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Research article

Robotic Intervention in Preserving Artifacts: The Case of the Bini Cultural Artifacts in Nigeria

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Abstract

This study examines the role of robotic assistance in preserving cultural artifacts, with a particular emphasis on Bini artifacts in Nigeria. The objective is to mitigate the loss of Bini artifacts, which contain cultural treasures representing the pride and distinctiveness of the Bini people in Nigeria. Robots are considered a critical possibility in this context, as they can function remotely in hazardous areas and protect cultural artifacts. This study employs a phenomenological methodology, using semi-structured interviews with museum curators, robotics scientists, and cultural heritage preservationists. The results indicate that the design and application of robotic devices, such as drones, arms, mobile robots, cameras, sensors, and excavators, can engage with and preserve the Bini artifacts. This research suggests a promising avenue for studying robotic engagement in global digitized conservation efforts, reconstruction, and the curation of cultural items in the twenty-first century and beyond.

Keywords: Robotic Intervention, Preservation, Bini, Cultural Artifacts, Art, Religion, Africa, Nigeria

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1. Introduction

In Nigeria, the Bini ethnic minority is the ninth-largest, and they are renowned for their artistic creations, particularly bronze statues. Every cultural artifact is showcased and accepted during cultural and religious festivals and communal rituals. The traditional religious leader and the curator of the artifacts alone decide how to treat these treasures. Colonial domination led to the collapse of the Bini kingdom, which in turn gave rise to ongoing disputes over the theft of cultural treasures (Granjon et al., 2018, p. 3). The Bini Kingdom, located in Nigeria, possesses cultural objects that are esteemed as a source of pride, identity, and heritage for the Bini people. In 1897, these relics were seized by the British imperial military expedition, resulting in the kingdom's setback (Asojo, 2011). The cultural items, considered important heritage relics, are currently in various museums globally. The privatization of cultural items in Western museums has estranged the Binis from their cultural heritage, resulting in a continual sense of loss, anxiety, and misery. However, since the British military invaded the Bini kingdom, numerous new artifacts have been produced in addition to the remaining cultural objects not seized. In addition, some of the artifacts seized by the British and other countries worldwide have recently found their way back to the kingdom in piecemeal. Hence, their conservation and preservation are of the utmost importance since their present preservation methods are inadequate. Thus, utilizing robotic intervention to preserve the Bini artifacts is a *sine qua non*.

1.1 Stating the Problem

Bini cultural artifacts comprise a collection of unique cultural items belonging to the Bini tribe in Nigeria. These objects have a historical value that dates back to the 15th century AD (Hicks, 2021). These cultural relics are currently kept in the Bini Museum; nevertheless, their existence is in jeopardy due to environmental influences, decay mechanisms, a lack of sufficient labor for preservation, and neglect due to economic and political issues. There are a significant number of Bini cultural objects that are being misplaced, destroyed, or transported out of the nation (Procter, 2021). Similar dangers are also posed by artifacts that are housed in museums all across the world. In the setting involving Bini cultural artifacts in Nigeria, where the physical presence of cultural artifacts at the Bini museum is in jeopardy, there is an urgent requirement to examine the application of robotic intervention in preserving cultural relics. Robotic assistance in preserving cultural artifacts is not being extensively embraced, nor has it been the topic of in-depth research. Consequently, there is a lack of documented expertise concerning the creation and effectiveness of robotic involvement in preserving cultural items.

In light of this, an urgent need is to examine the use of autonomous robotic interventions in safeguarding cultural items. The cultural history of Bini has been explored not only by local interests but also by interests from other countries. On the other hand, even though they have the potential to attract tourists, a couple of these cultural relics have been neglected and poorly kept. It is possible that a significant number of these cultural items could be destroyed as a result of irresponsible vandalism, disruptions in politics, and economic difficulties. The intervention of robotics preservation is considered a potential solution to the problem of the complete loss of the Bini artifacts, in particular, and the cultural artifacts of Nigeria, in general, to the point of historical oblivion.

2. Research Objectives and Significance

The overarching objective of this study is to investigate the use of robotic assistance in preserving Bini cultural objects in Nigeria. There are three specific goals that this study aims to accomplish: first, to investigate and document the use of robotic interference in the protection of cultural artifacts; second, to assess the efficiency of robotic involvement in preserving cultural artifacts, taking into consideration the circumstances and characteristics of the cultural artifacts; and third, to investigate whether or not those associated with the preservation of cultural artifacts are willing to accept artificial intervention. These objectives address the difficulties in conserving antiquities and traditional murals in Nigeria, including modernism, which encompasses the process of urbanization, western education, western religion, and technology. One example of a comparable artistic cultural legacy in danger of being lost due to industrialization is the Bini cultural objects (Phillips, 2021). Exploration of robotics is advocated as a necessity for safeguarding the Bini cultural heritage, transcending the dangers of modernization and the exploitation of foreign interests. Consequently, it is important, possible, and practical to investigate the use of robotic interventions in preserving cultural items in Nigeria. This research paves the way for additional studies into strategic robotic interventions in the precise modeling, documenting, and digital preservation of cultural heritage in Nigeria and beyond and it also opens the door for such research.

3. Methodology

This research employs a qualitative strategy for data collection and analysis (Tanioka et al., 2021). Specifically, the phenomenological approach is employed. Employing participatory robotic art as a research and proof-of-concept case, the exploratory case study proposes a technique that highlights the needs, aims, and concerns for developing and carrying out robotic intervention in the safeguarding of cultural objects (Pereira et al., 2018; Duniya & Gyegwe, 2014). Robotic artwork is structured to optimize the quality of input and involvement. This will help reduce access concerns and make it possible to create more sophisticated intervention interventions. For the purpose of gathering primary data regarding the Bini cultural objects and the ongoing preservation efforts, field surveys were carried out in the old Bini kingdom, Nigeria. Among the majority of them, interviews were conducted with curators, cultural specialists, and consumers of the Bini cultural items. Collecting pertinent documentation, such as photos, photographs, and audiovisual recordings of the artifacts, followed this. The interviews that concentrated on the cultural items, their past and current use, and measures of preservation resulted in the collection of documented, sampled and analyzed data. The interview data were supplemented with other types of information, such as photographs, video recordings, and written documents. This was done to address the cultural artifacts currently being preserved and the risks they face.

