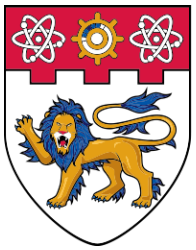

NANYANG TECHNOLOGICAL UNIVERSITY
SINGAPORE

THE ROLE OF IMMERSIVE MEDIA IN ENGAGING SINGAPORE'S HISTORY & CULTURAL HERITAGE: SINGAPORE HISTORY GALLERY AND DIGIMUSE AS A CASE STUDY (2006-2018)

CHENG SHAO MENG (MERLIN)

SCHOOL OF ART, DESIGN AND MEDIA

2022

The Role of Immersive Media in Engaging Singapore's History & Cultural Heritage: Singapore History Gallery and DigiMuse as a Case Study (2006-2018)

CHENG SHAO MENG (MERLIN)

School of Art, Design and Media

A thesis submitted to the School of Art, Design and Media, Nanyang Technological University in partial fulfillment of the requirement for the degree of Master of Arts (Research)

Statement of Originality

I certify that all work submitted for this thesis is my original work. I declare that no other person's work has been used without due acknowledgement. Except where it is clearly stated that I have used some of this material elsewhere, this work has not been presented by me for assessment in any other institution or University. I certify that the data collected for this project are authentic and the investigations were conducted in accordance with the ethics policies and integrity standards of Nanyang Technological University and that the research data are presented honestly and without prejudice.

24 Oct 2022

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Date

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Cheng Shao Meng

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I have reviewed the content of this thesis and to the best of my knowledge, it does not contain plagiarised materials. The presentation style is also consistent with what is expected of the degree awarded. To the best of my knowledge, the research and writing are those of the candidate except as acknowledged in the Author Attribution Statement. I confirm that the investigations were conducted in accordance with the ethics policies and integrity standards of Nanyang Technological University and that the research data are presented honestly and without prejudice.

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Date

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Cheng Shao Meng

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Table of Contents

Summary / Abstract

This thesis investigates the role of (digital) immersive media (IM); such as virtual reality (VR); augmented reality (AR); mixed reality (MR); immersive environment (IE); among others; in the context of the National Museum of Singapore (NMS) from 2006 to 2018. It acknowledges that digital IM is a small part of the NMS's larger exhibition planning strategy as the NMS's institution trend. The discussion begins with the intertwining history of the NMS, the National Heritage Board, and immersive media development. The thesis will focus on the 2006 and 2015 iterations of the Singapore History Gallery, which were exhibited differently before and after the revamp from 2014-2015. It will discuss two specific examples in the museum's 2018 DigiMuse programme and how they suggest that the NMS was serious about working with local and overseas technology companies to enhance the museum experience. The thesis also discusses the NMS adaptability in using IM to engage with their audiences by creating offsite experiences at a time when museum capacity was limited. It looks at how the NMS compare to two other museums in Singapore in creating onsite and offsite IM experiences – ArtScience Museum (ASM) and Asian Civilisations Museum (ACM). Lastly, this thesis looks at how new technology is reshaping the museum-going experience and some best practice frameworks of using IM technology by keeping it short, and simple to use and creating a personal connection with the visitor to meaningfully engage, enrich, and excite them with the exhibition's content.

Keyword

digital museum – digital immersive media – digital heritage – museography – national museum of Singapore

Abbreviations

Asian Civilisations Museum	----------	ACM
Augmented Reality	----------	AR
ArtScience Museum	----------	ASM
Extended Reality	----------	XR
Head-Mounted Display	----------	HMD
Immersive Environment	----------	IE
Immersive Media	----------	IM
Infocomm Media Development Authority	----------	IMDA
Information and Communication Technology	----------	ICT
Indian Heritage Centre	----------	IHC
Information Technology	----------	IT
Mixed Reality	----------	MR
National Gallery Singapore	----------	NGS
National Heritage Board	----------	NHB
National Museum of Singapore	----------	NMS
Nanyang Technological University	----------	NTU
School of Art, Design and Media	----------	ADM
Science Centre Singapore	----------	SCS
Singapore Heritage Society	----------	SHS
Singapore History Gallery	----------	SHG
Virtual Reality	----------	VR

