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Identifying, restoring, and remastering of the Sarinah relief sculpture in Jakarta of Indonesia: the limitations of time, space, and technology

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Abstract

The Sarinah historic building transformation project in Jakarta, Indonesia (2020–2022) is an adaptive reuse of the original building formed through a scientific conservation process. Therefore, this research identified, restored, and remastered the Sarinah relief sculpture of *alto-relievo* (high relief) and *mezzo-relievo* (medium relief). The invasive demolition method was used to form an atrium space to show the reappearance of the artwork by dismantling two layers of building floors above where the relief was found. The non-invasive method was implemented (a) by identifying damaged mapping artifacts, (b) by restoring, cleaning, and repairing the broken artifacts, and (c) by remastering the 3D model. All activities were supported by digital applications such as the Cartesian diagram coordinates, AutoCAD, Adobe Photoshop, Zbrush software, and close-range photogrammetry. The case study's contribution to heritage science showed the process used to restore *alto-relievo* and *mezzo-relief within* time, space, and technology limitations.

Keywords *Alto-relievo*, Lightweight concrete, Relief sculpture, Photogrammetry, 3D virtual mold

Introduction

The contributions of relief sculpture to "grand narratives" are associated with religious ideologies and political movements used to justify social and political institutions. According to preliminary studies, the attractiveness of sculpture is defined as *alto-relievo* (high relief), *mezzo-relievo* (medium relief), and *bas-relievo* (low relief) [1]. The best samples of alto-relievo include the Apollo in Bassae (*c.* 429–400 BCE) and the Parthenon East pediment marble (438–432 BC) [2], some of which were shown at the New Acropolis Museum in Athens [3]. Owen stated that the Indian relief sculpture in the Kailasanatha at Ellora was the largest monolithic rock-cut, with a height and length of approximately 32 and 78 m, respectively [4]. In South-eastern Bulgaria, pirovska, a specific mezzo-relievo made from silver breastplate with zoomorphic, was used to decorate Museums [5]. Aplin stated that the ancient Assyrians of Ashurbanipal hunted a lion (645–635 BC), and the remains were shown in the British Museum's low-relief sculpture or *bas-relief* panels [6]. Similarly, Bryant [7] reported that *The Progress of Civilization (1851–1852)* was found at the portico in the South Entrance of the British Museum.

Several centuries later, reinforced concrete materials were used to make statues alongside Modernist Architecture. The Torso (1926) was the first concrete casting

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designed by Artist Henry Moore [8]. Afterward, the giant statue of *Christ the Redeemer* of Brazil was placed in a 30-m concrete sculpture [9]. In the 1950s, Brasilia was well-known as an Architectural Sculpture [10]. Ardhiati stated that in the 1960s, several modern architectural structures were recognized in the facades of the buildings in Jakarta City. These were constructed using various materials and artifacts, such as stone sculpture, wood, bronze, copper, ceramic mosaics, murals, and copper to show the grand narratives of Indonesian cultural diversity proposed by Mr. Soekarno [11, 12], and also led to the development of lightweight concrete [13].

The first department store in Jakarta during the pandemic from 2020 to 2022, part of the Modernist Indonesian legacy, was named Sarinah Project Transformation. The legacy aimed to enhance the original form of the building (1960–1966), which comprised scientific conservation and digital analysis through the application of invasive and non-invasive procedures. During the renovation process, lightweight concrete-based relief sculptures were rediscovered. Part of it had been concealed on the ground floor for 30 years inside the former Air Handling Unit (AHU) engine room [11, 12] and required a major restoration. The Sarinah relief sculpture was made of lightweight concrete attached to the wall of the building, layered to form *alto-relievo* (high relief) consisting of 15 figures and objects, and *mezzo-relievo* (medium relief) comprising a panoramic background as well as Indonesian agriculture and maritime. These expressed a localized heroic narrative about the agrarian civilization of the people before the arrival of Modernism and Independence. During the early restoration of the Sarinah project, the Jakarta Post (2021) reported that [14]:

> *"...Project Farmers residing in conical hats evoked idyllic Indonesian rural life while harvesting rice paddies. Meanwhile, a group of women from neighbouring villages carrying their wares to the market past grazing water buffaloes. These scenes were extracted from the Sarinah Relief, measuring 12-by-3-meter uncovered at the Jakarta departmental store in October 2020. The workers found the stone and cement structure in the warehouse of the shopping center after it had closed for renovations in June last year. President Sukarno was thought to have commissioned reliefs, mosaics, and other artworks before Sarinah opened for business in 1966.*

The first relief sculpture from lightweight concrete restoration by an artist-conservator must be properly evaluated. According to Ahmed [15], these are still rare in Indonesia, including experts capable of operating digital photogrammetry and sculpting software. Evaluating the situation showed the main problem associated with restoring the rediscovered relief sculpture to meet the Sarinah transformation project (2020–2022), which was ongoing during the Pandemic, irrespective of time, space, and technology constraints.

Bacci conducted a scientific conservation and digital analysis process integrated with invasive and non-invasive technology [16]. Furthermore, the Indonesian Conservation Law Number 11 of 2010 must be implemented by a Cultural Heritage Expert Team [17] in line with the international declarations, such as the Amsterdam Paper (1975), Nara Document (1994), Faro Convention (2005), and Central Melbourne Design Guide (2021). Invasive demolition was carried out at the location where reliefs were found on the ground floor by dismantling the two-story building to form an atrium space showcasing sculpture. Meanwhile, non-invasive technology focused on (a) identifying or mapping the broken artifacts, (b) restoration, meaning how to clean and repair relief sculpture, and (c) remastering or generating a 3D model as a virtual mold based on the original, which was printed by chance on any scale.

This research contributed to the scientific heritage by restoring relief sculpture (as *alto-relievos* combined with *mezzo-relievos)* despite time, space, and technology constraints by simultaneously applying manual drawings and digital images.

Method, theory, and material

Digital technology and theory

The application of non-invasive methods in scientific heritage entailed the use of photogrammetry. This scientific method determines the position, shape, and dimensions of objects and phenomena in photographic images. Furthermore, the measurements are not made directly on the objects. For historical artwork, digital photogrammetry and terrestrial laser scanning were used in outdoor objects [18–20] Yastikli stated that documentation of historic buildings was performed using these technological methods [18]. Meanwhile, Guery et al. used the same methods to document the preservation of cultural heritage [19]. Fawzy used close-range photogrammetry and a hybrid laser scanning system to evaluate the historic mosque building at Kafrelsheikh University. The laser scanning system, characterized by the ability to scan at 360° horizontally and 270° vertically, covered distances of approximately 350 m [20]. However, photogrammetry, a relatively low-cost technology, requires a camera and specialized software to function efficiently and accurately. It can be carried out with a handheld camera or drone, including using UAVs in architecture surveys [21]. Recently, the measurement process was preferably carried out using a smartphone [22] to ascertain the scanning and modeling systems of 3D objects. Generally, the model can be morphed based on the front and side views of 2D photos or figures concerning specified measurement points such as waist, hips, thighs, etc. This easy method motivated and inspired the younger generation to develop and implement low-cost procedures for 3D modeling.