4. Literature Review

Cultural artifacts are items that have significant information regarding the people and culture of a society. A cultural artifact can be material, such as an old tomb, or intangible, like a contemporary non-fungible token. A people's cultural artifacts are cumulated in their cultural heritage, which is,

according to Onu (2016), a cohesive setting of sites that embody values transmitted through centuries of a specific socioeconomic and ethnic community. The procedure involves safeguarding cultural assets against environmental and anthropogenic factors that may lead to its deterioration in both intangible and material forms. Nation-states that have ratified the Convention are mandated to uphold a responsibility for safeguarding cultural heritage monuments. For Lupetti et al. (2015), cultural heritage encompasses both tangible artifacts and intangible attributes, including structures, statues, literature, manuscripts, sculptures, artworks, coinage, and additional elements.

The locations where they are housed are vulnerable to catastrophic occurrences due to variables including pollution, negligence, theft, urbanization, tourism, warfare, and conflicts (Ramos, 2018). Advanced technologies include airborne or robotic cameras, multimedia, computerized three-dimensional in-nature simulation, virtual reality, and robotics, which can track, document, inspect, and conserve cultural heritage places and their contents (Granjon et al., 2018). Ramos (2018) underscores the need to safeguard cultural artifacts for posterity and endangered cultural heritage sites due to human negligence, urban development, climate change, catastrophes, contamination, neglect, and vandalism. The UNESCO World Heritage Convention in Nigeria has instituted cultural heritage conservation policies that acknowledge the joint duties of the government, the state, local authorities, and the community (Onu, 2016). Nonetheless, these strategies are inadequate to confront the escalating difficulties presented by catastrophes caused by changing environments, degradation, political upheaval, and the transformation of social and societal structures (Ernesto, 2021; MFARF, 2023; Kottoor, 2013; Dijkstal, 2019). This is seen in the worldwide disasters of cultural heritage degradation.

Granjon et al. (2018) examine the pressing necessity for robotic intervention and the potential role of robots in preserving cultural heritage artifacts and monuments. It highlights the limitations of specific robotic intervention programs and recommends suitable robotic intervention strategies to augment and enhance current preservation initiatives, thereby improving the capabilities of robotic agents. Granjon et al. (2018) analyze two robotic art installations created by the author and his associates, concentrating on the creative challenge of integrating robotics into public space art. The installation features a participatory component in which a robotic bird observes and interacts in dialogue with a group of individuals. This piece presents the challenge of reconciling the control imposed by the robotic system with the necessity for an open social environment that allows visitors to demonstrate their behavior and creativity freely. Cultural heritage preservation can be categorized into two central systems: established systems and those under development.

Ramos (2018) argues that preservation procedures are employed to maintain cultural heritage artifacts. In contrast, preservation technologies pertain to the tools and systems utilized to facilitate or enhance the preservation process. Presently, two classifications of preservation methods exist: traditional conservation and innovative preservation strategies developed via technological advancements. Physical repair and preservation procedures necessitate direct intervention to restore, recover, or conserve an artifact, whereas environmental control techniques focus on conserving an artifact within a regulated environment concerning humidity, temperature, and light exposure (Skublewska-Paszkowska et al., 2022; Baglioni et al., 2021). Consolidation and materials repairs are techniques employed to enhance the strength of an item by reinforcing its

constituent parts with natural or synthetic adhesives. Restoration is substituting aged materials with contemporary equivalents, frequently of the same category as the original substance. Conservation rules, environmental oversight, documentation, and monitoring are further techniques employed (Baglioni et al., 2021). The adept hand of an artist or conservator is essential for the preservation and authenticity of an antique.

Cultural heritage is crucial for communities, societies, and nations, encompassing history, values, beliefs, practices, aesthetics, knowledge, and morality (Ottuh, Omosor & Abamwa, 2023). Nonetheless, an artifact will ultimately degrade over time due to internal and external factors. Modern materials, procedures, or technologies may have adverse effects on the object, necessitating caution when using new techniques or materials in conservation efforts (Onu, 2016). It is imperative to conserve and transmit this knowledge repository to subsequent generations. Nevertheless, it is continually subjected to harm, deterioration, and destruction, endangering both the accessibility and preservation of history. Skublewska-Paszkowska et al. (2022) also noted that natural phenomena, such as floods, erosion, pests, and human activities, including warfare, illicit trafficking, negligence, and vandalism, can lead to damage or devastation. In recent years, the domain of cultural artifact restoration and preservation has witnessed the advent of modern technology solutions. Progress in digital technology has positively impacted the industry, resulting in developing and implementing various new solutions within cultural heritage organizations. These technologies enhance precision and mitigate risks to fragile artifacts, facilitating modern methods' restoration to original or comparable conditions.

5. The Historical Overview of the Bini People

Benin is a historic African kingdom situated in present-day southwestern Nigeria. It is considered one of the oldest and most sophisticated nations in the African hinterland, founded before 1000 AD and enduring until its colonization by the British Empire in 1897 (Eisenhofer, 1995; Bondarenko & Roese, 1999). The core of the ancient Benin kingdom is inhabited by a populace that identifies themselves, their capital, and the kingdom, including their language as Edo, while 'Bini' was employed by early Europeans as a descriptor for the predominant ethnic group and their language. The terms Benin and Bini are Portuguese distortions derived from the word Ubini, which gained prominence during the reign of Oba Ewuare in 1440 (Eisenhofer, 1995). Ubini is an Edo term for 'livable', employed by Pa Idu, the ancestor of the Edo people, to characterize the region identified as a habitable place during their migration from Lower Egypt. Ubini was subsequently altered to Bini by the diverse ethnic groups cohabiting in the area, and further transformed to Benin in 1485, when the Portuguese initiated commercial contacts with Oba Ewuare, providing coral beads. Based on the initial Bini scholars of history, the Bini people moved from Egypt, across Sudan and Nupe and ultimately settled in their current location in Edo State (Eisenhofer, 1995; Bondarenko & Roese, 1999; Shoup III, 2011). The Edo people reside in Edo State of Nigeria, named after the principal occupants of the region's prominent historical entity, Benin City, which serves as the central capital of the Edo people to date.

