

Virtual Preservation: Digitising the rare collection of the Saint Joseph Seminary Historical Library

Preservação Virtual: Digitalização da coleção rara da Biblioteca Histórica do Seminário de São José

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ABSTRACT: This research presents a case study on the virtual preservation of the Saint Joseph Seminary Historical Library in Macau, a heritage site adjacent to the Seminary and its Chapel, which housed a rare and valuable collection of ecclesiastical books, archival materials, and portraits of nearly every bishop throughout the Diocese's history. With the impending reallocation of the library's physical space for other educational purposes and the removal of its contents for pest control and archiving, a timely initiative was undertaken to preserve the library's essence and significance digitally. The spatial characteristics of the room were meticulously documented through photography and manual measurement to support its recreation in Virtual Reality (VR), which also integrates online documentation of its rare collection. The project employed a hybrid approach that combined AI-generated 3D models with human-crafted digital assets to reconstruct the library's interior and historical ambience. This interdisciplinary collaboration, uniting university researchers, administrative staff, and alumni, illustrates how virtual heritage initiatives can foster cultural entrepreneurship by creating new pathways for cultural valorisation, community engagement, and sustainable access to historical resources. The research explores the technical strategies, ethical considerations, and broader

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cultural implications of digitally preserving religious and historical sites, providing insights into how emerging technologies can support heritage conservation, education, and innovative cultural practices.

KEYWORDS: Virtual Preservation, Digital Heritage, 3D Reconstruction, Ecclesiastical Archives, Macau Diocesan History, Knowledge, Education

RESUMO: A presente investigação apresenta um estudo de caso sobre a preservação virtual da Biblioteca Histórica do Seminário de São José, em Macau, um espaço patrimonial adjacente ao Seminário e à sua Capela, que albergava uma rara e valiosa coleção de livros eclesiásticos, materiais de arquivo e retratos de praticamente todos os bispos ao longo da história da Diocese. Perante a iminente reafetação do espaço físico da biblioteca para outros fins educativos e a remoção do seu acervo para efeitos de controlo de pragas e arquivamento, foi desenvolvida uma iniciativa atempada para preservar digitalmente a essência e o significado deste património. As características espaciais da biblioteca foram cuidadosamente documentadas através de fotografia e medição manual, permitindo a sua recriação em Realidade Virtual (RV), que integra igualmente documentação em linha da sua rara coleção. O projeto recorreu a uma abordagem híbrida que combinou modelos tridimensionais gerados por inteligência artificial com recursos digitais desenvolvidos manualmente para reconstruir o interior da biblioteca e a sua ambiência histórica. Esta colaboração interdisciplinar, envolvendo investigadores universitários, pessoal administrativo e antigos estudantes, demonstra de que forma as iniciativas de património virtual podem promover o empreendedorismo cultural, criando novas oportunidades para a valorização do património, o envolvimento da comunidade e o acesso sustentável a recursos históricos. A investigação analisa as estratégias técnicas, as questões éticas e as implicações culturais mais amplas da preservação digital de espaços religiosos e históricos, oferecendo perspetivas sobre a forma como as tecnologias emergentes podem contribuir para a conservação do património, a educação e o desenvolvimento de práticas culturais inovadoras.

PALAVRAS-CHAVE: preservação virtual; património digital; reconstrução 3D; arquivos eclesiásticos; história da Diocese de Macau; conhecimento; educação.

Background and Introduction

Macau, located on the western side of the Pearl River Delta in Southern China, possesses a distinctive geopolitical and cultural identity shaped by over four centuries of Sino-Portuguese interaction. It was originally a Chinese fishing village with maritime folk religions, Macau underwent a profound transformation in the mid-16th century when Portuguese merchants established a permanent settlement (Mendes, 2014). The city also developed a complex cultural synthesis characterised by a long, influential Portuguese administrative and Catholic history. The arrival of Jesuit missionaries in the late 16th century established Macau as the Vatican's primary springboard for the spread of Christianity across East Asia. This historic core, inscribed as the "Historic Centre of Macao" on the UNESCO World Heritage list, stands as a testament to early globalisation and cultural hybridity. However, this rich material heritage faces significant transformation due to the rapid economic growth with the release of gaming license, intense urbanisation, and hyper-dense along with the handover to China in 1999. It is within this context of accelerated physical change and environmental vulnerability that digital humanities and virtual heritage frameworks become crucial, offering a vital means of safeguarding Macau's complex, dual-heritage identity for future generations (Ye, 2020). Thus, this research has taken the opportunity and challenge to virtual preserve a soon-to-be gone historical library in the St. Joseph Seminary together with its rare collections, as a starting point to this long journey of virtual heritage

1. Digital Humanities and Virtual Heritage

Digital humanities and cultural preservation have moved from static preservation to more dynamic, interactive, and intelligent over the years, especially on historical data accessibility. As observed by Jaillant, the integration of artificial intelligence into archival science has fundamentally altered how researchers and the public encounter "dark" or complex historical repositories. Rather than maintaining archives as passive repositories, modern digital frameworks utilise artificial intelligence to unlock hidden, massive, or siloed data collections, facilitating a more democratic and exhaustive retrieval of cultural data (Jaillant, 2022). This structural unlocking of the past is further exemplified by large-scale digital initiatives like the LUSTRE project, which leverages machine learning and AI tools to process and contextualise voluminous, unstructured administrative and historical records, making previously inaccessible digital pasts legible for contemporary research and reconstruction (Jaillant, 2023).

