mirror is used to scan the region of interest with a maximum angular step of 0.002° and a maximum sampling rate of 10,000 points per second. The backscattered light is collected in a multi-mode optical fiber and then split again into the three RGB components by another WDM. The RGB return signals are then separately detected by three low-noise Avalanche Photo-Diodes (APDs). These signals are finally analyzed by means of three Stanford SR-844 lock-in amplifiers, which are also used to modulate the laser sources, to obtain the amplitude (RGB triplets) and phase shift (related to target distance) of the collected signal. The RGB triplets are then subject to a calibration procedure as a function of distance, which enables the white point to be fixed in color space by means of raw data preliminarily acquired using a white certified diffusive target (Spectralon STR-99-020) [13]. Calibration curves are acquired for color normalization and white balancing to enable the collected data to be reused for further comparisons over time not only in terms of the structure degradation of an artwork but also in terms of pigment (color) alteration. A satisfactory result in terms of color hue and purity is therefore observable in the RGB-ITR images, which are unaffected by environmental lighting conditions and are characterized by minimized aberrations and the absence of shadows.

Custom copyrighted programs ScanSystem and itrAnalyzer are used to acquire and process the RGB-ITR data, respectively. Faithful, high-resolution 3D color digital models of the investigated real scenes (e.g., artworks) are therefore generated [10].

RGB-ITR successfully matches requirements for applications in the field of cultural heritage—especially in terms of non-invasiveness (no damage to the investigated surfaces), accuracy, versatility and integration—with other imaging systems. RGB-ITR is therefore a suitable and reliable instrument for the accurate fruition of artworks and the realistic mapping of the structural and colorimetric degradation.

The lack of a minimum operation distance meant that the RGB-ITR could not be used in the small (less than 2 m wide) room adjacent to the sales room used to store materials, herbaria and receipts. Therefore, 3D photogrammetry was employed to reconstruct the old wooden closet that was used to host the drugstore spices for fruition purposes. This closet comprises four parts each of which has two shutters, most of which are decorated and painted on the inside. Three of these parts contain boxes for spices, while the other has a display cabinet with salt crystallized samples.

The first step in the workflow [14] was to quickly acquire images with a commodity mirrorless and compact Fuji X-T20 camera equipped with an APS-C sensor with 24 Megapixel and XF18–55mmF2.8-4 R LM OIS lenses configured with an 18 mm focal length. To obtain a complete set of pictures; even of the upper part of the closet; the camera was mounted on an extendible stick bar. With such a simple configuration it was possible to collect roughly 700 pictures of the inner and exterior parts of the closet (with opened/closed shutters) in about half of an hour.

The second step was to upload images onto the ENEA It@cha platform, a software environment hosted on the powerful ENEA Cresco HPC infrastructure that enables remote work with graphic computing software thanks to a web connection. Once uploaded, the images were processed with Agisoft Metashape to obtain a 3D reconstruction thanks to the Structure from Motion (SfM) algorithm [15]. The hardware resources that host the platform (shown in Table 1) obtained a detailed 3D model of the closet interior and exterior in under six hours from 473 images of the exterior and 152 images of the interior.

Table 1. Hardware characteristics of the machine used for both photogrammetry reconstruction and 3D model building.

OS	**Linux 64 Bit Centos 7.3**
CPU	2x Intel(R) Xeon(R) Platinum 8160 2.10 GHz
Memory	188 GB
GPU	Tesla V100 m
Photogrammetry software	Agisoft Metashape v1.7.2
3D model software	Blender v2.82

2.2. EASD-València & Universitat de València Digital Acquisition Systems

An LED Shining EinScan Pro 2X Plus handheld scanner with texture module and volumetric light technology was used to begin the three-dimensional scanning of the cultural assets preserved in the *spezieria*. In this first phase these comprised the wooden boxes that stored the medicinal substances in both the backroom cabinet (Figure 6) and the oldest drug containers as well as the complex formulations (in the 17th and 18th century showcase in the sales room).