Klein conducted research on photogrammetry by comparing image-based and manual field survey methods for indoor as-built documentation assessment and obtained only an average error of approximately 2% [23]. After investigating several software, Gagliolo et al. stated that photogrammetric products focused on the realization of two different objectives, namely documentation and the restoration of Cultural Heritage to preserve artistic, historical, and testimonial values [24]. A specific kind of photogrammetry and terrestrial laser scanning (TLS) are the methods widely used for 3D metrical reconstruction. The methods are costly and difficult to handle because they need accurate planning to satisfy the required precision, number, location of scans, and orientation of images for TLS and photogrammetry, as shown in Qasr Al-Abidit, Jordan by Alshawabkeh [25]. According to Lucet, the photogrammetry applied to historical artwork must be implemented with a Photo Modeler Scanner supported by an Autodesk 3D Max. A free-standing sculpture, specifically a *chac-mool* figure of the pre-Hispanic culture representing the Mayan and Aztec worlds, was examined concerning standardization. [26]. Zhang, used a similar method to design line-based sunken *bas-relievo* (low relief).[27]. Furthermore, Frank et al. examined the partial reconstruction of a 3D model showing the tomb of Sir John Neville at Durham Cathedral, County Durham, UK [28].

Tucci researched the Zbrush software application using high-quality 3D models to virtually restore the lost face of the shown loggia (1512). During the process, a mesh model of the female figure whose face had been lost was reproduced, which consisted of the reconstruction hypothesis based on surviving elements and virtually incorporated anthropometric data [29]. However, after the development of 3D software, Dovramadjiev successfully designed 3D models of ancient angel fragment Odessos from the city of Varna. The models were produced using photogrammetry supported by Autodesk ReCAP, Blender, and Autodesk Mesh Mixer software application. Because the software can be integrated with others, it is commonly used, including the UAVS photogrammetry for architecture surveys.[30].

Lhuillier stated that the lack of photogrammetry software provided neither vertical direction nor scale, aside from the advantages [31]. The experiment focused on computed orientation, with the camera motion on a horizontal plane during the image acquisition process, making it easy to define the process manually. However, the result obtained was unsatisfactory, including the inaccurate vertical estimation. Scher focused on obtaining the accurate result of photogrammetry by proving that the distance between two points on a plane parallel to the photograph can be determined by being measured on the image. Assuming the scale (s) of the image is unknown, then it is determined by multiplying the measured distance by $1/s$.[32].

Portland State University reported that the Collinearity Condition Formula was expressed as a mathematical model when the perspective center, image, and corresponding ground points were on a straight line. This is consistent with the book titled *Close Range Photogrammetry and Machine Vision*, published by Atkinson in 1996. Assuming the collinearity condition was achieved on both photos in a stereo pair, the ground X, Y, and Z can be computed from the x and y image coordinate system [33].

Meanwhile, Penn State University reported that there are three types of imagery or photography, depending on the angle the optical axis of the camera makes with the vertical (nadir). These include (a) true vertical photography $\pm 0^\circ$ from nadir, (b) tilted or near-vertical photography $> 0^\circ$ but less than $\pm 3^\circ$, (c) oblique photography between $\pm 35^\circ$ degree and $\pm 55^\circ$ off-nadir. The vertical photograph is an image taken with the camera facing downward. An aircraft in motion cannot capture a true vertical image because the movement affects the camera. This definition enables a few degrees of deviation from the nadir (the line connecting the lens frontal point and the point on the ground exactly beneath the aircraft). A vertical image faces downward to the ground or a few degrees to either side of the aircraft [34]. According to the reviews of several digital technologies, the use of photogrammetry was recommended for (a) outdoor [18–22], indoor and architectural areas [23–25], free-standing object of artwork [26–28], 3D model [29, 30], unsatisfactory rendering [31, 32] and, accuracy in vertical images [33, 34].

Cleaning, restoring, remastering theory

The laser method transmits nanosecond-length pulses of laser light through the artwork surface to detect extremely dirty statues on sculptures, monuments, and architectural details found outdoors [35]. According to Pouli, two-wavelength methods were used in Athens to remove dark deposits and encrustations accumulated on the surface mainly due to environmental pollution for approximately 2500 years. The presence of soot and heavy metals, including copper (Cu), lead (Pb), iron (Fe), zinc (Zn), and sulfur dioxide [36], were also found on statues [37], provided detailed information on laser cleaning in the dedicated YouTube of the New Acropolis of Athens [38].

Lightweight concrete relief sculpture cleaning methods entailed the use of hand tools, including chisels, different types and sizes of brushes with varying bristle stiffness, non-ferrous, stainless-steel wire, and abrasive blocks. The hand tools were used according to the substances that needed to be removed, a major step in cleaning relief-sculpture surfaces with fine detail to spin-off the dirt and weathered face.

The artist conservator must be careful of original materials and authentic documents, to avoid damage to the fine detailed sculpture. The use of non-ionic detergent to remove stains included dipping a small piece of cotton wool in the solution, applying it on the sculpture surface, and brushing it with water afterward. The restoration process uncovered sculpture details, increasing the artistic value and adding to the natural beauty of the sandstone [39–41].

Statues, also known as positive and negative mold, were conventionally produced by engraving cuttings on silicone or clay [42], while casting was made on plastic or metals [43]. The replication of ancient stone statues was realized using resin materials, but not for the marble or stone sculpture, as well as the Caryatids of Athens found in several cities around 1900 [44]. The best sample of a replica of the stone sculpture was realized during the restoration of the Ganesha statue in Banon village [45].