Once these archival foundations are digitally established, they provide the empirical groundwork for Virtual Heritage (VH) applications. Virtual heritage extends beyond mere 3D

digitisation; it serves as a critical mechanism for safeguarding both tangible structures and intangible cultural identity. For instance, Al-Ghamdi and Yusuf (2026) demonstrate that combining AI with virtual archives allows for the preservation of complex cultural identities and ephemeral heritage practices—such as historic fashion and material culture—ensuring they are not lost to material decay or geopolitical shifts.

However, the efficacy of virtual heritage depends heavily on how authenticity and user interaction are managed within these simulated environments. Champion (2021) argues that preserving authenticity in virtual heritage requires a deliberate balance between historical accuracy and user interpretation. Instead of presenting a singular, unyielding digital facsimile, virtual heritage must communicate the ambiguity, gaps, and layered histories inherent to archival material (Champion, 2021). To achieve this deeper historical comprehension, Champion (2015) suggests the concept of "critical gaming" and interactive history, asserting that passive observation is insufficient for cultural transmission. Immersive media and interactive mechanics allow users to actively explore, experiment, and engage, i.e. virtual environments, fostering a deeper understanding of historical spaces that traditional, text-based databases cannot replicate (Champion, 2015).

Beyond historical education, digital heritage frameworks offer important solutions to the contemporary crises of physical site management, climate vulnerability, and over-tourism. In their study on historic urban landscapes, Spallone and Vitali (2024) illustrate how digital technologies can map and enhance complex historic routes, serving as an essential toolkit for accessible, non-invasive, and sustainable cultural tourism. By diverting physical tourist traffic to meticulously designed digital pathways and virtual tours, fragile historic centres can be protected from structural degradation without restricting public access to their cultural narratives (Spallone & Vitali, 2024; Tabaeian & Mohammad Shafiee, 2026). Consequently, the synthesis of intelligent digital archiving (Jaillant, 2022; Link et al., 2023) and immersive, authentic virtual heritage frameworks (Champion, 2015, 2021; Tabaeian & Mohammad Shafiee, 2026) offers a robust, sustainable methodology for preserving vulnerable, cross-cultural historical landscapes facing rapid modern transformation.

Macau, a city rich in cultural heritage, has been embracing modern technology to preserve and share its historical treasures. Two of its iconic libraries—the Senado Library⁵ (IAM Building, formerly the Leal Senado Building) and Sir Robert Ho Tung Library⁶—have been digitally preserved using 360-degree photography technology. As part of Macau's historical sites, these virtual libraries provide a digital platform to engage a wider audience with their rich historical backgrounds. Nonetheless, these

⁵ [https://vr.icm.gov.mo/wh/IAMstudent library collection was relocated to the Ilha Verde Campus of the University of Saint Joseph for further organisation, under the university reorganisationlibrary's management/](https://vr.icm.gov.mo/wh/IAMstudent%20library%20collection%20was%20relocated%20to%20the%20Ilha%20Verde%20Campus%20of%20the%20University%20of%20Saint%20Joseph%20for%20further%20organisation,%20under%20the%20university%20reorganisationlibrary's%20management/)

⁶ <https://vr.icm.gov.mo/wh/HortonLibrary/>

libraries focus on their interior, architectural aspects, as well as paintings and other cultural artefacts, rather than archive collections.

Beyond historical preservation, the University of Macau has also preserved its Wu Yee Sun Library as a VR experience, featuring photographs of the interior and the library directory. Macao Millennium College, however, has taken a step further. They partnered with Guangdong University of Science and Technology to launch a 360-degree VR tour⁷ with high-resolution photographs, like the above-mentioned ones developed by the Government, and a dynamic digital library project. Utilising advanced VR rendering technology, this initiative combines the library's physical layout with Macao Millennium College's academic resources to create an interactive virtual environment⁸. Unlike those VR tours with photographs, this experience uses a walking avatar, enhancing user engagement through interactive features such as virtual navigation and resource access. It also provides a digital reading function, allowing users to consult an AI librarian and search the archive during the immersive experience.

These two approaches demonstrate the versatility of VR in education and cultural preservation. By leveraging virtual reality, these institutions are breaking geographical barriers and fostering a deeper appreciation for Macau's literary and historical heritage. Both approaches demonstrate their pros and cons, depicting the true focus sought by their hosting entities. The photographic technique presents users with reality; however, anything added on top of the visual would have to be digitally recreated, creating differences in graphical style. The pure 3D modelling technique shows less detail in the physical objects but allows greater flexibility in decoration and in alternating the setting for different occasions. It can also maintain a similar visual style to maintain immersion depth.