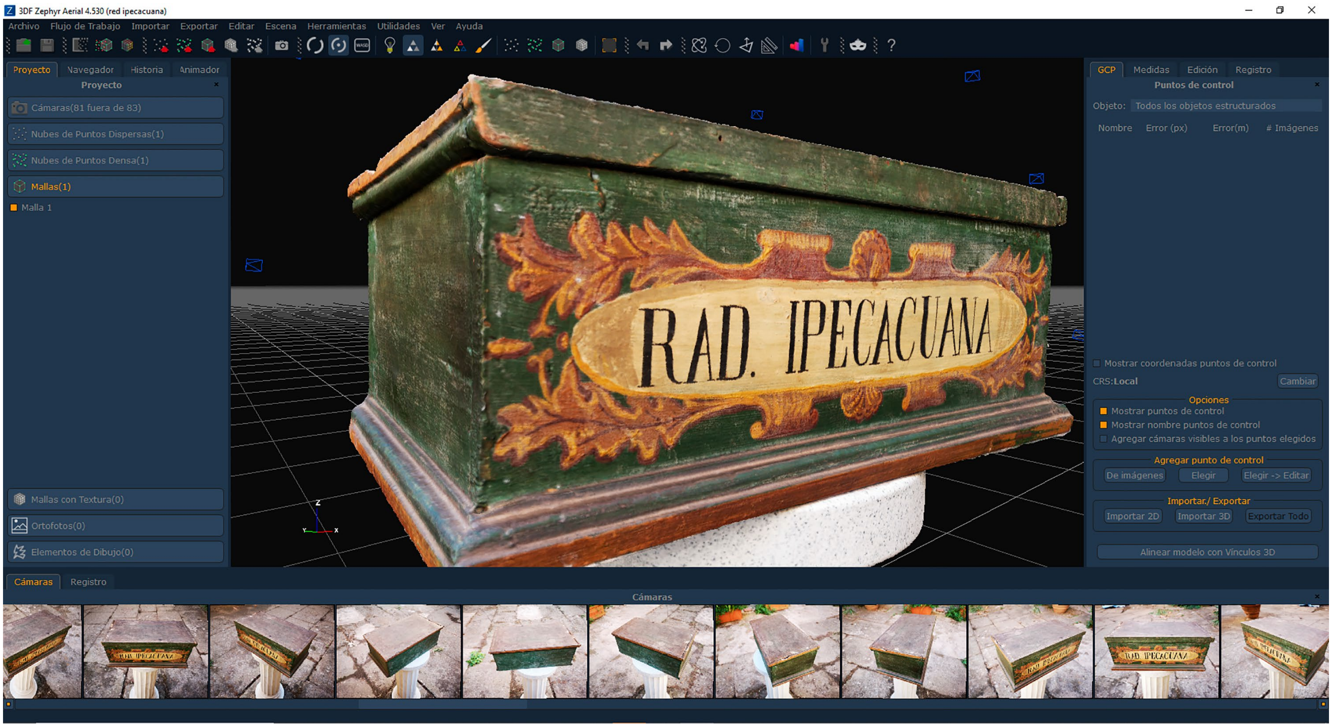

Figure 6. The box in which Ipecacuanha (*Carapichea ipecacuanha*) root, imported into Europe from South America from the 17th century onwards, was preserved. © *Hispanic Rome Project*.

The first step in the workflow was to position each box selected for scanning in an open room at the entrance to the *spezeria* on a small column to enable the handheld scanner to orbit the object and avoid the use of a turntable. The lighting conditions were ideal as the object did not receive direct sunlight. Since the light was diffuse and homogeneous, it was possible to work in “Hybrid Alignment” mode. Alignment was achieved by feature without the need for markers or coded markers. The scanning area ranged from 208 × 136 mm to 312 × 204 mm and the working distance was 510 mm. The scan speed was 30 frames; 1,500,000 points. The scan accuracy was up to 0.1 mm and the volumetric accuracy was 0.3 mm/m. The distance between points ranged from 0.25 mm to 3 mm. Use of the color pack module made it possible to obtain both the geometry and the texture of the object.

The second step in the workflow was to manage all the information received by the scanner. This was achieved by using an MSI i9 Win10 x64 laptop with an NVIDIA RTX3050 graphics card and 3D Multifu. SHINING 3D EinScan. PRO 2X Plus (Valencia, Spain) (Figure 7). The result of each scanned object was a high-resolution mesh in OBJ format with an associated texture in MTL format.

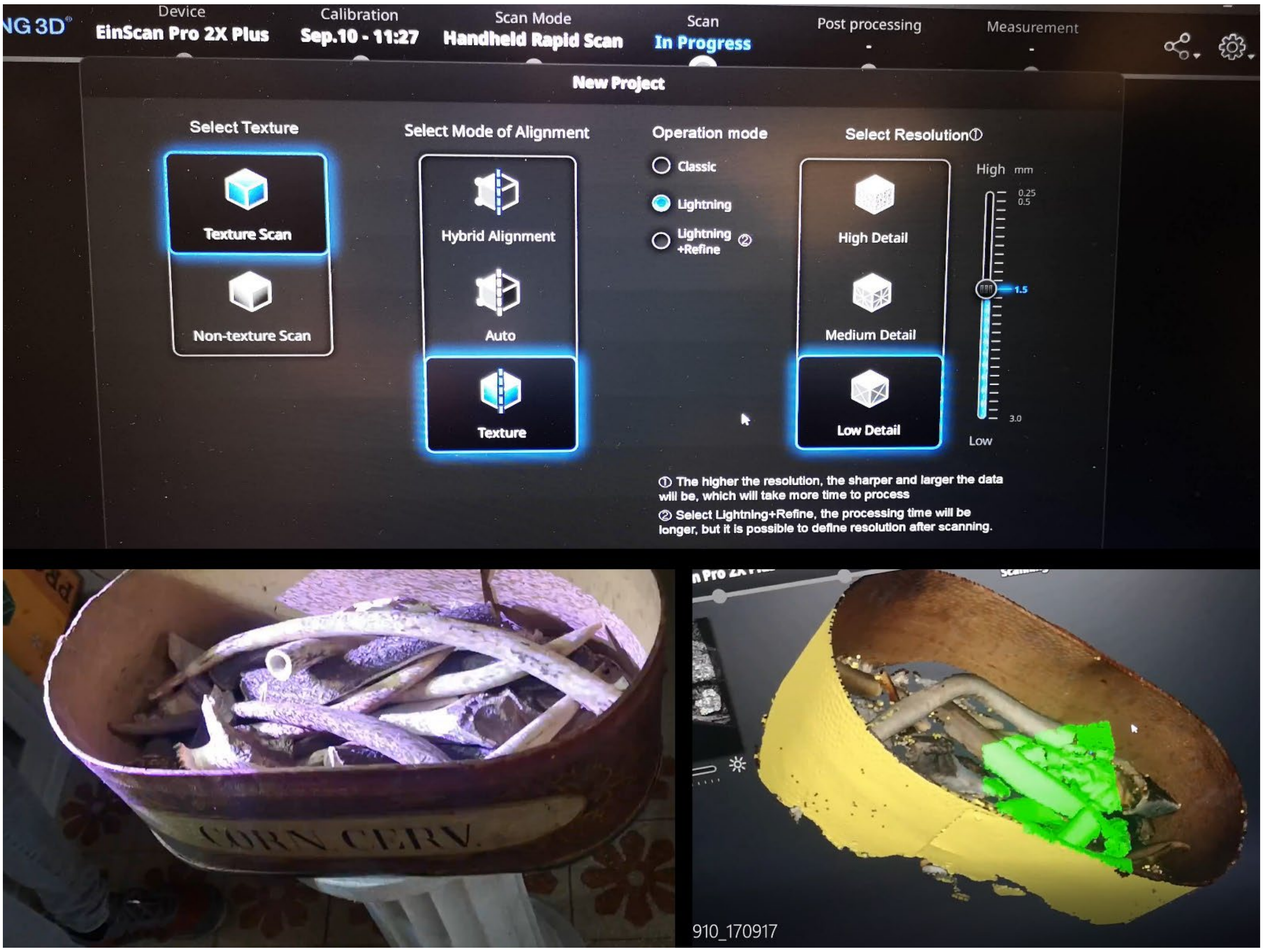

Figure 7. Common settings used in 3D scanning software: EXScan Pro (**above**) and real-time scan results of the *ufficio* box "Corn. Cerv.", uncovered in order to scan its interior, which contained deer antlers (**below**). © *Hispanic Rome Project*.