The Edo traditional religion encompasses, in addition to the human realm, an unseen domain of supernatural entities that serve as intermediaries between humanity and the divine. Tributes are presented to them at their designated shrines. Osanobua is the Creator as well as the Supreme

Deity (Sare, 2024). Traditional Edo art encompasses recognizable sculptures, plaques, and masks that embody diverse spiritual and historical elements of their cultural heritage. According to Okpokunu et al. (2005), prominent Edo art artifacts encompass the mask of Queen Mother Idia and the extensive assemblage of historical Edo art known as the Benin Bronzes, which are located not only in Nigeria but also globally, including institutions such as the Metropolitan Museum of Art in New York.

6. Perspectives on Bini Cultural Artifacts

The Benin culture is a significant aspect of history, as it was not founded on literature and wielded considerable authority before the 16th century. Benin art, predominantly crafted from cast bronze and carved ivory, was created for the court of the Oba of Benin, a sovereign of divine status (Benin Bronzes. 2024). The art is regarded as artistic creations and historical artifacts in Benin, with leopards symbolizing the Oba as a preeminent authority (Singer, 2024). Benin bronzes and other artworks are essential to historians as they embody the tangible manifestations of the culture. These arts, extant since at least the beginning of the thirteenth century, have been employed by rulers to elucidate the kingdom's history and bolster its endeavors (Cartwright, 2023). The Oba is tasked with establishing an altar in honor of his parents, featuring ivory tusks and commemorative brass heads specifically designed for royal altars. Before the British takeover, an Oba's courtyard was the central venue for rituals commemorating him (Docherty, 2021; Cartwright, 2023). Currently, all royal altars are situated collectively within a singular courtyard. Benin art features an Ikegobo, or "altar to the hand," that commemorates the achievements of distinguished individuals (Singer, 2024, p. 4). Private and public ceremonies commemorate significant events in the kingdom's annual calendar, including the year-end festival known as Igue, which is believed to rejuvenate the Oba's magical abilities and purify the country of restless spirits (Cartwright, 2023). Significant ceremonial festivals include Ague, Ugie Ivie, Ugie Erha Oba, Oduduwa, and Ugie Oro.

The Bini cultural artifacts are manifestations of human ingenuity that embody the beliefs and lifestyle of the Bini people of Benin. Artifacts or artworks comprise artifacts crafted from brass, bronze, clay, wood, coral, and leather by the Binis of the ancient Benin kingdom. According to Onibere and Ottuh (2024), specific artworks depict historical and religious facts, mythological occurrences, and political storylines. Some artworks fulfill valuable purposes in the everyday lives of the Binis, including religious purposes, while others are solely for aesthetic appreciation. Artifacts or artworks are regarded as human-made objects possessing archaeological, historical, or cultural significance (Ananwa, 2014). The Bini cultural artifacts are objects initially created by the indigenous people who inhabited the Bini kingdom in Nigeria. They encompass, but are not restricted to, bronze and brass sculptures, ceramic sculptures, coral art, carved ivories, wooden artifacts, cloth artifacts, bead artifacts, ritual and ritualistic objects, and architectural designs (Smith, 2007). Out of the over 106 bronzes initially housed at the palace, just about 29 are now preserved within the kingdom, and over 900 are located at the British Museum. At the same time, the remainder is dispersed throughout Europe and America (ArtNet, 2021). Over 160 museums and institutions globally own antiquities pilfered from the Bini Kingdom in their private collections (ArtNet, 2021; Bondarenko & Roese, 1999). These artifacts encompass bronzes, referring to various

items, including beautiful bronze plaques, wood sculptures, and ivory. The table below contains a few of the museums and institutions currently possessing some of the Bini artifacts.

Table 1: Showing some of the museums and institutions in possession of the Bini artifacts

Sl. No.	Institution	Country	No. of Artifacts
1	British Museum, London	United Kingdom	928
2	Weltmuseum, Vienna	Germany	176
3	Museum of Archaeology and Anthropology, Cambridge	United Kingdom	136
4	Oxford University's Gardens, Libraries and Museums	United Kingdom	105
5	National Museums Scotland, Edinburgh	United Kingdom	74
6	Horniman Museum, London	United Kingdom	50
7	National Museum of Ireland, Dublin	United Kingdom	21
8	Museum of Anthropology at the University of British Columbia, Vancouver	United Kingdom	34
9	Museum of Cultures, Basel	Switzerland	36
10	National Museum of African Art at the Smithsonian, Washington, D.C.	United States of America	66
11	Glasgow Museums, Glasgow	United Kingdom	21
12	Cleveland Museum of Art	United States of America	8
13	Royal African Museum, Tervuren	Belgium	1
14	Royal Ontario Museum, Toronto	Canada	1
15	The National Museum of World Cultures, Leiden	Netherlands	114
16	Bern Historical Museum, the ethnographic museums of St Gallen, Geneva, Neuchâtel and Zurich University, and the Museum Schloss Burgdorf	Switzerland	61
17	Canterbury Museum, Christchurch	New Zealand	17

Source: ArtNet News, 2021: https://news.artnet.com/art-world/art-bites-georgia-o-keeffe-dole-pineapple-commission-2549249