2. Saint Joseph Seminary Historical Library

Founded by the Jesuits in 1728, St. Joseph's Seminary in Macau was established for the dual purpose of clergy formation and the cultivation of civic talent. Over the centuries, its administration alternated among the Jesuits, the Congregation of the Mission, and the Diocese of Macau. The Seminary operated two distinct educational tracks. The first comprised theological education, designed to train candidates for the priesthood through a university-level curriculum that included philosophy, theology, and classical languages, all taught by ordained clergy. The second track offered secular education, dating back to the mid-19th century, when the Seminary provided public and elementary courses supported by the Macau government. These included navigation, commercial studies, and

⁷ https://mmc.edu.mo/blog/library_zh_hk/1278/

⁸ <https://zone.bookan.com.cn/?id=72740&gid=784c13&cid=0310#/>

instruction at the Sino-Portuguese College. The Seminary also shared its facilities, instructors, and resources with external institutions, providing secondary education to non-seminarian students (*St. Joseph's Seminary*, n.d.). At a time when access to education in the region was limited, St. Joseph's Seminary emerged as a pioneering institution in secular education, playing a foundational role in the development of modern education in Macau. Its adoption of a Western educational model emphasised the humanities, particularly language instruction, music, and the arts. As a result, many of its alumni became prominent figures proficient in both Eastern and Western cultural traditions. The Seminary's history thus mirrors the broader trajectory of Macau's educational evolution.

Today, St. Joseph's Seminary serves as the centre for religious education at the University of Saint Joseph, housing the Faculty of Religious Studies and Philosophy (FRSP) ("Faculty of Religious Studies and Philosophy," n.d.). The FRSP is a scholarly community engaged in research and instruction in theology, philosophy, and associated disciplines such as English, Latin, Greek, Hebrew, psychology, sociology, history, and canon law. Upholding the classical view of theology as the "Queen of the Sciences" and philosophy as her "Handmaid," the Faculty continues the Seminary's original Catholic intellectual mission. The Seminary complex also includes a church and is connected to the Colégio Diocesano de São José 2 (CDSJ2) (*CDSJ | Macau*, n.d.), the English-language division of the Diocese's primary and secondary schools.

Architecturally, the church associated with St. Joseph's Seminary is one of only two surviving examples of baroque architecture in China, as identified in *Atlas mundial de la arquitectura barroca* by UNESCO in 2001. Notably, it houses a significant religious relic: a bone fragment from St. Francis Xavier's arm, formerly held by the Church of Mater Dei (now the Ruins of St. Paul's). The church's façade, 27 metres wide and 19 metres high, features a broken arch above the main entrance and a curved pediment bearing the Jesuit insignia. The baroque styling is evident in the use of moulded white plaster relief on a yellow wall. The building follows a Latin cross floor plan measuring 16 by 27 metres, with three ornately decorated altars featuring pediments supported by spiral columns adorned with gold-leaf motifs. The high choir is supported by four Solomonic columns, a characteristic of the Mannerist artistic movement that influenced European church architecture before the Baroque era. A central dome, 12.5 metres in diameter and rising to a height of 19 metres, features three tiers of clerestories, with the uppermost fixed and the lower two functioning as ventilators (*St. Joseph's Seminary Church, Forecourt and Staircase*, n.d.).

Adjacent to the church is the Treasure of Sacred Art of St. Joseph's Seminary, a museum established in collaboration with the Cultural Affairs Bureau of the Macao SAR Government and the Catholic Diocese of Macau (*Treasure of Sacred Art of St. Joseph's Seminary*, n.d.). This space exhibits an extensive collection of religious artefacts, including rare books, manuscripts, oil paintings, icons,

liturgical vestments, and ceremonial vessels. While this curated collection is open to public appreciation, the Historical Library, located just behind it, remains a lesser-known repository of ecclesiastical heritage. This research presents not only the historical values of the location and collection but also a methodology for combining various 3D creation techniques to promote easy yet professional preservation guidelines for historical environments, for informational and educational purposes.

2.1 Memory of the World

In 1992, UNESCO established the Memory of the World (MoW) programme to preserve the world's documentary heritage. The programme aims to facilitate preservation of the valuable documentary heritage, ensure the worldwide accessibility of the records, and raise international awareness of their cultural significance. A key instrument of this initiative is the Memory of the World Register, which identifies documentary heritage of "world significance" at the international, regional, and national levels.

Within this framework, the documentary heritage of Macau holds a profound importance. The Diocese of Macau was established in 1576, marking it as the first diocese founded in the Far East. It includes a significant repository of documentation, records, books, and materials that reflect the evolution of Catholic missionary activities and their expansion from Macau into China and Southeast Asia.