To add another resource for the online musealization of the *spezieria*, panoramic views were taken of its interior spaces using one of the most traditional techniques employed since the origins of photography, i.e., by "stitching" together several images taken from the same point in order to cover the whole surrounding space.

To ensure that the images were of the highest quality, we used the High Dynamic Range (HDR) technique. This allows for a greater dynamic range of luminance between the lightest and the darkest areas of an image by mixing several photographs at different exposures. Specifically, at Santa Maria della Scala three photographs were taken for each camera position—one with correct exposure, one overexposed to +2EV, and one underexposed to −2E. The stitching of these images was conducted with the best available software for this process, i.e., PTGui Pro. The result of all this work are images in a projection format known as equirectangular, which collects information from the entire interior space (Figure 8). They are images in which the user can move, as also occurs with 3D models obtained using the RGB-ITR technology described earlier.

Figure 8. Panoramic view of the Galenic laboratory. © *Hispanic Rome Project*.

3. Results

In 2021 ENEA conducted two field campaigns in the sales room of the Santa Maria della Scala apothecary. The first of these was from 10th to 14th May and the second was from 25th to 29th October for a total data acquisition time of 80 h.

The laser surveys were performed from a distance ranging from 2.5 m to 7.5 m and at a sampling rate of 3 kHz.

The scanning environment presented a number of problems as several showcases that contained glass objects reflected the laser light in various directions, while a large chandelier in the center of the sales room and a metal rod near the ceiling presented important obstacles to the laser light during the scanning and data-acquisition phases. Nevertheless, interesting results were achieved by the high-resolution 3D color digitalization of the sales room that could be extremely useful for the fruition, valorization, monitoring and diagnostics of the site's state of conservation.

Significant preliminary results obtained in the sales room by RGB-ITR are reported in Figures 9 and 10. Figure 9, in which the color information has been preliminarily calibrated, shows the high-resolution RGB-ITR 3D color model of the sales room (7.0 × 4.5 × 4.0 m). Note that the missing areas are due to obstacles to laser light transmission lines during different acquisitions (such as a large lamp holder hanging from the ceiling). These areas can be successively integrated by adding data from our earlier studies obtained by photogrammetry at a lower resolution [8]. In most cases, the contents of several cabinets containing drugs and color pots and bottles were acquired through the glass windows. The most interesting of these elements is the venom cabinet, which is clearly visible in the lower right-hand side of the model (Figure 9 left).

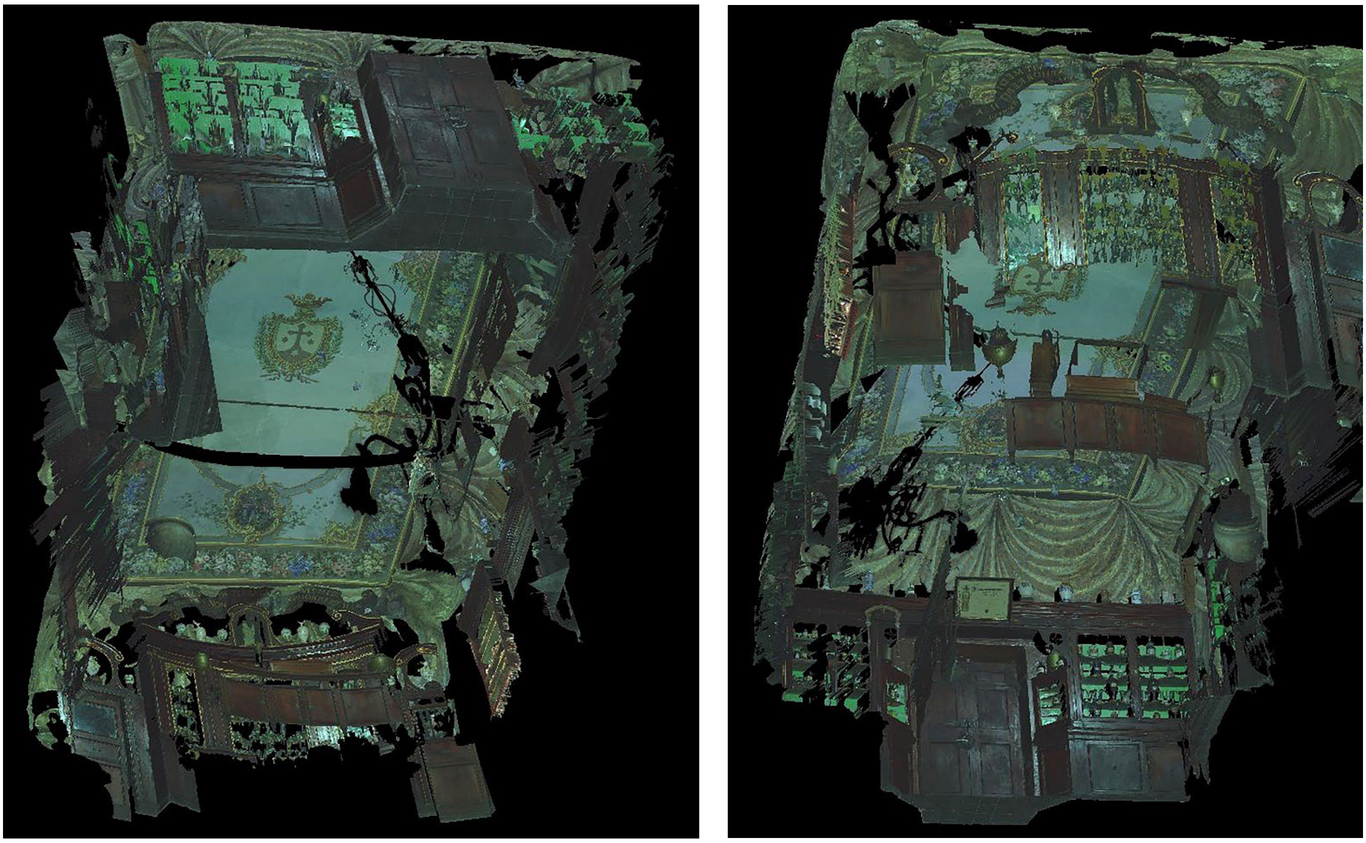

Figure 9. High-resolution 3D color model of the sales room obtained by the RGB-ITR system (October 2021). (**Left**) view of the ceiling, the wall in front of entrance one and the wall on the right-hand side with the poison's cabinet. (**Right**) view of the ceiling and the entrance wall. © ENEA.