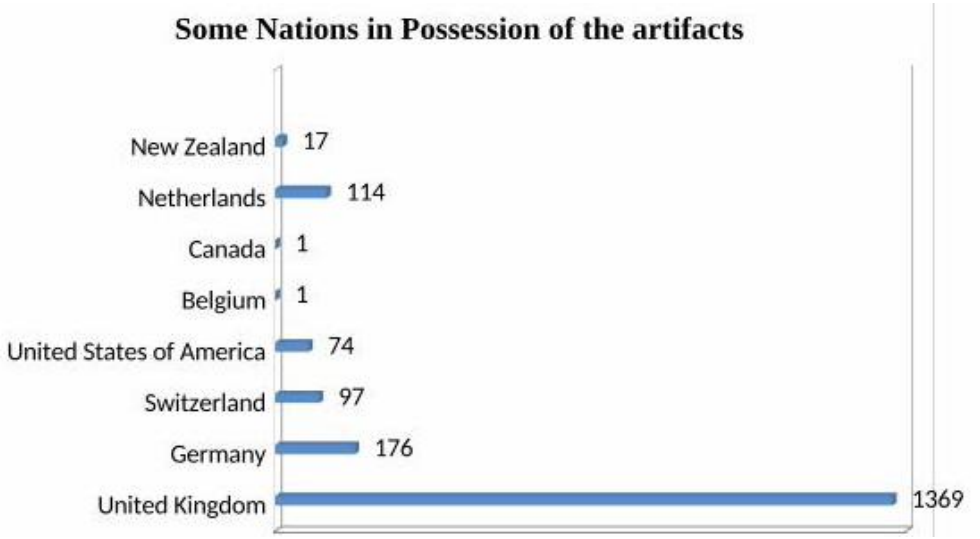

Figure 1: Showing summary of the nations in possession of the Bini artifacts

Figure 2: A selection of Bini bronzes in the British Museum in London

Source: Getty: David Cliff/SOPA

(a) (b)

Figure 3: Queen mother (Iyoba) masks.

Source: ESTMACTDA

Above is Idia (mask 'a'), a significant person in Benin's royal heritage, depicted in an ivory pendant mask. This mask is thought to have been crafted at the beginning of the sixteenth century for King Oba Esigie to commemorate his mother. Currently, these pendants are donned during yearly spiritual renewal rites. The worn wrap skirt in the statute ('b') features Portuguese merchants'

profile features, such as a frontal African head and several typical Benin motifs, including river foliage, mudfish, and interlace patterns.

Figure 4: Court Official.

Figure 5: Head warrior and his attendants

Source: ESTMACTDA

Figure 4 shows a statue of a court-man in the Oba's (King) court, while Figure 5 shows the subservient status of the images accompanying the warrior head signified by the things they bear. One attendant wields a fan to chill the warrior leader while the other brandishes a trumpet to herald his presence.

Figure 6: Bini brozes

Source: ESTMACTDA

Figure 7: These bronzes made of brass adorned the court of the Oba of Benin

Source: Flickr: Offspring of Groucho

Figure 8: British soldiers possessing artifacts plundered from the Bini imperial palace in 1897

Source: Brown (2023)

The artworks of a people are highly esteemed among their cultural and historical treasures. They are frequently seen as the quintessential symbols and custodians of history, representing the nation's dignity and pride, the definitive manifestation of national identity. Consequently, nations fervently embrace, value, and retain their cultural artworks. Artifacts are crucial in nation-building

and preserve the narratives of a people's cultural heritage (Ananwa, 2014). These cultural artworks constitute the foundation upon which a nation's identity is established. Their preservation is essential to prevent the collapse of national identity and subsequent cultural degradation. Cultural pride and confidence depend on the ownership of cultural artworks. In contemporary times, Bini's artworks have achieved regional and international acclaim (Smith, 2007). Naturalists see artworks as divine creations with an intrinsic soul guiding their production and utilization. Although inherently material, they are infused with spiritual energy.

7. The Preservation Challenges Faced by Bini Cultural Artifacts

The Bini cultural heritage represents a substantial legacy that includes traditions, innovative expressions, beliefs, customs, artistic manifestations, knowledge, and skills inherent in cultural icons, artworks, and artifacts. It is a collective heritage that necessitates preservation for future generations, and the Bini society, as a whole, is tasked with safeguarding it as guardians of wisdom. Nonetheless, Bini cultural heritage is endangered due to its designation as a legacy. Protecting cultural heritage from unintentional or intentional harm or obliteration has emerged as a critical issue globally (Manzuch, 2017). The escalating concerns regarding cultural genocide and persistent wartime conflicts have heightened awareness of the fragility of cultural heritage. Furthermore, natural and anthropogenic threats, including flooding, earthquakes, volcanic eruptions, climate change, pollution, and various environmental hazards, pose a threat to the integrity of collective cultural memory (Baglioni et al., 2021). Artifacts are susceptible to natural decay, damage, and destruction, which unfavorable environmental conditions can exacerbate.

Human elements hamper protection and preservation initiatives. Disregarding artifacts or failed efforts to recover them can be more detrimental than beneficial. A deficiency in understanding the significance of artifacts or appreciation for their value is a substantial difficulty in numerous contexts. This may also be exacerbated by the indiscriminate destruction of artifacts, particularly those of more recent origin, resulting from socio-political changes driven by globalization. Numerous socioeconomic transformations induced by globalization might undermine cultural preservation initiatives. In poor nations such as Nigeria, where the impact of climate change is expected to be most pronounced, regulatory structures for cultural preservation initiatives are often inadequate (Onu, 2016). Even when policies are established, inadequate implementation exacerbates the issue. Frequently, the implementation is merely a dissonant fusion of ancient traditions and contemporary governmental requirements, each possessing its deficiencies.

Additionally, environmental variables are external factors that pose a threat to the preservation of artifacts. These include natural calamities such as floods, thunderstorms, global warming, industrial pollution, and vandalism. Wood artifacts are particularly vulnerable due to prolonged inundation, which undermines their inherent defense against fungal infestation. Climate change facilitates the dissemination of fungus spores, enabling them to access even remote artifacts. Often composed of copper or brass, metal artifacts undergo progressive deterioration intensified by industrial pollutants. To alleviate these concerns, effective proactive methods are absent. Coping solutions prioritize the public's consciousness of the artifacts and the environmental alterations jeopardizing them.