Remastering is the production of relief sculpture replication or copying by making a new master. The method is currently being supported by digital software, producing virtual or 3D models that have been changed to a printed scale. The production of all figures requires meticulous attention and expertise in touching details. Digital sculptor artists need to review each relief sculpture vis-à-vis the overall photo documentation, as well as details of all figures by re-measuring the panel and other objects referred to in Leonardo's proportion drawing [46, 47]. The ZBrush software is a digital sculpting application that combines modeling 3D/2.5D, enriched by texturing and painting enabling virtual models to appear like watching a realistic sculpture seen through a monitor screen. The advantage of the application over other 3D modeling software includes the development of realistic sculpture supported by a high-resolution model within a 3-dimensional screen, namely on the Y and X-axes, as well as a Z-depth on the Z-axis [48, 49]. The Zbrush software was developed for 3D models and physically printable types, even on a full-size 1:1 scale [50]. Digital sculptor-artists use 3D digital sculpting in line with future trends and developments, specifically related to recent patents on engineering inventions [51].

The 3D modeling can be characterized by applying a hybrid method, including using geometric primitives and shape-from-shading algorithms [52]. Alcaide-Marzal used digital sculpting in conceptual product design [53]. According to Deng, it has been developed as a future trend, such as 3D printing technology [54–56]. For some reason, laser cleaning of statues had been mandatory for years, specifically for old statues placed outdoors. However, removing different stains on fragile surfaces, namely concrete sculptures, requires using non-ionic detergent applied as a poultice on a small piece of cotton wool to wipe over the surface. Remastering was supported by digital software to produce virtual or 3D models that were changed to a printed scale. The ZBrush software combined modeling, enriched by texturing and painting, to ensure the virtual model appeared realistic. The 3D model was easily re-created using close-range photogrammetry [22] based on the front and side views of 2D photos on specified measurement points.

Lightweight concrete sculpture

Relief sculptures, including the structures of columns, beams, and slabs for each floor in the Sarinah building, were made from lightweight concrete. The most essential characteristic of lightweight concrete is the extremely low heat conductivity, used for thermal insulation to construct blocks to protect steel buildings. Furthermore, it has a low density of less than 1900 kg/m^3 [57, 58]. In Indonesia, this material has been popular since the 1960s due to three distinguishing characteristics, namely plasticity, durability, and economy. A typical example is cement, which hardens into a solid mass after being mixed with water, caused by hydration. This chemical reaction produces microscopic-level crystals or a gel-like material known as calcium silicate hydrate within a high specific surface area. The gel has adhesive properties and cohesive forces binding other solid materials together. The mixed concrete can be poured into any form when wet, thereby fitting into space, filling the vacuum, and used to coat any surface. Once dried and cured, it retained the shape, growing stronger, harder, and more settled over time [59].

The artwork, made from cementitious aggregates reinforced and supported by a wire mesh, appeared sturdy. The rough texture and color were visually compatible with natural stone finishes. The relief sculpture produced a porous and brittle structure that was less strong than the compressive strength of carved volcanic stone during the Indonesian Classical era, implemented at the *Borobudur* and *Prambanan* temples [60].

The restoration methods carried out laboratory tests. The pathologies analyzed in the Materials Laboratory at the Archaeological Center in Yogyakarta included (1) pollutants or lichen, mosses and algae, (2) discoloration by some lichen which secreted organic acids that ate away parts of concrete, resulting in mold formation, as well as white, and rust spots, (3) breakage and vandalism due to being covered with paint splashing, water staining of the figures, or unspecified impact resulting in broken parts. Boakye-Yiadom stated that a typical example of conservation was the Paa Grant outdoor concrete sculpture [61]. The cementitious relief sculpture supported by a wire mesh mixed with concrete material tends to produce a porous and brittle structure. Occasionally, cementitious structures are discolored by the secretion of some lichen.

Result

The restoration of the Sarinah relief sculpture of Jakarta, Indonesia, was realized based on several steps, namely (a) identifying or mapping the broken artifacts, (b) cleaning and repairing the relief sculpture, (c) remastering by producing virtual mold, and (d) launching to public appreciation. According to Ahmed [15], the artist-conservator team was headed by the senior sculpture curator of the National Gallery of Indonesia, Asikin Hasan, who is familiar with the abilities and skills of Indonesian sculptor artists [62]. The team also comprised a restorer, the senior female realist sculptor Yani Maryani, an expert in realist sculpture [63]. A digital sculptor artist, Nus Solomo [64] was responsible for the Remastering of virtual mold and had a background in sculpture production processes, specifically applying Zbrush digital sculpting [65].

The decision of the project management regarding the rediscovery of the Sarinah relief sculpture was perceived as the new building icon. A huge void was observed on the right side of the building, showing relief sculpture in a crucial condition during construction. The first response of the artist-conservation team was how to erect a boundary shield to protect the workers from any form of accident during the dismantling of the two building floor layers [12]. However, the artwork at the center of the existing building was being evacuated by the project workers using heavy equipment. The boundary shield was approximately 0.50 m from the top, while the distance to the artwork was relatively 1.50 m. This means that the boundary does not serve as a representative space or working area for the restoration of relief sculpture attached along 15 m of wall structure and 2.9 m in height, as shown in Fig. 1.

Identification and mapping of the damaged or broken artifacts

Experts carried out the relief sculpture restoration process, and the treatment included conservation, cleaning, and repairing of broken elements [17, 18]. The surface cleaning included adherence to the following steps (1) pollutants or lichen, mosses, and algae, (2) discoloration by certain lichen-secreting organic acids that eat away parts of concrete, leading to mold formation, as well as white and rust spots, (3) breakage and vandalism due to being covered with paint splashing, water staining of the figures, or unspecified impact resulting in broken parts [12]. According to Ahmed [19], the recent restoration of historic buildings was subjected to updated non-invasive methods. This was realized through the application of multiple investigation methods, including using new tools for documentation and digitally mapping the damaged artifact simultaneously.

The critical conditions of the Sarinah relief sculpture comprised (i) realistic statues, eight females, seven males, floras, fauna, and background objects, (ii) all artwork dimensions (l x h x w = 15 m × 2.9 m × 1 m), (iii) artwork attached vertically on the wall structure consisted of two different layers, (iv) *alto-relievo* (high relief) of sculpture included 15 figures located in the front, and *mezzo-relievo* (medium relief) as background at an average distance of 20 cm, attached to a structural wall of 15 m in length, (v) relief sculpture were placed inside the narrow boundary shield at a distance of approximately 1.50 m from the object and 0.50 to the top.