A section of the RGB-ITR high-resolution image of the poisons cabinet is shown in Figure 10 (left). Note that the high resolution achieved by the prototype enables the small writing on the glass containers in the poisons cabinet to be read from the target-sensor distance of roughly 4.5 m at which the scanning was performed. The ability to read labels from a distance is of great interest because of the unknown state of conservation of the potentially hazardous substances stored in the containers. A section of the sales room's frescoed ceiling is shown in Figure 10 (right). Cracks in the ceiling are clearly visible. The size of these cracks can be directly measured on the model using the RGB-ITR data (e.g., the lower crack was measured at roughly 1.52 m long and 1–2 mm wide and had a thickness in the order of millimeters). This function enables researchers to study the conservation state of the artworks. In particular, restorers can detect from the model those areas which are subject to structural alterations (such as cracks and paint layer losses), identify where restoration work is needed, and schedule the completion of this work.

Figure 10. (**Left**) RGB-ITR image of a small area of the poison's cabinet in the sales room. (**Right**) section of the frescoed ceiling in the sales room obtained by RGB-ITR raw data. © ENEA.

Photogrammetry, performed with the components shown in Table 1, obtained a model of the interior and the exterior of the closet in under six hours from 473 images of the exterior and 152 images of the interior. The fourth and final step in the workflow conducted by ENEA was the construction of the 3D model using the open-source software Blender to merge the interior and the exterior of the closet to produce an open version, i.e., one with the shutters open, that makes visible both the interior of the closet with its spice boxes and the precious portraits and paintings on the inner side of the shutters (see Figure 11).

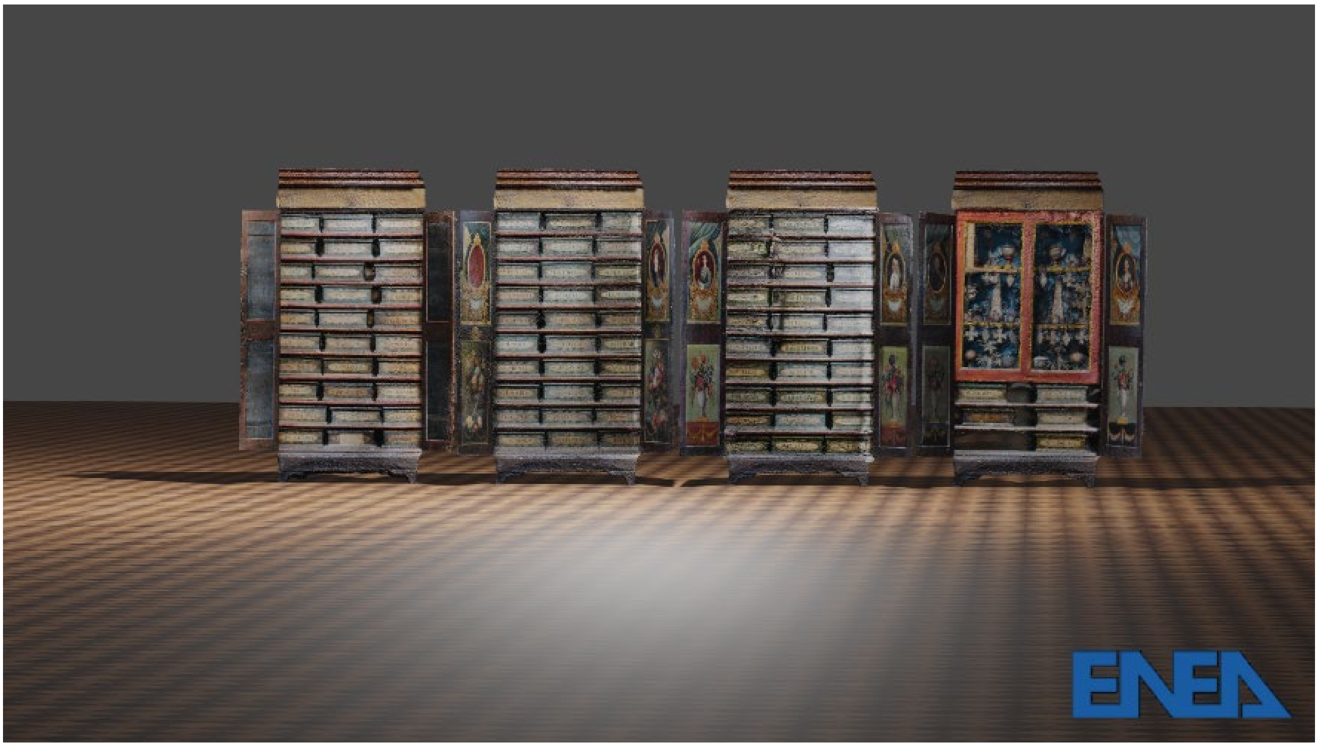

Figure 11. 3D model of the opened closets obtained with Blender. © ENEA.

Photogrammetric reconstruction has proven that this technology and methodology produce good results thanks to rapid and inexpensive acquisition and image processing. They are therefore shown to be a valid support for other diagnostic and survey technologies in a wide range of cases in the field of Cultural Heritage [16].

Finally, few vessels in the Sales Room at Santa Maria della Scala could be three-dimensionally scanned since most of them are made of glass. The results obtained are from boxes and other containers that are mostly made of wood. These results are of vital importance for developing a virtual musealization whose objectives align with those of the international thesaurus and semantic web, work on both of which is currently in progress.