8. The Interventional Role of Robotics in Preserving Cultural Artifacts

In contemporary times, every sector in human society that craves modernity and accelerated growth needs to embrace computer technologies (Ottuh, Idjakpo & Uviekovo, 2022). This is applicable to cherished cultural artifacts. The qualities of individual cultural items require attention for cultural preservation. Solid cultural artifacts, such as those requiring preservation, are characterized by their invariance and fragility, whereas fragile cultural objects are defined by their dependence on time and context. The emphasis is on potential advancements in robotic technology that may be utilized to improve the preservation of cultural objects. Potential uses of robotic technology can be explored to enhance the preservation methods of cultural relics, such as the Bini artifacts. In this instance, robots can be designed and utilized to play a preservative role in preserving cultural artifacts. These robotic functions can be accomplished using robotic drones, robotic arms, mobile robots, cameras, sensors, and excavators (see the figure below).

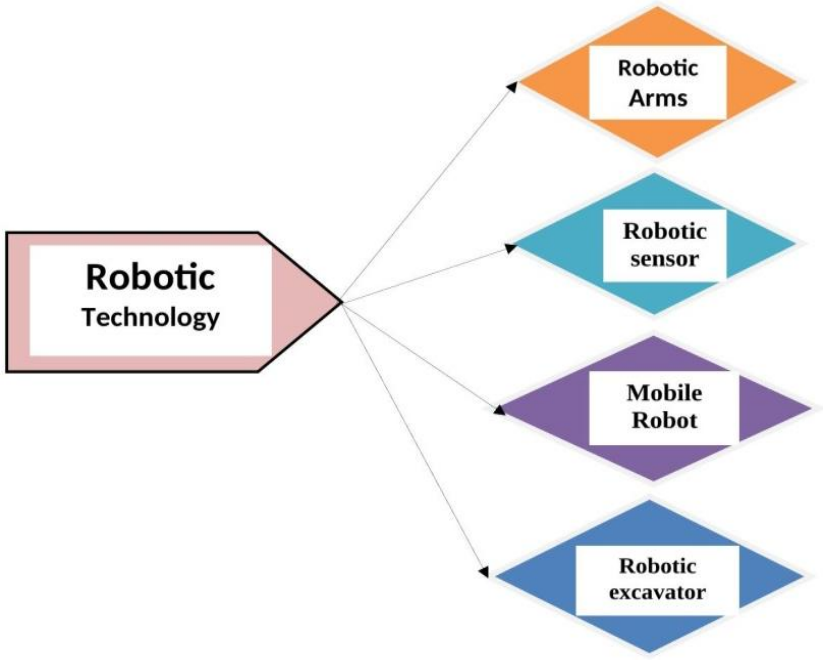

Figure 9: Robotic function through different robots

8.1 Robotic drones

Robotic drones have become crucial for the preservation of cultural artifacts. They are adaptable and efficient devices capable of effortlessly reaching inaccessible locations. Various varieties of drones exist, including fixed-wing and multi-copter designs (Saldes et al., 2018). For instance, a project in Romania utilized drones to examine cultural heritage sites, including Corvin Castle in Hunedoara and Adamclisi Fortress in Dobrogea. The drone is employed to get low-altitude exterior photogrammetric of Byzantine churches in Cyprus and the old Roman ruins complex (Ioniță & Turcanu-Carutiu, 2022). These robots can be autonomously operated with predetermined flight patterns. Certain advanced drones possess cutting-edge technological capabilities that allow them to execute intricate operations securely and efficiently (Giakoumidis &

Anagnostopoulos, 2024). Robotic drones acquire aerial imagery, conduct extensive site surveys, and generate 3D models through photogrammetric methods. They can also aid documentation processes and generate comprehensive records of contemporary harm.

Many of the world's esteemed cultural heritage artifacts are vulnerable to the effects of time and terrorism. Robotic drones serve as a cost-effective tool capable of swiftly and efficiently documenting these delicate places before they are lost irretrievably (Opitz & Herrmann, 2018). In areas where artifacts are vulnerable to environmental exposure, such as storms, drones can be used to document these objects before any damage occurs. This establishes a baseline dataset facilitating comprehensive analysis following exposure (Karachaliou et al., 2019). This technology, employed for site protection, can equally facilitate invasions of personal privacy or the theft of antiquities.

The robotic system modifies its course to accommodate objects of diverse forms and sizes by recording multiple viewing angles and assigning 3D coordinates. It may optimize angular displacement between successive acquisitions according to the desired resolution, making it suitable for both extensive volumes with low detail and compact volumes with high detail. There is also the need for careful regulation and supervision to safeguard society against the immoral application of drone systems. Drones supply unprocessed imaging data for analysis, utilizing various application software that conduct sophisticated data processing incorporating artificial intelligence methodologies. They aim to obtain high-resolution photographs from specific, meticulously regulated locations, facilitating photogrammetry and image processing methodologies (Ioniță & Turcanu-Carutiu, 2022). Drones provide digital assistance for artifact authenticity in scenarios where terrestrial research is unfeasible, items are located in hazardous or contaminated regions, or there is a potential risk of damaging the artifact through alternative examination techniques. These independent software applications offer essential digital resources for photogrammetry and image analysis methodologies.

8.2 Robotic arms

Restoring and conserving antiquities is a complex and sensitive process that requires precise tools to recreate the careful human movements of the past. Robotic arms employed in conservation initiatives vary from essential, cost-effective tools that assist restorers in mending fractures in ceramic artifacts to advanced multi-limbed apparatuses capable of executing complex repairs on paintings. Robotic arms perform precise movements in various applications, achieving proficiency in handling and maintaining delicate objects that would take humans years to master (Ioniță & Turcanu-Carutiu, 2022). The most basic robotic arms are engineered to aid with a singular delicate task: filling fissures in mended ceramics. In such applications, off-the-shelf plastic robotics arms can be utilized to construct low-cost, easily assembled devices capable of mimicking the intricate movements of a human, which could then serve as tools for restoration professionals in museums worldwide (Nicholas, 2020). In contrast to the human hand, these robotic arms are engineered for accurate and delicate movements, decreasing the potential for harm or mishaps sometimes associated with restoration processes. Advanced robotic arms can integrate multiple tools and appendages, enabling restorers to automate various tasks on delicate relics. For intricate activities like adding color retouching to a restored painting, meticulous control over numerous variables is essential.