Considering the difficult situation, the Conservator Team had two choices of selecting between using a scan-type photogrammetry with Trimble Inpho or Photo Modeler or using a digital camera DSLR series enriched by manual drawing simultaneously. The first choice is to use scan-type photogrammetry with the Trimble Inpho or the Photo Modeler software, an alternative tool for scanning digitalization to find the detailed characteristics. Both software, which served as a scanning device, were used to produce 3D models from 2D images. An example of the photogrammetry method is scanning using multi view stereo to capture images from various angles, avoiding distortion because it has an overlap of relatively 80%. However, the position of the artwork, attached vertically to the wall structure made capturing by the device difficult. The Sarinah relief sculpture had two layers, namely at the front were *alto-relievo* (high relief) consisting of 15 figures and objects. At the rear was *mezzo-relievo* (medium relief), comprising a panoramic background with complicated details.

Referring to the formula of Vertical Aerial Photograph [26] proposed by Portland State University, the required distance of an object referred to DTM Extraction and Editing in approximation, H (height) of the object plus f (focus lens). The boundary shield is unsupported when the formula of Vertical Aerial Photograph is applied in the artwork dimension (l × h × w = 15 m × 2.9 m × 1 m) because the distance was approximately 1.50 m. The

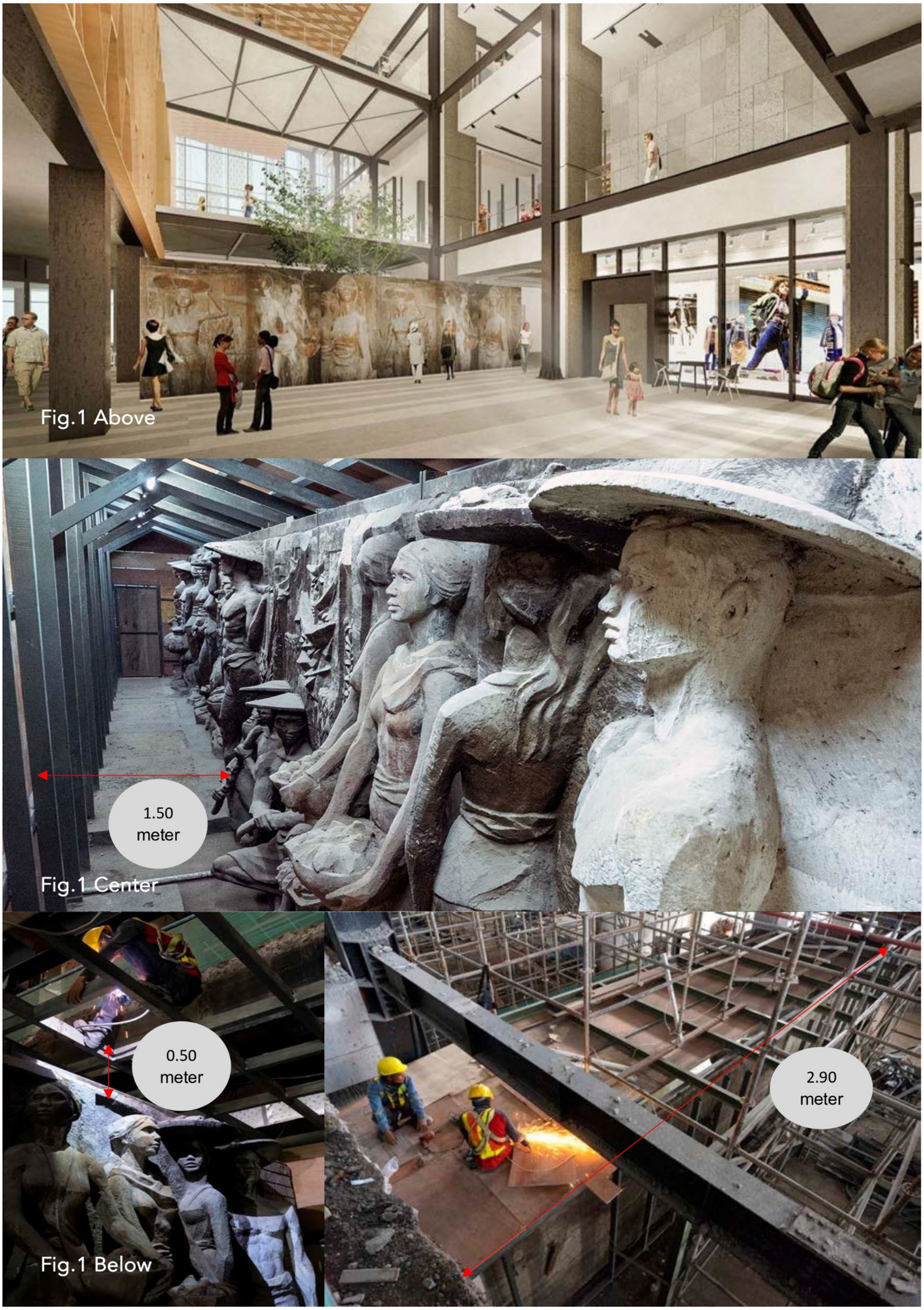

Fig. 1 Above. The image plan proposes a huge atrium above the relief sculpture. Center. The inside boundary shield of the Sarinah relief-sculpture work area is not representative space. The cramp/narrow/tight space of the artwork is attached along a 15-m wall. Only 1.50 m between the boundary shield to the artwork and 0.50 cm from the artwork to the top boundary shield. Below is the dismantling of two-level floors above the location of relief sculpture. Courtesy of Asikin Hasan and Yuke Ardhiati, 2021

camera was unable to scan the slight details found behind the sculpture when faced inward. Therefore, the result lacked data, which impacted the accuracy as shown in Fig. 2.

The second choice entailed using a digital camera DSLR series enriched by manual drawing simultaneously. The application of a photograph follows the imaginary grid scale of 1 m × 1 m rather than the original dimension of l × h × w = 15 m × 2.9 m × 1 m. After the compilation of photos, these were rearranged into a photograph. All artwork, supported by manual data measurements, was enriched by hand-drawn figures and objects to complete