The virtualization of Santa Maria della Scala's interior space is completed with 3D models of the cultural assets of this museum of the history of science and medicine so that future virtual visits integrate all possible narratives. The work carried out in the last two years on the wooden boxes containing the various substances with which the friars prepared their curative remedies has therefore acquired special importance (Figures 6, 7 and 12). These boxes form part of the interior of the back room cabinet shown in Figure 11.

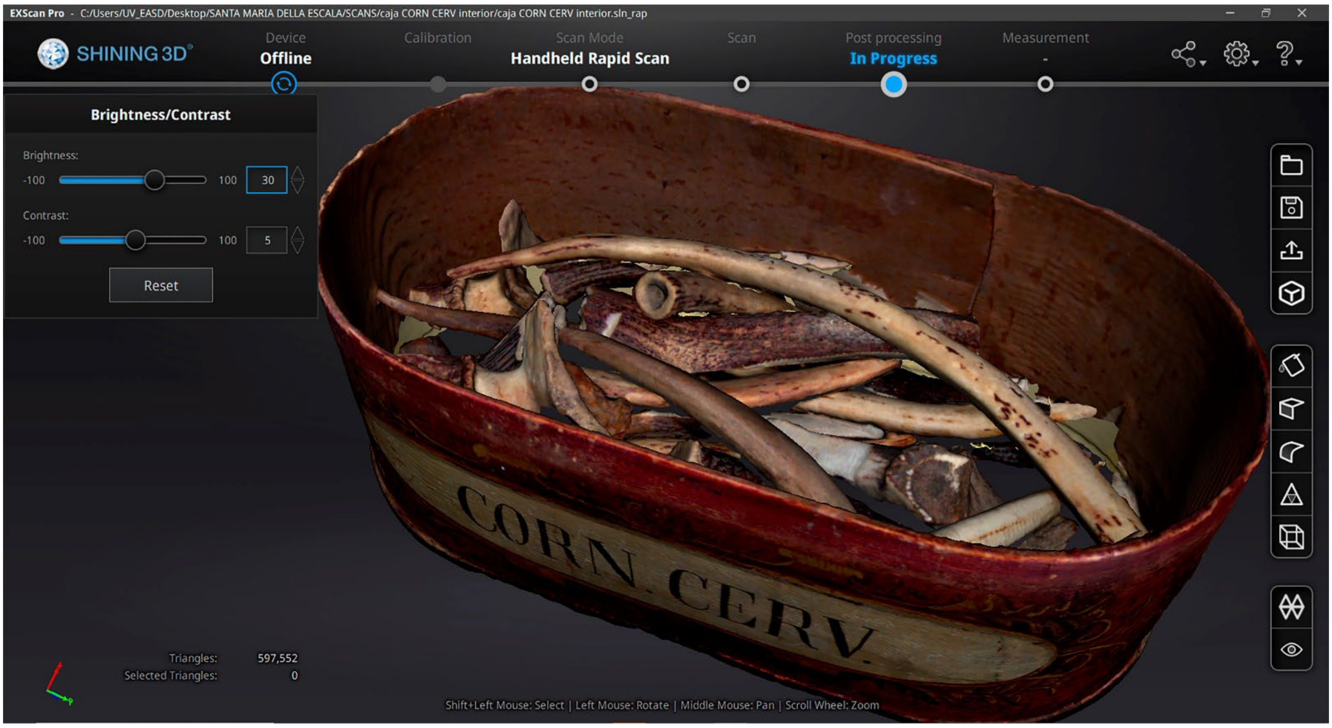

Figure 12. The box in which deer horn (*Corn. Cerv.*) was preserved. © Hispanic Rome Project: the *spezieria* of Santa Maria della Scala.

Finally, the panoramic views will make it easier for users to move around the rooms of the *spezieria*. Whether they choose to navigate using the 3D model or the panoramic views, they will be able to reach the interior spaces of this historic apothecary (Figures 1–4), approach, select and open its cultural assets, and display information about the medicinal treatments preserved there.

Unlike 3D scanned spaces, the use of which requires tools and specific knowledge, virtual tours with 360° panoramic photographs enable information to be disseminated to a greater number of users, since internet connection and a computer or mobile device able to immerse in the virtualized space are sufficient.

As well as linking the various perspectives from which we have photographed the space, the tools we used to generate the virtual tours enable us to add various levels of information (e.g., videos, PDFs, 3D models of objects and sounds) that we can access from interactive points known as hot-spots, which can be updated whenever new information is available to add to our virtual tour.

To obtain the equirectangular images with which the virtual tour was generated, the entire space surrounding the point of view where we placed the camera had to be photographed. One of the most important steps was therefore choosing the points of view to show a given space with a sufficient level of detail and information (Figure 13).