In 2010, the Archives and Record Materials of the Macao Diocese, spanning the 1550s to the 1890s, were inscribed on UNESCO's Memory of the World Register for the Asia-Pacific region (MOWCAP). This collection includes official correspondence, records, training materials, and various publications, preserved at the Diocese of Macau and Macau St. Joseph's Seminary. (*Memory of the World*, 2016, 82–83)

2.1.1 Saint Joseph Seminary Libraries

The Saint Joseph Seminary stands as a cornerstone in the evolution of religious education, typography, and cross-cultural translation in Macau. After the closure and destruction of St. Paul's College, the St. Joseph Seminary Library became the oldest existing higher academic library in Macau, the library's collection has expanded in tandem with the institution's pedagogical development, increasing a diverse array of missionary linguistic tools, Western astronomical treatises, and sinological studies, alongside ephemeral administrative materials such as loan records and archival documents. The collection presents precious historical significance.

The Seminary Libraries consist of the Historical Library, the Student Library, and the Chinese Rare Literature Room. (Lam, 2000, 77) Under the current administrative structure, the Historical Library and the Student Library are integrated into the management of the University of Saint Joseph Library and serve archival and research purposes. The Chinese Rare Literature Room remains under the management of the Macau Diocese Archives, and the research team does not have access to its information.

2.1.2 The Historical Library: A Sanctuary of Rare Documentary Heritage

The Seminary Historical Library is located adjacent to the Treasure of Sacred Art at St. Joseph's Seminary⁹. It houses approximately 5,000 volumes, although the collection currently lacks a formal digital index or systematic catalogue. The materials are organised by subject headings, with an emphasis on theological studies, as indicated by the subject labels.

Beyond its documentary wealth, the library serves as a gallery of Macau's ecclesiastical history, housing the portraits of former bishops who governed the Diocese. The space is currently undergoing relocation and the planned repurposing for other educational functions. The collection has been sent to another campus for archival treatment due to pest control measures. As a core component of Macau's religious and cultural history, the Historical Library represents a high-priority subject for preventive conservation and digital surrogacy, ensuring that these uncatalogued treasures are shielded from environmental decay and preserved for future global scholarship.

2.1.3 The Student Library: The Living Legacy of Pedagogy

The Student Library bridges the Seminary's traditional missiological mandate and modern pedagogical paradigms. The collection contains approximately 8,000 volumes and is divided into various special collections, including a repository of 20th-century intellectual history, with Encyclopaedias, dictionaries, textbooks, and pedagogical resources.

Originally housed on the ground floor of the current Faculty of Religious Studies and Philosophy at the University of Saint Joseph (USJ). In 2019, the student library underwent renovation as part of the broader university library initiative. Subsequently, the collection was integrated into the University of Saint Joseph's management framework. Consequently, the holdings were transferred to the Ilha Verde Campus, where they are currently undergoing systematic reorganisation to meet contemporary academic standards and enhance accessibility for the modern scholar.

⁹ <https://www.macaudahpc.org/treasure-of-sacred-art-of-st-josephs-seminary>

3. The Rare Collection of the Seminary Library

The St. Joseph Seminary Historical Library is more than an architectural landmark; it is a repository of diverse and evolving historical collections. Therefore, it must move beyond maintaining the physical structure to actively protecting and promoting its unique archival materials. By digitising these documents, the project seeks to transform fragile physical records into accessible assets for the global scholarly community.

Rare collections constitute the cultural and intellectual foundation of libraries and institutions worldwide. Traditional preservation methods, such as restricted handling, controlled environments, and limited viewing hours, protect the materials but also limit accessibility, which drives scholarly advancement. The emergence of digitisation presents possibilities to address these challenges. By carefully scanning and digitising fragile texts, libraries and institutions can broaden access to these collections for global audiences. Through Virtual Reality (VR), it offers immersive experiences that go beyond traditional flat screens; users can virtually "handle" and explore rare books, examining intricate details such as binding, marginalia, and texture. Rather than merely viewing pages, VR environments facilitate interactive learning, allowing users to immerse themselves in the history and context of these rare materials within a three-dimensional, navigable world.

3.1 Material Selection of Rare Collection

As an initial phase of this project, we have selected several books that represent the seminary's progress in digitisation. The selection provides insight into the institution's historical evolution and contributes significantly to ongoing research in religious and cultural studies. Digitisation will not only facilitate better academic engagement but also ensure long-term preservation against physical degradation. An essential component of this project is raising public awareness of the need to protect cultural heritage and historical documentation. Utilising innovative tools such as virtual reality (VR) rendering, the project aims to create immersive experiences that engage a broader audience in appreciating the significance of the seminary's legacy. This approach encourages communal responsibility towards protecting historical assets, fostering a greater appreciation for cultural preservation in society. In alignment with the Seminary's historical milestones, the following seven works have been identified as representative of its core pedagogical, theological, and linguistic themes.

The list of seven selected works:

- i. Imagem da Virtude (1714)

- ii. Metamorphoses (1765)
- iii. The Regulamento do Seminário de S. José de Macau (1904)
- iv. Twentieth Century Impressions of Hong Kong, Shanghai and Other Treaty Ports of China (1908)
- v. Legende Chinoise: La Tour Du Pic Du Tonnerre (1919)
- vi. Catálogo dos livros da Biblioteca do Seminário de S. José (1932)
- vii. The Ordinary and the Eucharistic Prayers of the Mass: Cantonese Romanization (1969)

Rather than a disparate list, these volumes are divided into four sections to present a chronological and functional map of the institution's evolution (Table 1).