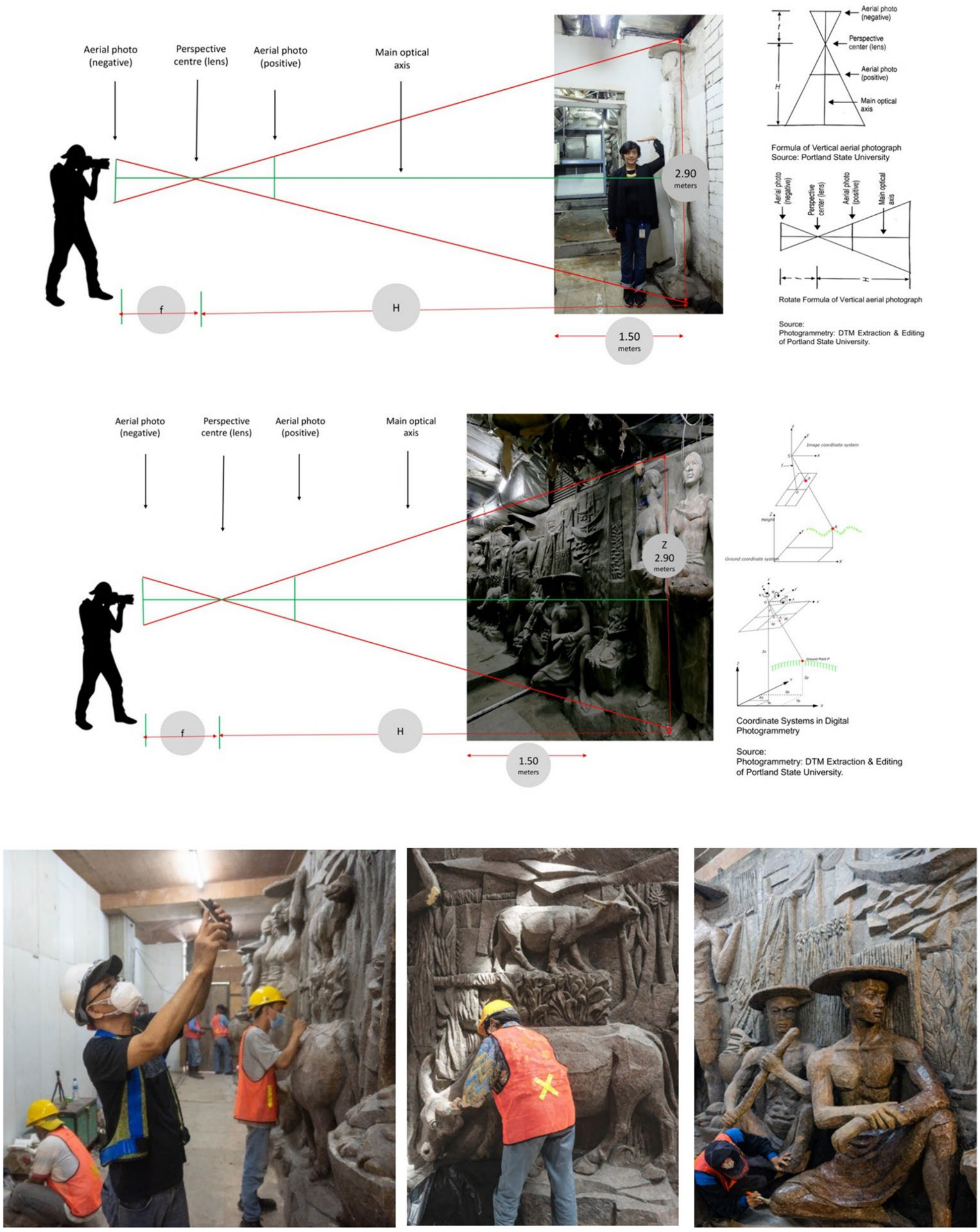

Fig. 2 Above. A simulation of the vertical aerial photograph by using a photogrammetry formula for a single object. The formula needs the distance H (height) plus f (focus lens). Center. A vertical aerial photograph of all artwork objects needs the X, Y, and Z as a ground coordinate system. Unfortunately, neither simulation can apply because the maximum distance object to the boundary shield is only 1.50 m. Below. The artwork has two layers; sculpture form as *alto-relievo* (high relief) consisting of 15 figures and objects, and *mezzo-relievo* (medium relief) consisting of a panoramic background with complicated details. The part of the artwork behind the statue (or partially covered) cannot be reached by the camera using the photogrammetry method. Courtesy of Asikin Hasan and Yuke Ardhiati, 2021

the gesture of relief sculpture, specifically in terms of recording the two different layers of artwork. The completion of data measurement and the gestures of all human figures referred to the theory of proportions formulated by Leonardo da Vinci [42, 43]. In addition, 2D data documentation was potentially used to generate a 3D model using the ZBrush software application [44, 45] (Fig. 3).

Both documentation methods were changed due to a lack of results. First, the photogrammetry software provided neither vertical direction nor scale, leading to unsatisfactory rendering because the vertical estimation was inaccurate. Second, using a digital camera DSLR series enriched by manual drawing produced inaccurate or distorted relief sculpture gestures. Therefore, the Cultural Heritage Expert Team of Jakarta suggested using a digital camera DSLR series enriched by manual drawing. The photogrammetry methods were applied after launching the Sarinah Project Transformation in 2022 to take photos from the huge atrium above the relief sculpture.