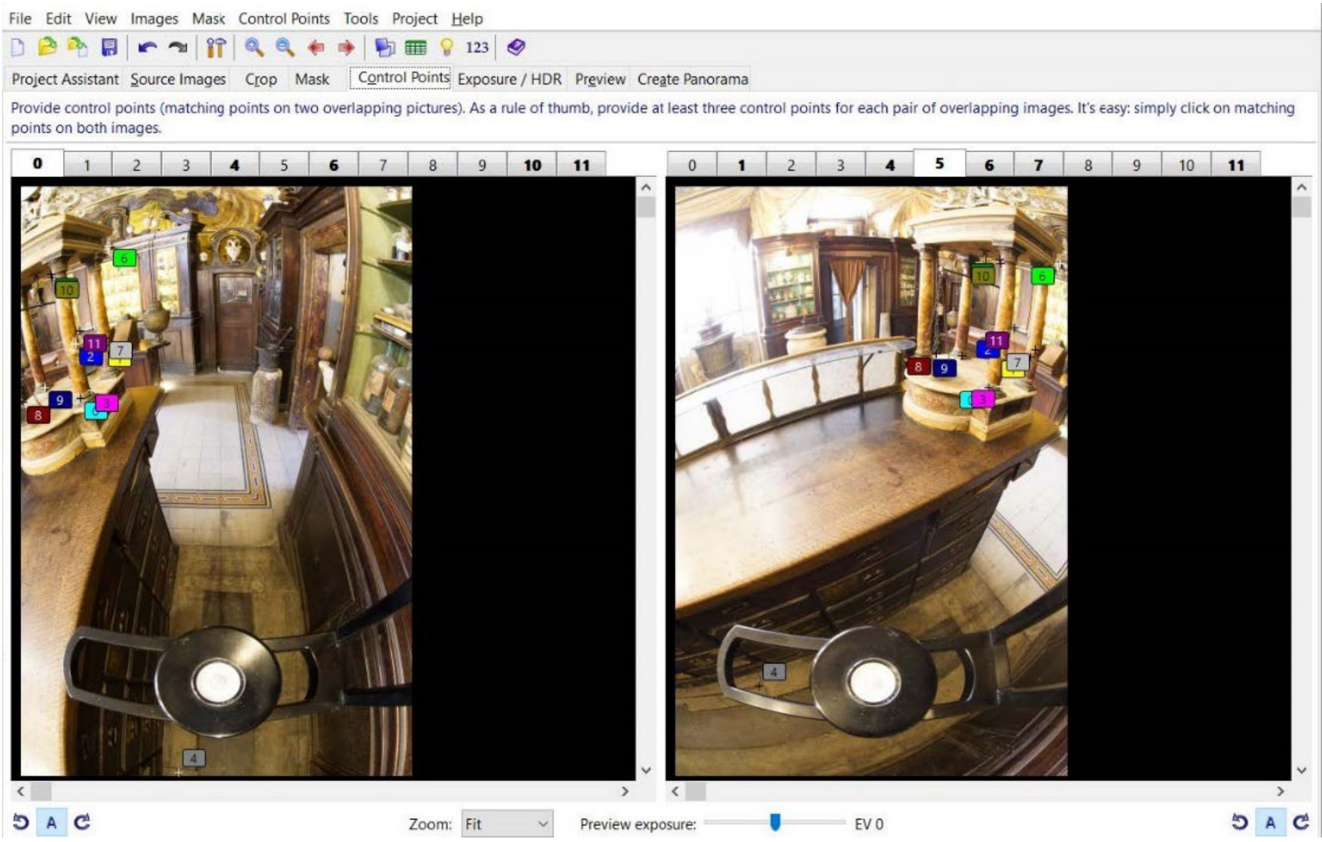

Figure 13. Matching points manually between pair of images. © Hispanic Rome Project: the *spezieria* at Santa Maria della Scala.

The virtual musealization of the spaces that make up the ensemble at the *spezieria di Santa Maria della Scala* required three sequential and completely different processes: (1) acquire data by taking the photographs needed to produce the equirectangular panoramic images that enable access to each chosen location inside the *spezieria* and their various spaces; (2) process these photographs to obtain, at a later stage, equirectangular panoramic photographs of each space; and (3) merge these panoramic photographs to generate a virtual tour of each chosen space. The workflow for obtaining the equirectangular panoramas was always the same, i.e., (a) adjust the shooting position; (b) take the photographs; (c) process the RAW photographs; (d) conduct HDR processing; (e) merge the photographs.

Once the equirectangular panoramic photographs of each chosen 360° point of view were generated, virtual tours of the various areas of the *spezieria* at Santa Maria della Scala were generated using 3DVista Pro software. This software enabled us to link our equirectangular panoramic photographs and add other levels of information via interactive hot-spots where users could be provided with materials such as videos, documents, 3D models and sounds.

Virtual visits were also generated in a set of sequential and quite differentiated phases. The first of these involved incorporating all the elements that make up our project into the 3DVista virtual tour editor: from equirectangular panoramic photographs to 3D models, including other elements such as videos. At a later stage (1) links were created between these elements, (2) links to elements other than panoramic photos were added using traditional icons, and (3) the virtual tour, edited with 3DVista and comprising both the elements and the links between those elements (Figures 8 and 14–16), was generated. We then began the process of hosting all the generated files on a web server to enable access to the virtual tour of each room via a specific URL. The URL for the virtual tour of the *ufficio*, for example, is: https://santamariadellascala.uv.es/panos/ufficio (accessed on 5 June 2022).

Figure 14. Panoramic view of the sales room. © *Hispanic Rome Project*.

Figure 15. Panoramic view of the back room. © *Hispanic Rome Project*.

Figure 16. Panoramic view of the distillation room. © *Hispanic Rome Project*.

4. Discussion

The purpose of combining all these 3D technologies and applying them to the spaces and cultural assets of the *spezieria di Santa Maria della Scala* in Rome is to present the apothecary's *Virtual Museum* in 2023 as a pilot model for other museums of the history of science and medicine. We conceive this museum as one in which users will be able to move around the rooms of the *spezieria* online, approach its various cabinets and showcases, open them, and point to a drug container to open a window with pharmaceutical, historical and cultural information about the treatment stored within it that has previously been collected in the International Thesaurus and Semantic Web currently being worked on with artificial intelligence. This unique experience in museums of this category aims to become a national and international reference for identical or similar projects and collections whose tangible and intangible heritage is presented as a great legacy of cultural identity and historical memory.

This approach has already been demonstrated for the 3D model of the Blue Daemon Tomb in Tarquinia, which was formerly collected by the same RGB-ITR prototype [17]. Point and image data collected by other instrumentation were linked to the 3D model in such a way that information on surface morphology and composition, including constituents (original materials, pigments and degrading agents such as saline efflorescences), could be acquired simply by interrogating selected geometrical locations relevant to the additional measurements or performed data elaboration.

Specifically, the website could be used to upload the 3D model of interest, such as that which reproduces the Sales Room, the poisons cabinet, or the wooden closet in which the drugstore spices were kept. The 3D models could be stored in a database and made accessible to external users through commercial software such as MeshLab by means of a direct link from the website. One possibility for this is to use ENEA's CRESCO (or other) platform, especially for uploading the model and making it usable to the public through suitable 3D imaging software.