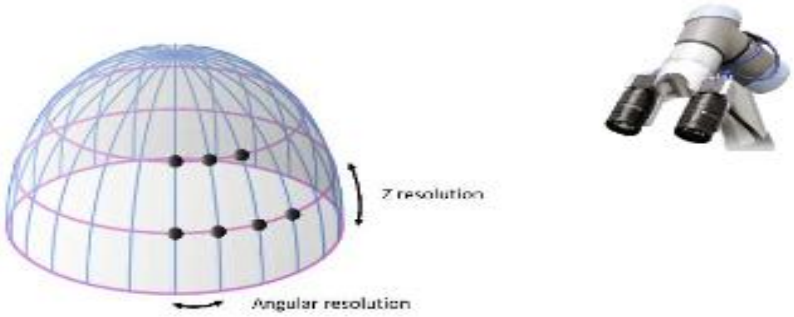

Figure 10: 2D image acquisition system using UR3 robotic arm

The 2D image acquisition system utilizes a UR3 robotic arm equipped with a stereo camera to delineate a hemisphere around the item intended for reconstruction. The arm halts at a predetermined speed, enabling the camera to capture photographs. Acquisition points are denoted by black dots, indicating both Z resolution and acquisition rate, thereby establishing angular resolution.

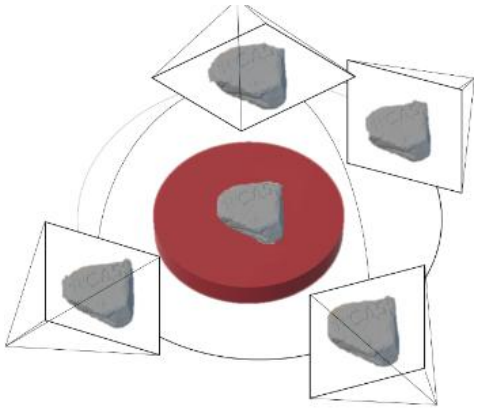

Figure 11: Schematic illustration of the reconstruction process

Adopted from Marchello (2023)

This is a schematic illustration of the reconstruction process, as seen in Figure 11. Following a series of predefined circular trajectories, the robotic arm, equipped with the vision system, rotates around the focal point of the scene, represented by the red pedestal, and acquires a series of images. Articulated robotic arms with precise control over each joint can emulate the same range of motion as a human hand. Such systems have been developed internally for specific tasks or frequently utilize commercially available robotic arms for industrial applications (Jaillant & Caputo, 2022, p. 825). Most commercialized robotic arms are fixed and necessitate intricate designs to enable access for inanimate objects to limbs equipped with various tools. Such systems must be meticulously engineered to perform sensitive tasks, such as restoring a painting, while minimizing the risk of degradation to artifacts. Robotic arms can perform intricate cleaning procedures crucial for preserving surface integrity (Shutterstock, 2023). Basic robotic robots can assist in categorizing newly retrieved artifacts or those relocated, minimizing human error.

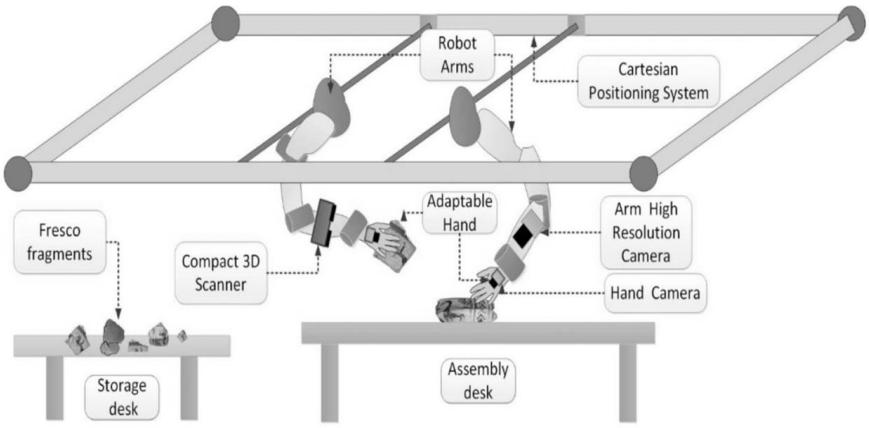

Figure 12: The working process of robotic arms

Source: Adopted from Yan (2022)

For instance, an EU-sponsored project intends to employ technological means to restore fractured cultural treasures in ancient Pompeii, utilizing robotic arms to manipulate the paintings from the House of the Painters at Work in the Insula of the Chaste Lovers and the Schola Armaturarum (Yan, 2022). However, the technology remains in its experimental phase; nevertheless, the completed frescoes will be displayed to the public, allowing tourists to engage with ancient Pompeii and enabling academics to pursue more studies. This marks the inaugural instance in archaeological history where technology will be employed extensively, with robotic hands handling a substantial quantity of artifacts.