Author's Note

The main bulk of the dissertation was written during the second year of the COVID-19 pandemic (2021). The idea of writing a thesis on the use of emerging technology, which in this case includes virtual reality, augmented reality, mixed reality, and so on, was to highlight how these technologies can be used to enhance visitor engagement and their role in a Singapore museum. The COVID-19 situation changed that.

With the success of an exhibition no longer determined by mere visitorship alone due to reduced capacity and straight-out closure, museums in Singapore had to look for other ways to engage with their socially distanced audiences. For this thesis, it meant having a choice in the tone and emphasis – this thesis could be written by ignoring the pandemic entirely or taking the thought process and new-found knowledge and applying it to a post-COVID-19 world moving forward.

Given the point of academic research is to uncover new knowledge and how it can be used for the betterment of society, it made sense to write this thesis to help museums in the future, which in this case meant being in a post-COVID-19 world.

While much of the thesis writings would probably remain unchanged from its original conception, considerations would be given to the COVID-19 situation, such as the preference for contactless interactivity in exhibitions or the use of an online exhibition. A large part of the study – audience interaction, was scrapped because of the visitors' restrictions placed on the museum. Instead, the thesis focuses on the literature review and interviews to fill in the missing gaps.

The past two years were tough and challenging. Still, it also helped highlight what is essential when all the extravagant digital media and technology are taken away in a museum. It forced me to look at the museum exhibition in a new light – stripping them to their bare essence, which are the artefacts and the narrative, and how they can be augmented (using immersive media or otherwise) to serve the museum visitors better. This includes being physically in the building or virtually at home and the museum's role in engaging them.

CHAPTER 1: RESEARCH OVERVIEW

1.1 Introduction

This thesis is divided into eight chapters, with Chapters 1 and 2 looking into the research overview and methodology deployed. The thesis findings are divided into Chapter 3, Chapter 4, and Chapter 5. Chapter 3 focuses on the history and development of immersive media (IM) and the National Museum of Singapore (NMS). Chapter 4 centers on the theoretical and conceptual framework of IM and the theatre-museum and how it relates to the NMS. Chapter 5 examines the examples used for the case study. Chapter 6 attempts to answer the research questions by analyzing the findings, while Chapter 7 provides some best practices based on the analysis. Chapter 8 concludes the thesis and offers possible future studies.

> *"Museums today are all about immersive experiences. Digital technology is here to stay, and we need to be open to featuring new ideas and concepts."*
> *- Ms Angelita Teo[1], NMS Director, 2017*

In the past decade, there has been a resurgence of "immersive media" (IM), especially with the advancement and mainstream popularity of virtual reality (VR), augmented reality (AR), and mixed reality (MR) both in personal entertainment and professional usage in business, engineering, and research environments. It has led to more studies and discourses on incorporating information technology (IT), including IM, into the museum and digitizing culture, heritage, and history. This discussion is evident in publications such as '*Theorizing Digital Cultural Heritage: A Critical Discourse'* (2007)[2]; *'Digital Technologies and the Museum Experience'* (2008)[3]; '*Museum in the Digital Age: Changing Meanings of Place, Community, and Culture'* (2014)[4]; and '*The Routledge International Handbook of*

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[1] Ho, Olivia. "The National Museum of Singapore launches first dedicated digital space". The Straits Times. 2 Feb 2017. https://www.straitstimes.com/lifestyle/arts/making-exhibits-come-alive
[2] Cameron, Fiona., and Sarah. Kenderdine, eds. Theorizing Digital Cultural Heritage: A Critical Discourse. Choice Reviews Online. Vol. 45. Media in Transition. Cambridge, Massachusetts: MIT Press, 2007.
[3] Tallon, Loïc, and Kevin Walker. Digital Technologies and the Museum Experience. Altamira Press. Plymouth: AltaMira Press, 2008.
[4] Bautista, Susana Smith, ed. Museums in the Digital Age: Changing Meanings of Place, Community, and Culture. Lanham: AltaMira Press, 2014.