In summary, the following information is provided by the collected 3D models:

(a) The surface conditions of the fresco paint on the walls and roofs, including the position and metric information (length, area) of cracks and detachments, which can be obtained automatically by available software such as the Measuring Tool feature of MeshLab commercial software. This may be important for preserving the rooms' painted surfaces and for monitoring the structural integrity of the whole building, as has been demonstrated over several years in checks on critical structural elements of Orvieto Cathedral [9].

(b) The drug and spice contents of the glass vessels and wood cabinets. This can be organized via links to information collected by various analytical techniques and made accessible by pointing at the container labels on the 3D model. This will be like opening the container and holding, rather than the physical object, all the scientific information about its contents (e.g., composition of chemicals, classification of herbs, dating of wood and organic substances, provenance of all materials) and the methodology used to acquire that information (spectroscopy, spectrometry, gas chromatography, etc.) as well as the opportunity for experts and the general public to consult original data.

The additional value of the 3D model complements its intuitive use for a virtual tour of the *spezieria*, which is currently not included in the mainstream circuit of visits in Rome. Virtual visits on the internet will help to promote knowledge of the site. Virtual visits are also of paramount importance since real visits are likely to remain limited in the near future. This is due to substantial limitations related to internal access via stairs, the small location site, and the building's maintenance requirements.

With regard to the field work conducted to scan objects in three dimensions, we should mention that finding suitable space and lighting conditions is complex because this type of work coexists with others, such as taking physical-chemical samples or photographs for virtual tours and artwork, and a small set must therefore be improvised in a space that does not interfere with any other work. This was achieved in the lobby in front of the entrance to the sales room. On the other hand, lighting conditions in the patio were optimal since the northerly orientation provided indirect and homogeneous light and so many objects were scanned there. However, this posed a risk when the objects were moved.

In addition, the volumetric light technology used by the hand scanner made it impossible to scan transparent, translucent or metallic-reflective objects. Many medicines were kept in small glass containers. To generate 3D images of them, a set was therefore created in the patio and back room to be able to make orthophotographs of both elevations as of plants from each jar. From these photographs, three-dimensional meshes can be made using the Blender software. This leads to the possibility of working with the system provided by photogrammetry. Mesh calculation tests were carried out by photogrammetry using these sets plus a reflex camera with RAW technology to later perform calculations with RealityCapture software. Surprising results were obtained, though the calculation of the objects was not performed in real time as they were when the hand scanner was used.

Finally, we believe virtual tours are an alternative way of visiting a location and have the following advantages:

(a) Availability is continuous and the space does not need to be visited on the days and hours it is open.

(b) The space does not suffer by being visited by thousands of people. The paradox with protected spaces is that exhibiting them to promote their value is inevitably associated with their deterioration.

(c) The space is accessible to people with mobility limitations. Virtualization makes any space accessible.

(d) Virtualization allows for an individual experience of the visit that is completely different from the experience one has when physically visiting a museum in a large group.

What we have created so far are virtual tours that disseminate knowledge about this unique space. In future work we wish to embed documentary (herbalist) and multimedia (video and audio) elements to them by taking advantage of the options provided by 3Dvista software. This software also enables tours with virtual reality glasses or on computers without an internet connection.

5. Conclusions

The "Roma Hispana" project today is a reference as both an international scientific initiative involving the collaboration of five European countries and an interdisciplinary initiative integrating over 10 disciplines from five areas of knowledge recognized in our national research and transfer system, i.e., (a) arts and humanities, (b) sciences, (c) health sciences, (d) social and legal sciences, (e) engineering and architecture. This enables us to recompose both the history of this *spezieria* and the collection of knowledge and medicinal traditions it contains. This information is helping to trace new museographic discourses and itineraries that can be visited in situ or in the virtual mode whose horizon is the space's accessibility and collection and the knowledge it provides for all those who, for one reason or another, cannot reach it. Without doubt, the European networks this project has created and been consolidating for years—and which currently involve scientific collaborations and common goals between various historical *spezierias* and the research groups that investigate them—are the best result we could aspire to since they help to visibilize a common history about drugs, the treatment of disease, and cultural meanings, while contributing to the history of science and medicine. In this rich collection of material and immaterial heritage, the history of culture also finds resources with which to better understand a present that has never before experienced so closely the impact health can have in the fields of culture and society.

Finally, another important result is that the work conducted in recent years at Santa Maria della Scala has prompted the Sovrintendenza Speciale Archeologia Belle Arti e Paesaggio di Roma to commit to the forthcoming restoration of the building. There is no better example of how research of excellence in the field of Cultural Heritage can lead to alliances with public administrations to promote the conservation and restoration of Historical Heritage. This is something we owe future generations because within the *spezieria's* walls, images, colors, canvases, boards, aromas, and other cultural assets is the cultural heritage that explains the origins of what we are today: the lights and shadows of a history we cannot change but which enables allows us to learn in order to build a more sustainable world that safeguards human rights. These rights include access to heritage and culture and the enjoyment of them as sources of identity, well-being and health. We must remain committed to working together to make this possible and one way to do so is to apply new 3D technologies to the study, conservation and musealization of cultural heritage.

The preliminary results we present here illustrate how laser scanning and photogrammetry are important for obtaining information about the state of conservation of the surfaces investigated at the *spezieria*. These digital data enable proper scheduling of restoration or recovery work for the damaged surfaces, while the high-resolution 3D color models enable the valorization and virtual fruition of the room under study. At the same time, the three-dimensional scanning of objects and their link to the International Thesaurus and Semantic Web on the drugs, aromas and species preserved there (in progress), as well as their historical transmission (the subject of another article), are helping the *Virtual Museum: the spezieria di Santa Maria della Scala, Rome* (2023) to bring together Cultural Heritage of a material and immaterial nature. This latter aspect, i.e., the immaterial culture of millenary origin and its transmission, transforms users' in situ and online visits to Santa Maria della Scala in Rome into a journeys through time.