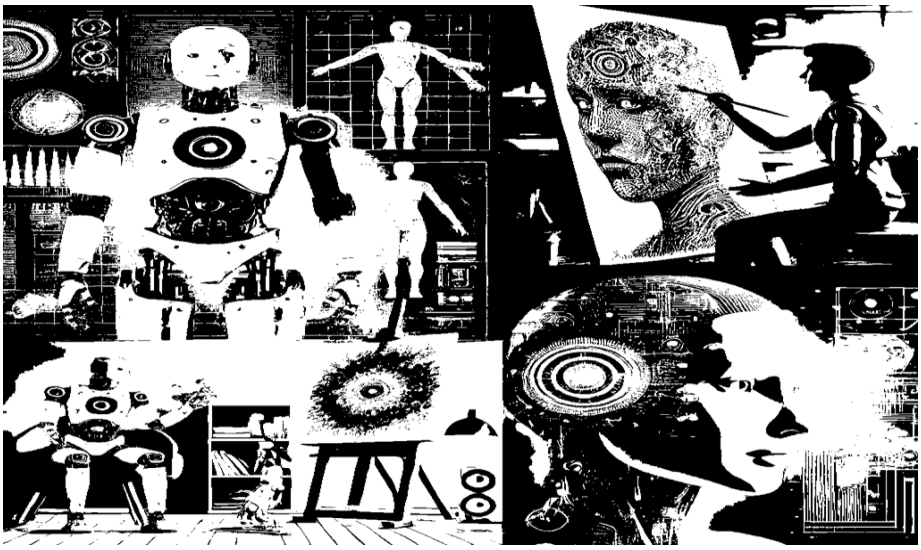

Figure 13: Robots in action

Source: Ashur (2024)

8.3 Robotic sensor

Mobile robotic sensors are essential in protecting cultural heritage and monitoring the environmental conditions of objects. Robotic sensors often utilize multiple sensor types, including thermal sensors for temperature detection, moisture sensors for humidity assessment, light

sensors for luminosity measurement, and air quality sensors for evaluating CO2 and CO concentrations (Jaillant & Caputo, 2022). Each sensor type makes a significant contribution to artifact preservation. Several passive methods have been employed to meet preservation requirements, including museum and gallery layouts, humid buffering mechanisms, and pH stabilization approaches. Dynamic surveillance and oversight of preservation conditions are often essential to prevent degradation and loss of fragile and priceless artifacts (Díaz-Arellano et al., 2021). Robotic sensors have garnered attention as intelligent and resource-efficient tools for monitoring the condition of cultural assets. Robotic sensors are technologies that integrate mobility with sensing capabilities, situated at the convergence of robotics and sensing technology (Marchello et al., 2023). Temperature is a critical environmental factor that influences the quality and dependability of artifacts. All materials undergo expansion and contraction in response to temperature fluctuations, which affects their dimensions and structural integrity. Consequently, understanding temperature levels is crucial for preserving cultural material.

Numerous artifacts consist of multi-material polyphony, possessing varying coefficients of thermal expansion that directly cause stress and cracking. Ongoing temperature monitoring is crucial to maintain an environment that preserves artifacts under optimal conditions. Nevertheless, such interventions typically require installing HVAC (Heating, Ventilation, and Air Conditioning) systems, which, if improperly calibrated, can generate condensation and result in irreversible damage. Relative humidity (RH) is a significant environmental factor influencing the preservation condition of cultural artifacts. Variations in humidity can induce the expansion and contraction of materials, affecting their structural integrity. Abrupt fluctuations in relative humidity can induce cracking or distortion of materials (Germak et al., 2015). A humidity level range of 40% to 60% is typically recommended for long-term preservation. Organic materials typically accumulate moisture from their surroundings, potentially resulting in significant economic expenses or, more critically, irreparable damage, including cracking or deformation. Ongoing surveillance of relative humidity levels is crucial for maintaining an environment that preserves artifacts in ideal conditions.

8.4 Mobile Robots

A primary advantage of robotics is its mobility, which enables it to traverse diverse terrains that would otherwise be inaccessible to human intervention. Mobile robots can be categorized as wheeled, tracked, or clawed devices; however, wheeled and tracked variants are the most commonly utilized in practice. The efficacy of a mobile robot is predominantly contingent upon its design, which must account for the various barriers it may face in its environment (Giakoumidis & Anagnostopoulos, 2024). Mobile robots precisely perceive their environment, facilitating real-time monitoring in industrial contexts. Their autonomy, which permits them to navigate their environment using blueprints or maps, facilitates rapid adaptability and enhances industrial output. They also aid in the painting and stripping of machines or structures. A lightweight robot can efficiently navigate the site without harming delicate items. A semi-automated robot, for instance, can be employed to repair ceramics by adhesive bonding. As artifacts deteriorate over time, they often become buried underground, leading to fragmentation. The procedure encompasses damage evaluation, surface cleansing, alignment, and adhesive application. Alignment is essential for effective repair, as even touch between fractured components can lead

to misalignment. A collaborative configuration can be established, enabling an artisan to position a workpiece, whereas the robot modifies it. This technique ensures efficient cleaning without the risk of damage. Experiments on a robotic system used for a historic sculpture demonstrate the efficacy of this method (Jiangda & Zhao, 2020). Notwithstanding these benefits, the functioning of a mobile robot presents numerous obstacles. Most methodologies presume the robot can traverse the environment unimpeded or concentrate solely on path planning to the designated destination.

8.5 Robotic cameras

Robotic cameras are classified as robotic instruments designed to capture high-resolution images and detailed information of cultural artifacts. Among all preservation initiatives, generating high-resolution pictures and documenting cultural relics are essential (Giakoumidis & Anagnostopoulos, 2024). The utilization of robotic cameras diminishes the likelihood of human errors. These robotic cameras are available in diverse shapes and types depending on the preservation setting. Robotic surveillance equipment is versatile for various conditions, including outdoor and historical preservation settings. Specific systems have a solitary camera, but others are outfitted with many cameras affixed to a pan-tilt robotic apparatus, operating within either a walled studio or an open environment. Robotic cameras enable researchers, historians, and professionals to create precise electronic archives of cultural artifacts and assist curators in conducting thorough examinations. For instance, the Panoramic Robotic Camera was developed for the National Museum of Natural History in Paris, France, to capture the complete surface of large objects in 3D (Giakoumidis & Anagnostopoulos, 2024). The system, originally intended to document alternating digital models in three dimensions from high-resolution photos, was enhanced with 3D laser scanning functionality to produce intricate models of object geometries. Robotic cameras have a significant impact on the documentation of cultural heritage, historic sites, and artifacts. Recent technical advancements have enhanced various critical facets of robotic cameras, including mechanical reliability, durability, and exceptional image quality.