Section	Title & Publication Year
4.1.1 Global Context	Twentieth Century Impressions of Hong Kong, Shanghai, and Other Treaty Ports of China (1908)
4.1.2 Classical Foundations	Metamorphoses (1765)
4.1.3 Sinology & Mission	Legende Chinoise: La Tour Du Pic Du Tonnerre (1919)
	The Ordinary and the Eucharistic Prayers: Cantonese Romanization (1969)
4.1.4 Institutional Logic	Imagem da Virtude (1714)
	Regulamento do Seminário de S. José de Macau (1904)
	Catálogo dos livros da Biblioteca do Seminário de S. José (1932)

Table 1 Seminary Selected Material: Thematic Mapping

3.1.1 The Global and Regional Context

The Seminary operated within the complex geopolitical landscape of the early 20th-century China coast. **Arnold Wright's Twentieth Century Impressions of Hong Kong, Shanghai, and Other Treaty Ports of China (1908)** stands as an indispensable historical and visual inventory of this period. Beyond its narrative value, the volume captures the physical and political landscape of the Treaty Ports in which the Diocese operated. Through the lens of Digital Humanities, the book's detailed maps and architectural illustrations are transformed into high-value datasets, enabling the digital preservation and reconstruction of the historical cityscapes. This approach effectively synthesises the region's secular colonial history with its religious legacy, illustrating the Diocese's pivotal role in the urban evolution of the Far East.

3.1.2 Classical Foundations: The Export of European Pedagogy and the Delphin Tradition

The most direct evidence of Western intellectual export is the London edition of **Ovid's Metamorphoses (1765)**. As part of the Ad Usum Serenissimi Delphini series, this volume brought the peak of European Enlightenment scholarship to the Far East. The side-by-side prose interpretation and exhaustive scholarly notes were designed to master the Latin language which is the universal language of Western science and theology. Its presence in the Seminary library demonstrates that the students in Macau were trained using the same classical curriculum as the European elite (Genevieve Liveley, 2011).

3.1.3 Sinology and the Vernacular Mission

As the institution matured, its focus expanded toward a sophisticated, scholarly engagement with Chinese culture and language. **Maurice Verdeille's Legende Chinoise: La Tour Du Pic Du Tonnerre (1919)** exemplified this. This rare French translation of the "Legend of the White Snake" was sent by the translator Verdeille to Fr. Régis Gervain¹⁰, representing the evolution of missionary Sinology. Verdeille's "word-for-word" translation method sought to preserve the "genius" of Chinese syntax, offering a window into how Western scholars navigated Eastern thought and attempted to harmonise it with European literary forms.

In the mid-20th century, this scholarly interest transitioned into a practical liturgical necessity following the reforms of Vatican II. **The Ordinary and the Eucharistic Prayers of the Mass: Cantonese Romanization (1969)** marks a key moment of inculturation. By providing the Mass in phonetic Cantonese rather than characters, the Seminary equipped its international clergy with the "oral-aural" tools needed to serve the local community directly. It stands as a testament to the Seminary's commitment to making a universal faith accessible within a specific regional dialect.

3.1.4 The Institutional Logic: Mapping Knowledge and Life

The final layer of the collection reveals the internal organisational logic of the Seminary, showing how the institution governed both its resources and its residents. This foundation was set by **António Franco's Imagem da Virtude (1714)**, a meticulous Jesuit hagiography that provided a "moral compass" and a structured system of spiritual formation exported from Portugal to the Far East.

This inherited tradition was eventually codified in the **Catálogo dos livros da Biblioteca do Seminário de S. José (1932)**, which acts as the intellectual inventory of this era, mapping "what" the

¹⁰ Fr. Régis Gervain was appointed French teacher of S. José Seminary, by the Bishop Dom João Paulino d'Azevedo e Castro.

seminarians read. However, the library's purpose is defined by the lives of its readers. **The Regulamento do Seminário de S. José de Macau (1904)** provides this missing context. While the *Catálogo* tells us what was on the shelves, the *Regulamento* tells us how the students lived, detailing the strict study hours, moral expectations, and spiritual routines that gave the books their meaning. Together, these two documents allow us to reconstruct not just a physical space, but the "lived history" of the Macau Diocese, bridging the gap between the library's architecture and its social reality.

Ultimately, these seven works offer people a chance to enter theological training; they represent the region's knowledge and cultural development. Integrating these records into the 'Macau Story' not only serves specialised historians but also invites the broader public to engage with a cultural heritage that has helped define the city's identity.

4. Digitising Process of the Room Environment

Based on the literature review and the background of both the Historical Library and its rare collections outlined above, this research took initiative to develop a virtual environment. This virtual environment stresses on the preservation and digitisation of 22 historic oil paintings and several selected prints housed within the classical colonial architecture of St. Joseph's Seminary library in Macau. These painted portraits of bishops represent invaluable religious and cultural heritage, documenting centuries of the city's Catholic background. Given the challenging environmental conditions, i.e. high humidity, dim lighting, and architectural decay, photography was combined with advanced 3D reconstruction techniques to create comprehensive digital surrogates.