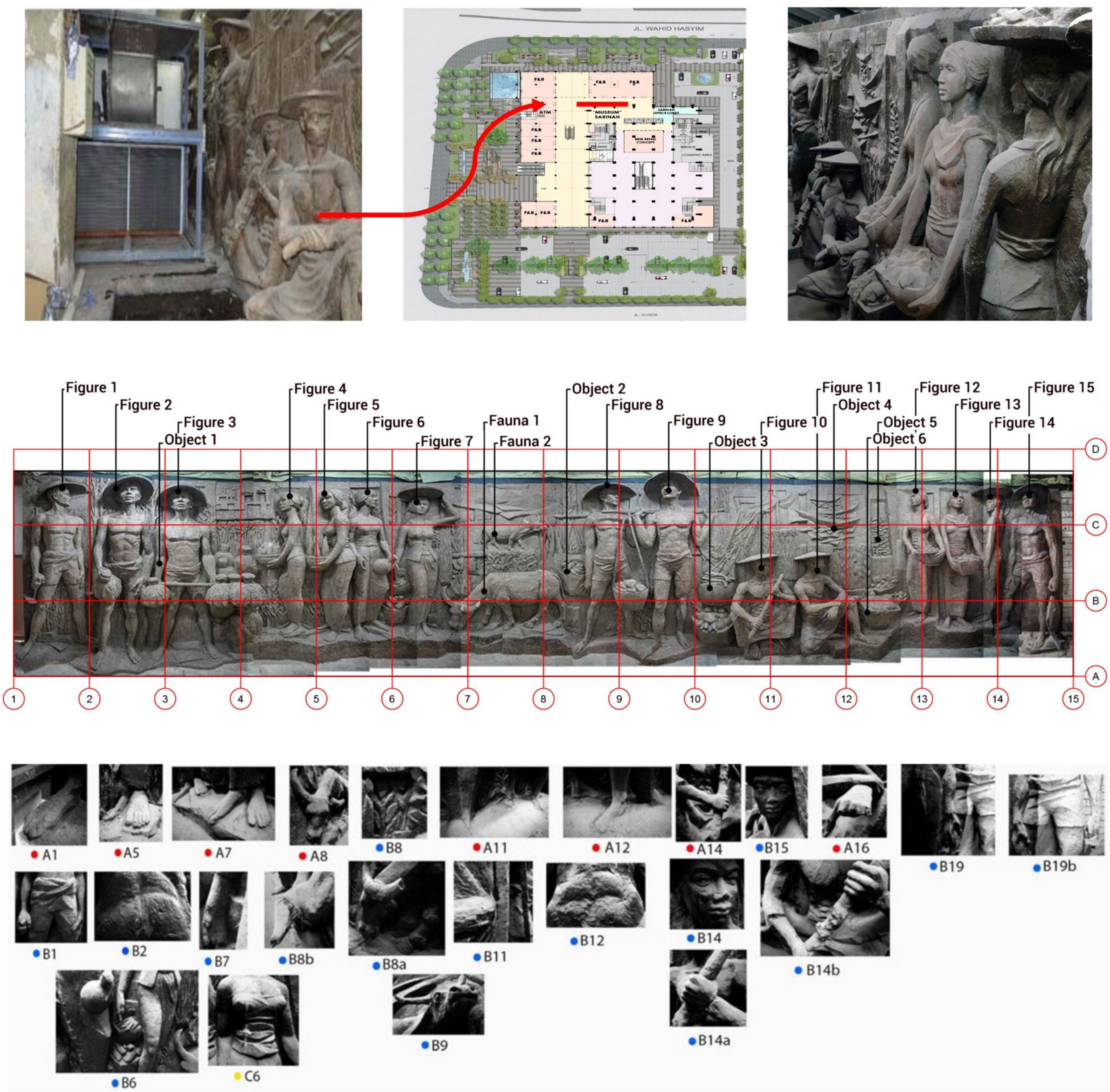

Fig. 3 Above. The ground floor plan of Sarinah, which the rediscovery relief-sculpture founded. Below. The Damage Mapping of the broken relief-sculpture with code and broken condition. Courtesy of Yuke Ardhiati and Asikin Hasan, 2021

To identify the broken artifact, the artist-conservator team engaged in documentation by using the following DSLRs 3 cameras at once: (1) an a6400 by Sony 25 Megapixel, (2) a Fujifilm X-A1 16.3 megapixel, and (3) a GoPro Camera. All devices were supported while focusing on the object, shooting faster to capture high-quality images. The a6400 and Fujifilm X-A1 cameras can be set to shoot in 4 K at relatively 24, 25, or 30fps, and 1080p captured at approximately 120fps by autofocus while setting the focus rack speeds on the object. The GoPro was responsible for recording the documentation journey, supported by the following software applications Adobe Photoshop 4+for photo editor and graphic design, Cartesian diagram coordinates, AutoCAD, Zbrush with Autodesk Maya, and 3D Max for rendering, all operated by using Macbook Pro.

The result of identifying or mapping the damages are shown in Fig. 3. The process captured the kinds and positions of the broken artifact by serving as (i) the database documentation of 2D objects, (ii) information details to identify various kinds, damaged, and broken parts digitally, (iii) a mapping tool that easily maintains authenticity for each figure, and (iv) details gesture images of all figures, including males, females, floras, and faunas.

Restoring by cleaning and repairing relief sculpture

Cleaning manually by artist-conservator

The restoration of lightweight concrete relief sculpture was the first of a kind performed in Indonesia. The Government of Jakarta Technicians and Art Conservation Team were not yet aware of the Laser Cleaning method. The restoration needed to be completed in line with the Project Management during the Covid-19 (2020–2022). The huge additional costs made it difficult to invite technicians from abroad, alongside bringing the laser equipment, particularly during the Pandemic.

The restoration was finally conducted manually by the artist-conservation team, led by a female realist-sculptor. All the procedures [15] shown in Fig. 5, were implemented. The female realist sculptor followed all the relevant cleaning steps, including using non-ionic detergent to remove different stains. The solution was applied as a poultice over the surface of the relief sculpture and left dampened to absorb the stains, followed by brushing with water. Specialist manual methods were used to remove the discoloration caused by the chemical effect of water dripping from the floor above for a long time, resulting in the yellowish and reddish tones apparent in the damaged and corroded surfaces of the relief sculpture. After the completion of the clearance in the restoration process, sculpture details were uncovered, raising the artistic value and the natural beauty of the sandstone [36–38] (Fig. 4).

Repairing the broken artifacts

Repairing the broken restoration was performed in five stages by using tools such as electric drills, hammers, chisels, etc. The artist-conservation team focused on identifying and mapping the damage, by following codes and details presented in the Cartesian grid diagram coordinates [12]. The first stage consisted of (a) repairing all damages that occurred from vandalism, chipped, broken, or cast-in-place concrete used for the foundation of the Air Handling Unit—AHU engine, (b) repairing artwork parts that had changed from a grey cement color to yellowish and reddish tones, due to the chemical effect of water dripping from the floor above, (c) recovering the body of sculpture stained and covered in white paint. The restoration process was carried out with the following tools electric drills, hammers, chisels, etc. In the second stage, the artwork was cleaned using a smoothing process to remove dust and dirt with a soft brush and cloth. The paint, cement, and varnish stains were removed with a fine wire brush, mini grinder, etc. This was followed by sweeping the trash and dirt from the cleaning process. The third stage focused on the strengthening and patching procedures by inspecting the wall relief sculpture and continued with the drying of damaged surfaces.

The next step focused on the installation of anchors into the broken artifacts. However, to achieve a similar texture, the cement was mixed with pigments and additives for a final casting to ensure it conformed with the existing surface. The fourth stage entailed returning the wall relief sculpture as closely as possible to the original shapes, following the aesthetic elements of each sculpture. The fifth stage concentrated on coating the sculpture with a finishing material and waiting for the surface to dry. After returning the relief sculpture as closely as possible to the original shapes, the aesthetic elements were closely examined. The restoration tools comprised handheld electric drills, hammers, chisels, etc. while the entire processes were conducted manually. Meanwhile, to achieve a similar texture, a cementitious aggregate was mixed with pigments and additives for a final casting, ensuring it conformed with the existing surfaces [6] as shown in Fig. 5.