Figure 14: Showing robots identifying extensive damage artifact

Source: Yan (2022)

Scan4Reco, as shown above, is a project funded by the EU, utilizing artificial intelligence to safeguard cultural resources. It employs advanced scanning cameras to generate a three-dimensional duplicate of an artifact, then converts it into digital information. Sensor data from the gathered artifacts is integrated with AI predictive modeling algorithms that replicate the objects'

appearance throughout time. This assists conservators in recommending suitable treatments to safeguard the artifacts before their condition deteriorates or to mitigate existing damage. Upon detecting damage or color degradation in a painting, the system recommends that conservators utilize a designated chemical, paint, or cleanser. The specialized sensors employed in conservation conduct non-destructive diagnostic analyses of several layers, comparable to more invasive chemical methods.

8.6 Robotic excavator

Robotic excavators have emerged as a viable solution for archaeological excavations, utilizing cutting-edge robotics and automation technology. Recent archaeological studies have revealed remarkable findings concealed beneath the earth's surface for ages (Giuliano, 2017). The conventional excavation method, which relies on heavy equipment operated by human laborers, poses considerable risks to fragile antiquities, with an estimated 90% likelihood of damaging subsurface items during excavation (Jud et al., 2021). The risk intensifies as the machinery operates without visibility below the surface, emphasizing the need for speed to prevent potential collapse and maintain safety. Robotic excavators present a compelling alternative, as they can meticulously and accurately reveal artifacts, shifting the emphasis from hasty excavation to deliberate exposure (Dana et al., 2023). The utilization of meticulous excavation robotic systems significantly enhances the likelihood of recovering artifacts intact, as these systems operate considerably slower than conventional gear (Jud et al., 2021). Moreover, robotic systems can operate remotely in hazardous environments, reducing the exposure of excavators and personnel to danger (Zytko & Louie, 2022). Furthermore, the sorting and positioning system enables the robot to identify soil clumps and categorize objects, ensuring that artifacts remain exposed while relocating soil to a different location.

Nonetheless, using robotics to preserve cultural artifacts may raise ethical concerns that were previously absent (Liang et al., 2023; Flessas, 2013). Thus, it is essential to acknowledge the potential use of robotics in addressing specific ethical challenges that affect the wider community, rather than solely focusing on the Indigenous perspective (Colavizza et al., 2021; Germak et al., 2015). While broader ethical questions may pertain to the community, distinct ethical concerns exist specific to the Bini tribe. It is essential to clarify that an ethical consideration pertinent solely to the Bini people may not be applicable to other communities, particularly those in Africa with similar cultural heritages.

9. Discussion of Results

The survey results on heritage preservation stakeholders' understanding of robotic interventions also indicate that a small number of participants are unaware of such interventions. This means Nigerian stakeholders have little knowledge of robotic interventions in cultural item preservation. All respondents concur on the need for robotic cultural conservation. In addition to the historical depredation, the results indicate that deliberate action toward the advancement of a form of passive preservation of cultural heritage has been hampered by a neglectful attitude toward in-situ preservation, a nonchalant attitude toward the cultural choices and opportunities available to young people, poverty, and the chaotic state of the nation. The most significant outcomes of the

exploratory study suggest that it may be possible to utilize robotic interventions to address the challenges associated with conserving Bini cultural objects in Nigeria. However, to properly create and implement robotic intervention, it is essential to consider the social, cultural, and technical characteristics of the environment in which it will be deployed (Zhang et al., 2023). This study demonstrates a strategy that can be extended to various cultural contexts, even though its main focus was preserving Bini cultural items. The investigation into robotic intervention for the preservation of cultural artifacts suggests that existing preservation methods have been ineffective due to insufficient funding and a lack of modern technologies (Onu, 2016). In this sense, relevant stakeholders can collaborate to get sufficient preservation financing.

Locally manufactured prototype robotic arms, previously tested with an 87.5% success rate in grip tests and a 100% success rate in movement testing, can assist curators and preservation specialists in handling artifacts with precision (Alboul, Beer, & Nisiotis, 2019; Zhang et al., 2023). The exploration with robotic intervention reveals the opportunity to begin on a modest scale and at a low cost, while also having the capacity to scale up as more resources become available. Furthermore, although the Bini people were the primary participants in the case study, the exploratory nature of the research allows the findings and intervention method to be applied to different cultural environments (Duniya & Gyegwe, 2014). This is the case despite the constraints of the robotic platform employed in the case study. Although robotic intervention should be co-designed and participatory, this exploratory study presents a case for temporary robotic interventions that can generate conversation opportunities. In low-tech cultural contexts, where knowledge regarding and ownership of technologies typically belong elsewhere, these conversations may be crucial for evaluating whether high-tech cultural interventions are suitable and determining the intended overall direction of these interventions. The exploration of robotic involvement in preserving culture is unprecedented in Nigeria and warrants consideration. Robotic intervention can enhance the conservation of cultural items in Nigeria, especially the cultural artifacts endangered by vandalism and decay.

10. Conclusion

This study has specifically investigated the application of current robotic technological advancements in the field of cultural heritage preservation, with a particular emphasis on the Bini cultural artifacts. Robotic preservation of Bini cultural artifacts offers a means to connect historical legacy with modernity, utilizing technology to maintain cultural identity and heritage. By integrating technology with tradition, Nigeria can assume a prominent position in the global conversation on digital heritage preservation, ensuring the Bini people's legacy endures for future generations. The procedures currently used to maintain the Bini antiquities are considered outdated and insufficient. The results have demonstrated that robotic intervention is capable of successfully addressing the preservation issues currently being faced. The protection of cultural treasures is an absolute necessity, as it is essential to record and transmit to succeeding generations the identity, history, values, and knowledge that have been accumulated throughout time. It is imperative that preventive measures be taken to forestall the irreparable destruction of cultural assets. To achieve this goal, further collaborative research on the robotic intervention of cultural heritage should be conducted among the various participants and non-participants in the

cultural heritage sector. This should focus on specific features of the architecture of robotics and artifacts, such as the digital representation of cultural symbols and their preservation.

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