The methodology employs a multi-faceted approach: high-resolution photography using professional medium-format equipment, followed by detailed 3D modelling that captures both the paintings and their spatial context. Leveraging AI-assisted modelling tools and interactive scanning technologies, the research creates immersive digital experiences that enable virtual exploration of these rare artefacts. This methodology bridges historical preservation with modern accessibility, ensuring that Macau's cultural treasures can be studied, appreciated, and protected for future generations while maintaining their physical integrity.

4.1 Equipment, Photo-documentation, and Post-processing

The library's interior was dark and damp, with signs of significant wear. Water stains and plaster detachment were evident on the walls, and a faint musty smell lingered in the air. The space was furnished with old wooden bookshelves and chairs, some of which featured Art Deco-style brass handles with engraved motifs. The flooring included sections of traditional Western ceramic tiles and

marble, though many were already lost or damaged. Interestingly, some bookshelf legs were elevated using modern stainless-steel rice bowls—a practical, if unusual, method for moisture protection.

The 22 oil paintings portray late Bishops in Macau throughout its 450 years of Catholic church history. They are mounted at various heights on the walls and wooden beams. The diversity in positioning required flexible shooting angles. Other parts of the seminary also featured notable architectural details: arched doorways typical of classical and Romanesque designs, large spiral marble staircases with slender metal railings, stucco wall finishes, and reddish-brown wooden corner guards—elements rarely seen in modern Macanese architecture.

Due to the dim lighting and high humidity on-site, the Fujifilm GFX 50S II, a medium-format camera known for its exceptional dynamic range and colour accuracy, was used, ensuring a faithful representation of the paintings' textures and tones. It was paired with the GF 35-70mm f/4.5-5.6 WR zoom lens, a compact yet capable lens that delivers high-resolution images across a range of compositions—ideal for both close-up and environmental framing. The camera was mounted on a Gitzo GK-2545T carbon fibre tripod for stability during long exposures and bracketed shots, as it offers excellent vibration resistance. Precise composition adjustments were made possible by the Leofoto G4 geared head, which allowed to make smooth, fine three-axis adjustments, even in tight spaces. This setup was critical in maintaining alignment across multiple exposures for later HDR blending.

Given the low-light conditions, exposure bracketing was employed to capture a broad dynamic range. In post-processing, Lightroom was used for HDR merging and precise colour correction, aiming to reproduce the original tones and textures of the paintings faithfully. White balance and sharpness were finally adjusted to ensure the resulting images could serve both archival and academic purposes (Fig.1).



Fig. 1. Collage of the 22 Bishops' paintings (photos by authors)

4.2 Model and Virtual Reality Recreation with Point-cloud Scanning and AI Integration

Like many digital reproductions of local churches in Macao, it is almost impossible to obtain exact measurements of all details, let alone an architectural plan. The researchers started the design process by taking measurements of items at smaller scales, i.e., floor tiles and wall tiles, to calculate tall furniture and room elements such as bookshelves, doors, and high windows (Ng & Caires, 2022). Based on this technique and workflow, the basic shapes of the library room were modelled in Blender for detailed decoration.

Once the room is ready for decoration, detailed patterns, such as tiles, are modelled and textured, using photographs taken on site. Most of the textures could be solid colour with optimised opacity, specular and metallic scale, which are adjustable quality built-in in Blender. For more detailed textures, assistance with material packs from asset libraries such as Poly Haven¹¹ and BlenderKit¹² was obtained. These textures enhance the realism of the virtual environment while reducing the time required for 3D texturing.

Along with the long history of the Macao Diocese, furniture is crafted from wood and sometimes plated with gold flakes. For instance, the legs of the main table have decorations that could only be modelled with sculpting tools like ZBrush¹³, which would take a long time and is not the main objective of this project. Assistance from an AI platform, 3D AI Studio¹⁴, was obtained to model at least part of the mesh, as the researchers followed the same approach in another of their projects presented at ARTECH2025 and an abstract published the same year (Ng, 2025a; Sá et al., 2025). Together with mirroring symmetrical meshes, sculpting to smooth seams, and integrating simple geometry to minimise face counts and simplify the workflow, and optimising the mesh by avoiding loading too many polygons (Fig. 2).