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References

1. Vázquez de Ágredos Pascual, M.L.; Cavallo, G.; Pagiotti, R. (Eds.) *Drugs, Colors & Aromatics. Tradition & Innovation in the Materia Medica of Italian Baroque: Studies from the Spezieria of Santa Maria Della Scala, Rome*; Aboca Edizione: Sansepolcro, Italy, 2022.
2. Vázquez de Ágredos Pascual, M.L.; Rojo Iranzo, L.; Cavallo, G.; Walter, P.; Van Elslande, E.; Izzo, F.C. Tradition and Renovation in the Ancient Drugs of the Spezieria di Santa Maria della Scala (Rome). Between Scientific Knowledge and Magical Thought. *Eur. J. Sci. Theol.* **2018**, *14*, 3–12.
3. Cavallo, G.; Vázquez de Ágredos Pascual, M.L. X-ray Powder Diffraction of Mineral Pigments and Medicines from the 17th Century Pharmacy (Spezieria) of Santa Maria della Scala in Rome, Italy. *Powder Diffr.* **2018**, *33*, 270–278. [CrossRef]
4. Izzo, F.C.; Lodi, G.C.; Vázquez de Ágredos Pascual, M.L. New Insights into the composition of historical remedies and pharmaceutical formulations: The identification of natural resins and balsams by gas-chromatographic-mass spectrometric investigations. *Archaeol. Anthropol. Sci.* **2021**, *13*, 2. [CrossRef]
5. Martínez García, M.J.; Vázquez de Ágredos Pascual, M.L. Ancient dyes with medical and pharmacological properties. In *Dyes in History and Archaeology 35–36*; Kirby, J., Ed.; Archetype Publications: London, UK, 2021; pp. 89–107.
6. Lodi, G.C.; Borsato, G.; Vázquez de Ágredos Pascual, M.L.; Izzo, F.C. Disclosing the composition of unknown historical drug formulations: An emblematic case from the Spezieria of St. Maria della Scala in Rome. *Anal. Bioanal. Chem.* **2020**, *412*, 7581–7593. [CrossRef] [PubMed]
7. Guarneri, M.; Danielis, A.; Francucci, M.; Ferri de Collibus, M.; Fornetti, G.; Mencattini, A. 3D remote colorimetry and watershed segmentation techniques for fresco and artwork decay monitoring and preservation. *J. Archaeol. Sci.* **2014**, *46*, 182–190. [CrossRef]
8. Caneve, L.; Colao, F.; Francucci, M.; Guarneri, M.; Mongelli, M.L.; Spizzichino, V. Non-invasive diagnostic investigation at the Bishop's Palace of Frascati: An integrated approach. *ACTA IMEKO* **2021**, *10*, 180–186. [CrossRef]
9. Fantoni, R.; Guarneri, M.; Francucci, M.; Caponero, M.A.; Lazic, V.; Pierattini, S.; Mongelli, M.L. Digital Imaging and Related Remote Diagnostics: New Tools to Support, Safeguard and Address the Conservation of Cultural Heritage. In *The Safety and Security of Cultural Heritage in Zones of War or Instability*; Romiti, B., Folliero., A., Eds.; NATO Science for Peace and Security Series: Human and Societal Dynamics; IOS Press: Amsterdam, The Netherlands, 2021; Volume 153, pp. 80–93.
10. Ricci, R.; Ferri De Collibus, M.; Fornetti, G.; Francucci, M.; Guarneri, M.; Paglia, E. ITR: A laser rangefinder for cultural heritage conservation applications with multi-sensor data integration capabilities. In Lasers in the Conservation of Artworks, Proceedings of the International Conference Lacona VII, Madrid, Spain, 17–21 September 2007; Marta, C., Moreno, P., Oujja, M., Radvan, R., Ruiz, J., Eds.; CRC Press: Boca Raton, FL, USA, 2007; pp. 447–452.
11. Poujouly, S.; Journet, B. A twofold modulation frequency laser range finder. *J. Opt. A Pure Appl. Opt.* **2002**, *4*, S356–S363. [CrossRef]

12. Guarneri, M.; Ferri De Collibus, M.; Fornetti, G.; Francucci, M.; Nuvoli, M.; Ricci, R. Remote colorimetric and structural diagnosis by RGB-ITR color laser scanner prototype. *Adv. Opt. Technol.* **2012**, *2012*, 512902. [CrossRef]
13. Danielis, A.; Guarneri, M.; Francucci, M.; Ferri De Collibus, M.; Fornetti, G.; Mencattini, A. A quadratic model with nonpolynomial terms for remote colorimetric calibration of 3D laser scanner data based on piecewise cubic Hermite polynomials. *Math. Probl. Eng.* **2015**, *1*, 606948. [CrossRef]
14. Puccini, M.; Camassa, A.; Mongelli, M.L.; Pierattini, S.; Migliori, S.; Canciani, M.; Spadafora, G.; Saccone, M. Integrated Survey and 3D Processing on ENEA CRESCO Platform: The Case Study of San Nicola in Carcere in Rome. In Proceedings of the 2021 International Conference on Metrology for Archaeology and Cultural Heritage (MetroArchaeo 2021), Milan, Italy, 20–22 October 2021.
15. Mongelli, M.L.; Chellini, G.; Migliori, S.; Perozziello, A.; Pieratini, S.; Puccini, M.; Cosma, A. Photogrammetry and structured light: Comparison and integration of techniques in survey of the Corsini Throne at Corsini Gallery in Rome. In Proceedings of the 2019 IMEKO TC-4 International Conference on Metrology for Archaeology and Cultural Heritage, Florence Italy, 4–6 December 2019.
16. Mongelli, M.L.; Bellagamba, I.; Perozziello, A.; Pierattini, S.; Migliori, S.; Quintiliani, A.; Bracco, G.; Tati', A.; Calicchia, P. Photogrammetric survey to support Non Destructive Tests at St. Alexander Catacombs in Rome. In Proceedings of the MetroArcheo 2018, Cassino Italy, 22–24 October 2018.
17. Ceccarelli, S.; Guarneri, M.; Romani, M.; Giacopini, L.; Francucci, M.; Ciaffi, M.; Ferri de Collibus, M.; Puiu, A.; Verona-Rinati, G.; Colao, F.; et al. Are the blue daemons really blue? Multidisciplinary study for the colours characterization of the mural paintings inside the Blue Daemons Etruscan tomb. *J. Cult. Herit.* **2021**, *47*, 257–264. [CrossRef]