Remastering by creating a virtual mold 3D model

The virtual 3D model was shown at various events, such as exhibitions, seminars, workshops, etc. for educational purposes and to be viewed by the general public, including heritage lovers, both professional and student artists, portraying the historical craftsmanship of the Indonesian sculptors who designed relief sculpture in the 1960s. Therefore, Remastering addressed the digital recording of all physical documentation concerning sculpture within appropriate scales, gestures, and characteristics using a

Fig. 4 Smooth cleaning to remove (1) pollutants or lichen, mosses and algae; (2) discoloration by some lichen secretes organic acids that eat away parts of concrete, grow mold, white spots, and rust spots;(3) breakage and vandalism due to being covered with paint splashing or water staining of the figures and or unspecified impact resulting in broken parts with a fine wire brush, mini grinder. Courtesy of Asikin Hasan and Yuke Ardhiati, 2022

3D scanning device. All images were separated into digital computer layers as follows (i) relief sculpture depth was digitized into a 3D model, (ii) all gestures and proportions were digitized concerning the other relief sculpture, (iii) every figure, texture, and details were retouched as shown in Fig. 6.

Virtual mold can be printed through a 3D printer set at a scale of 1:10, meaning height and length of 29 cm and 150 cm, respectively. Currently, the three established types of 3D printers for plastic parts include stereolithography (SLA), selective laser sintering (SLS), and fused deposition modeling (FDM). This research used the stereolithography (SLA) 3D printer, which required the application of light to dry the reactive thermoset material called resin. The resin was converted into a three-dimensional object by exposing the vat or tank to a light source,

Fig. 5 Repairing process of the broken artifacts by using electric drills, hammers, chisels, and welding. Courtesy of Asikin Hasan and Yuke Ardhiati, 2022

which resulted in hardening. SLA resin was exposed to light of a certain wavelength, including short molecular chains joining together, as well as polymerizing monomers and oligomers into solidified rigid or flexible geometries. An environmentally friendly synthetic fiber made from corn husks was used to produce the materials. Currently, 3D printing specifically required for digital sculpting at a scale of 1:1 scale is greater than 40 cm. The numerous parts must be divided into diverse components and assembled at the actual size, assuming the needs are higher than the proposed standard, In the future, digitally designed sculpture could be produced by 3D printing on metal, which would be regarded as the highest achievement. After printing a 3D set at a scale of 1:10, the original relief sculpture was compared with the printed one. However, there was a lack of accuracy specifically when inputting the data manually.

The overall gesture of printed model figures was approximated to 90%. However, the print was unable to show the features of the expressions resembling the original cementitious characterized by material strength and sturdy textures, specifically on the faces and bodies. *The*

Fig. 6 Top. Remastering process by using manual and digital drawings. Center. Data 2D process to 3D model by digital sculpting application software. Below. The realistic rendering process of virtual mold. Courtesy of Asikin Hasan and Yuke Ardhiati, 2021

model printed at a scale of 1:10 was unsuitable for comparisons, due to certain discrepancies. In addition, it served as heritage dissemination or educational outreach. The initial research observations showed that digital sculpting was quite different from the conventional processes, focusing on correlations between eye moments, processes of sculpting, and the final product (Fig. 7).

Post the new Sarinah building of Jakarta launching

The new Sarinah department store in Jakarta was launched in early 2022, inaugurated with an exceptional outlook compared to the contemporary concept of the 1960s era, including the Sarinah relief sculpture after the restoration project. After being launched, the Sarinah relief sculpture opened to public appreciation, however, avoid taking a serious photograph without Sarinah's permission. The good responses attracted approximately five million people, including residents of Jakarta and those from other cities. The average visit reached 40,000 people/day [67], who appreciated the building on various media responses by enthusiastically posting the documentation, selfies, and shares on social media platforms, namely Meta, Twitter, Instagram, etc. On the other hand**,** as the heritage dissemination and educational outreach the Artist Conservator Leader of the Sarinah relief sculpture and also an Art Curator, Asikin Hasan presented his last work in two occasions of art exhibitions titled *the Relief Sarinah* [68], and *the Reliefs of Sukarno Era* [69].

Fig. 7 Above The origin of the Sarinah relief sculpture after restoration in 2022. Below Virtual mold shown in the 'canvas' layer. Courtesy of Asikin Hasan and Yuke Ardhiati 2022

One of the enthusiastic people is Anita Fatmawaty Effendi (23 year old), a young researchers team who work in PT. Waindo SpecTerra [70]. They took their small research to create a 3D model of the Sarinah relief sculpture by using Close-Range Photogrammetry [22]. Refers to her [70] the documentation process was shared by using an Android 12 smartphone with back and front cameras 13 M+2 M and 8 M RAM 6 GB, respectively, including a processor MediaTek hellio G 85 octa core. The photos were taken on January 24, 2024, by taking 69 photos from various angles using a smartphone camera named *multi-view stereo* (MVS). Her team created 3D object files of the Sarinah relief sculpture by saving in the wavefront OBJ (*.obj), 3D models (*0.3ds), Collada (*.dae) with support Autodesk FBX (*.fbx) and Agisoft software application for the processing. Then, they uploaded 3D into social media [71].

This is a proof that the invasive demolition to form an atrium space to show the reappearance of the artwork was materialized, and the enthusiasm of the young generation to give appreciation to the heritage building and the artwork inside. Data collection was carried out using close-range photogrammetry, by ensuring the photos were compiled by scanning with multi-view stereo.

The requirement was shot from various angles to avoid distortion due to an overlap of approximately 80% aimed at obtaining a detailed 3D model. The next process focused on building thick clouds from dense ones, a collection of high points with large numbers based on camera position. The dense cloud aimed to interpolate point clouds, which lacked details in the photograph. Subsequently, a mesh aimed at performing a 3D reconstruction of the point cloud was built. At this stage, a 3D model was produced by tying a collection of tie points together in a closed manner, forming a surface plane. The building texture provided color to the 3D model, enabling the modeling to reach the actual state of the object.

Data processing was carried out by ensuring the conformity of the photos, which was perceived as the initial stage of producing a 3D model. The process aimed to match points from several photos by building a point cloud model by determining the position, and orientation of the camera for each photograph taken. This stage was also used to check the conformity of photos, including the requirement to produce good model quality (Fig. 8).

Discussion

Cultural heritage objects were not limited to outdoor or indoor locations, standing sculptures, or attached to the walls, these can be found in large areas or narrow vicinitys. All possibilities resulted in distortion when applying photogrammetry without initially studying the detailed instructions, specifically during the application of vertical images. The lack of vertical direction in photogrammetry during the documentation process meant the existence of a gap associated with the Collinearity Condition and Geometry of Vertical Image photogrammetry formulae, which required attention [32, 33].