¹¹ <https://polyhaven.com/>

¹² <https://www.blenderkit.com/>

¹³ https://www.maxon.net/en/zbrush?srsId=AfmBOoq_5-eOG3d0n71QcEEsE3TCD-FD-SOZsNwcjp6CvNzqLux2eH5q

¹⁴ <https://www.3daistudio.com/Dashboard>

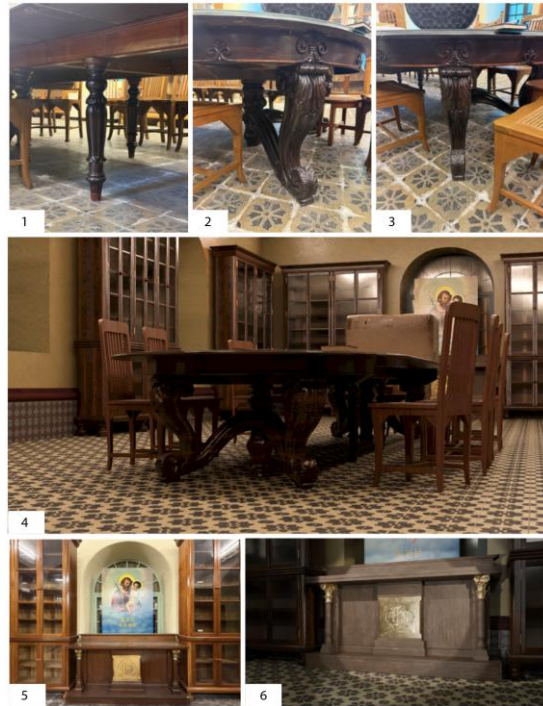


Fig. 2. Collage of interior details, reality (1, 2, 3, 5) vs virtual reality (4, 6) (photos by authors)

High-quality digital surrogacy requires more than a simple scan; it requires recreating an object's physical character. Through rendering tests in the Reality Composer application¹⁵, we verify the visual fidelity of the 3D book covers and bindings. It demonstrated that this tool could effectively represent intricate physical details, such as the texture of aged leather and embossed motifs, with high precision. The collection's digital "outlook" encourages closer inspection by the user.

Beyond static observation, this technical workflow provides a foundational extension for future interaction. It enables the scanned items to be manipulated and viewed from a 360-degree perspective within a virtual reality environment. This next step in development will allow users to explore the physical materiality of the rare materials in a way that replicates real-world handling, bridging the gap between historical preservation and immersive digital engagement.

4.3 VR Tour Interactivity, Challenges and Opportunities

The final high-resolution virtual environment is then uploaded and published on [Kuula.co](https://kuula.co)¹⁶ (Ng, 2025b). Visitors can navigate the environment using arrows and zoom into the paintings, patterns, and detailed information of the rare collection via hotspots. The scanned objects are exported in

¹⁵ Reality Composer is a 3D scanner using point cloud developed by Apple. <https://apps.apple.com/app/reality-composer>

¹⁶ [https://kuula.co/aboutcollaboration across Usingcollaborationacrossmodelling t](https://kuula.co/aboutcollaboration%20across%20Usingcollaboration%20acrossmodelling%20t)

the .usdz format¹⁷ and can be easily imported into Blender for photorealistic renderings. The research team placed six selected books from the collection on the reading table in the virtual environment. With hotspots integrated, viewers can interact with each book and read its information. (Fig. 3)

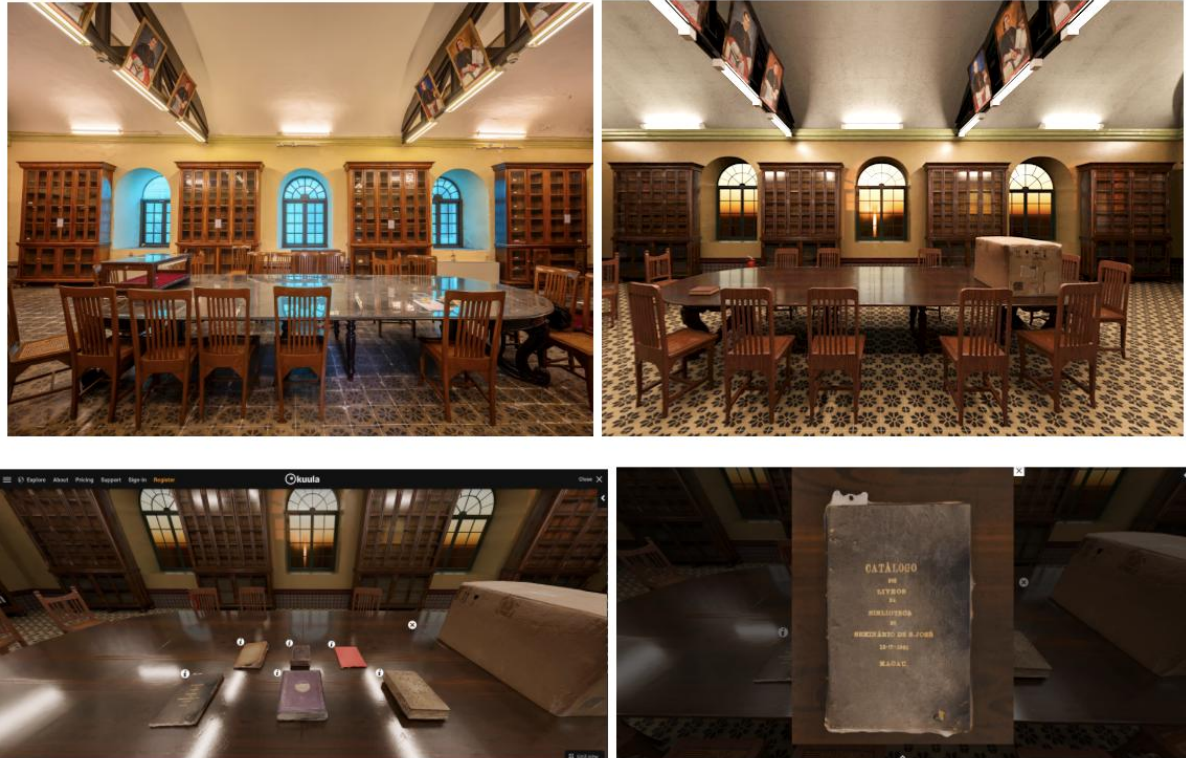


Fig. 3. Collage of VR tour details and hotspots (photos by authors)

¹⁷ A .usdz file is a 3D file format developed by Pixar and Apple. It is specialized and uncompressed. Widely used for augmented reality (AR) and seamless sharing of 3D models with materials mapped.

One of the biggest challenges in this project is balancing immersion depth, navigation, and information delivery. Researchers could have chosen one over the others if they were not careful enough. Nonetheless, the focus and main objective of this project is to preserve the environment, present the high resolution of the paintings and showcase a rare book collection from this library. It is important to achieve these three elements equally. Therefore, instead of developing the experience on a game engine that would also provide, or even better, realistic renders and a first-person perspective, we chose to render the environment statically and stream it on [Kuula.co](https://kuula.co). It not only provides high visual quality but also maximises usage, since users do not require a Head-Mounted Device (HMD) for the experience. Also, instead of going on a site visit and taking panoramic photos of the reality, we chose to model the room to provide greater flexibility and clarity in the visual presentation. This approach can also allow researchers to showcase rare collections seasonally, depending on their needs and occasions.

Conclusion and Future Work

While the primary function of the digitised collection is to serve the demands of global scholarship, this project places equal emphasis on broader public engagement. Rare materials are often perceived as inaccessible to the general public due to their fragility and the specialised environments required for their storage. As noted by Pipkin (Pipkin, 2024), public access is frequently hindered not only by physical restrictions but also by "library anxiety", a sense of intimidation felt by non-academics when entering specialised university spaces. By transitioning these collections into an interactive digital realm, we can bridge the gap between elite academic research and civil education, effectively dismantling the perceived barriers to these "exclusive" repositories.

"Interaction" is the catalyst for this transformation. In traditional museum or library settings, the public is often a passive observer, separated from historical artefacts by glass cases. However, by integrating Virtual Reality (VR) and 3D modelling, we can foster a sense of communal stewardship. This approach aligns with McGarvey's findings, which demonstrate that launching online repositories can create a "positive feedback loop," significantly increasing public awareness and attendance far beyond initial expectations. When users, particularly the younger generation and local citizens, can virtually "handle" a 300-year-old manuscript or explore the architectural nuances of the Seminary, history ceases to be a distant academic subject and becomes a living, shared heritage. (McGarvey, Rachael, 2016)

This interactive approach serves a vital role in cultural promotion. It democratises access to knowledge, enabling rare materials to serve as tools for lifelong learning and civic pride. By creating an immersive experience that does not require specialised hardware (HMDs), we lower the barrier to

entry, inviting the public to appreciate the significance of Macau's religious and intellectual legacy. Ultimately, the goal is to foster a society that values and actively supports the preservation of its historical assets, ensuring that the Seminary's treasures are recognised not just as archival objects, but as essential pillars of our collective cultural identity.

The project "Virtual Preservation: Digitising the Rare Collection of the Saint Joseph Seminary Historical Library" is an example of how collaboration across different fields can spark cultural entrepreneurship. It takes the idea of preserving heritage and turns it into an exciting platform for innovation and economic growth. By bringing together university researchers, administrative staff, and alumni, this initiative not only protects Macau's ecclesiastical heritage but also opens new avenues for cultural appreciation and sustainable economic development. Using 3D reconstruction, AI-generated models, and VR technology, the project transforms historical resources into engaging digital assets. This creates opportunities for educational tourism, academic partnerships, and commercial ventures (think virtual exhibitions, licensed digital content, and immersive learning experiences).

This approach really empowers cultural entrepreneurship by connecting the old with the new, allowing institutions to monetise their digital heritage while preserving its authenticity. By making these rare collections accessible to a global audience, the project attracts investment in cultural tourism, research collaborations, and grant-funded projects, turning heritage conservation into a scalable, financially sustainable effort. In the end, it shows how virtual heritage initiatives can foster innovation, engage communities, and create sustainable revenue streams, positioning cultural institutions as frontrunners in the digital economy while honouring their rich legacies.

This research exemplifies the potential of heritage preservation for Macau in the digital age. By showcasing rare historical materials, not only architectural but also paintings and prints, through immersive experiences, it breaks down traditional barriers between academia and public engagement while generating sustainable economic opportunities through cultural entrepreneurship. The initiative demonstrates how cutting-edge technology can preserve the past while building pathways for future cultural and economic growth, positioning heritage institutions as dynamic contributors to both education and the digital economy.

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