A similar situation encountered by Winaya and team members necessitated 3D scanning of Majapahit statues [66]. The use of close-range photogrammetry captured with Sony ILCE-5100, supported by Agisoft Metashape, lacked accuracy when the sculpture was attached to the wall, such as in the temple chamber and museum

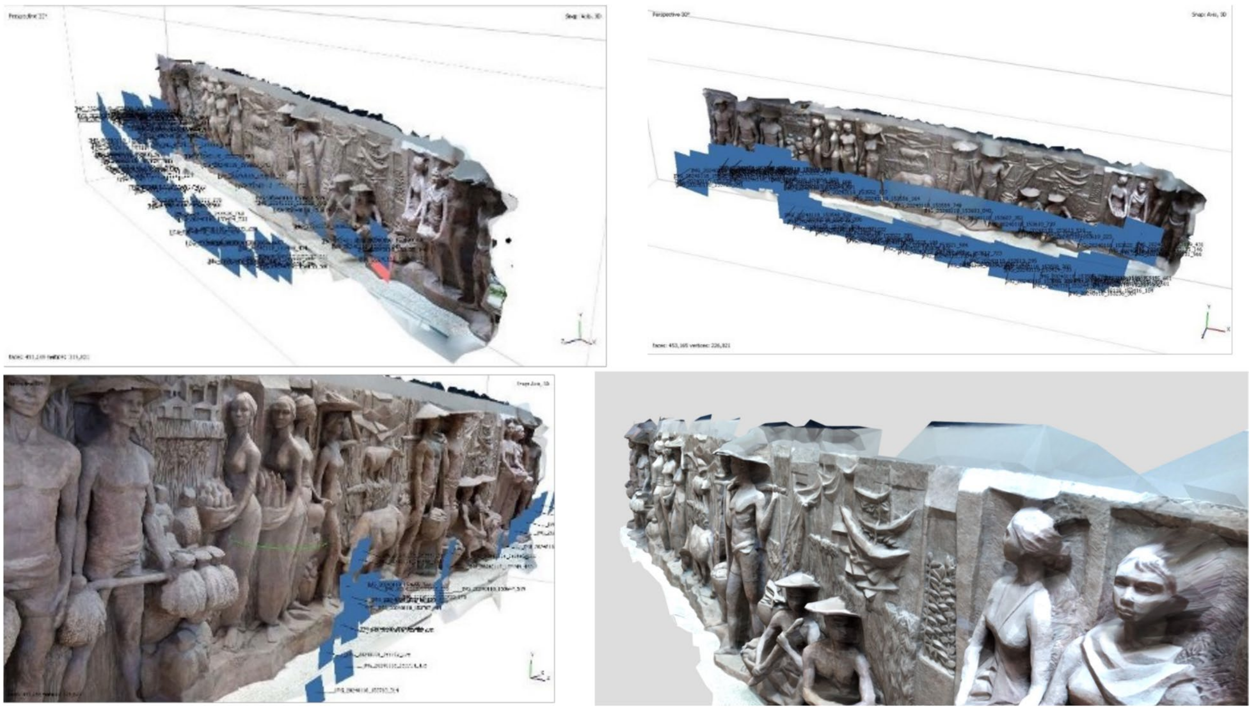

Fig. 8 3D model close range photogrammetry by using 69 photos of the Sarinah relief sculpture from various angles using a smartphone camera. Courtesy by sketchfab.com. 2024

exhibition room were captured. The team members shot the photos using the 360° method. However, the situation was impractical for the standing sculpture. The 180° method was used to strategically shoot the photos accurately due to the gaps or lack of data in the rear parts of the object. High accuracy [33, 34] was required during documentation in heritage science.

Meanwhile, not all the latest devices could resolve the crucial conditions, including the limited distance and sculpture attached to the wall, which had a direct impact on the outcomes due to lack of data. A smartphone could be used to carry out close-range photogrammetry, analyzed during the production of a 3D model. The younger generation was motivated by engaging in outreach and educational heritage due to the easy and low-cost method.

Lightweight concrete cement relief sculptures combining *alto-relievo* and *mezzo-relievo* were perceived as the best practice. It is assumed that the evaluation process would be of significant interest in future investigations. A specific strategy for completing documentation tasks, apart from updating, required several creative aesthetic activities to immortalize important moments despite the limitations in space, time, and technology. A typical example focused on connecting the artistic abilities of the artist-conservator team by using manual drawings and digital images simultaneously to enrich the cultural heritage restoration methods. The case study of *alto-relievo* and *mezzo-relievo* lightweight concrete relief sculpture was considered the best practice, leading to the need for further investigation.

Conclusion

In conclusion, the restoration of the Sarinah relief sculpture made of lightweight concrete (2020–2022) was carried out in three stages, namely (a) identification by generating a digital mapping of the damaged artifacts, (b) restoration which entailed the cleaning, and repairing of the on-site manually by artist-conservators, (c) remastering, in a normal condition is better using close-range photogrammetry, even by using a smartphone camera. However, to education reason in art presentation by producing a 3D virtual mold responsible for positive casting supported by a digital sculpting software application.

The disadvantage of lightweight concrete included porosity, defined as easily shaped, or restored. Additionally, the strong, dashing, slightly rough impression, formation of firm lines, massiveness, and distinctive color led to the categorization of the material as a natural stone.

An important contribution of this research to the scientific heritage was the restoration of *alto-relievos* combined with *mezzo-relievos* despite the time, space, and technology constraints. This was realized by simultaneously applying manual drawings and digital images and a close-range photogrammetry implementation using a smartphone camera.

The implications of these results enriched the non-invasive restoration method of cultural heritage despite the several limitations. In addition, manual and digital Remastering using close-range photogrammetry were adopted to produce 3D models or virtual molds printed on a scale for educational purposes. The attractiveness was shown at various exhibitions, seminars, workshops, etc. This was aimed at showing the historical expertise of Indonesian sculptor artists who designed light concrete relief sculptures in the 1960s by combining *alto-relievos* and *mezzo-relievos.* The realistic statue was 2.9 m high along a 15-m wall worthy of appreciation due to the complexity of relief sculpture scales, gestures, and characteristics.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40494-024-01346-7.

Supplementary Material 1.

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Author contributions

Yuke Ardhiati Wrote the main manuscript text; identifying broken relief-sculptures; references; theory and analysis, chart Asikin Hasan Wrote a part of the restoration and recording process text; digital sculpting process; references, photograph.

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