New Digital Practices in Galleries, Libraries, Archives, Museums and Heritage Sites' (2019)[5], among others. The National Museum of Singapore (NMS) is no exception to using digital tools to augment the audiences' experience.

This chapter introduces the dissertation's research questions, aims and objectives, focus, and scope.

1.2 Research Questions

1. What can we learn about the National Museum of Singapore's strategy and direction of engaging Singapore's history and heritage using digital technology and immersive media in the Singapore History Gallery from the first revamp in 2006 and the second revamp in 2015?

2. How does DigiMuse, specifically two prototype projects from DigiMuse 2018, fit into the National Museum of Singapore's overall strategy and direction as they were used in the Singapore History Gallery, and how do these projects engage in learning about Singapore's history and heritage?

3. What do the National Museum of Singapore's partnership and collaboration with digital technology industries tell us about the museum's attitude in the present day as compared to pre-2006 revamp period?

Sub-question:

- How does the National Museum of Singapore's exhibition strategy on using digital technology and immersive media differ from other local museums, and what are some noteworthy milestones of using them in local museum exhibitions?

[5] Lewi, Hannah, Wally Smith, Dirk vom Lehn, and Steven Cooke. The Routledge International Handbook of New Digital Practices in Galleries, Libraries, Archives, Museums and Heritage Sites. 1st ed. London: Routledge, 2019.

1.3 Research Aims and Objectives

The main objective of this thesis project is to examine the role that immersive media plays in the NMS and how it relates to their exhibition strategy.

It looks at the role that digital technology performs in the SHG, and in particular, the usefulness of IM to engage, enrich and excite museum visitors meaningfully. It investigates how these digital technologies have been used in the past and how they can be further improved in future NMS exhibitions and programming. Aligning with the NMS goals, it explores how IM can help museum visitors experience, learn, and appreciate Singapore's history and cultural heritage. It also contemplates how the use of IM has changed in a post-COVID-19 world.

The thesis investigates the NMS curatorial philosophy, their approach toward commissioning exhibition design and digital IM, the circumstances of creating the DigiMuse programme, the history of IT development in Singapore, and the museums that employed them.

It is noted that the NMS commissioned the permanent exhibitions to external consultants with a small team of NMS curators during both the 2006 and 2015 partial revamp[6]. They are GSM Design, and GSM Media (both currently known as GSM Project) for the 2006 revamps; and GSM Project, M'Go Films[7], and Kingsmen Creative for the 2015 updates[8].

In the end, the thesis hopes that the findings will play a part in the discourse to help strengthen local museums' goals and objectives. It aims to do so by looking at the evolution and trends of IM technologies, the limitations and challenges of implementing them, and the suitability of different IM for both long-term and short-term museum exhibitions and programming.

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[6] "Singapore History Gallery". GSM Project. https://gsmproject.com/en/projects/case-study/singapore-history-gallery/ (accessed 12 July 2022)

[7] "Sejarah Singapura". M'Go Films. https://www.margofilms.com/exhibit/index.php?projects/SEJARAH (accessed 12 July 2022)

[8] Seow, Janice. "Retelling the Story of a Nation". InDesignLive. https://www.indesignlive.sg/projects/retelling-the-story-of-a-nation (accessed 12 July 2022)

1.4 Research Focus and Scope

The thesis focuses primarily on using IM and related technologies in the NMS and how the museum factors their uses in its exhibition strategy. It acknowledges that both non-digital and digital technology create an immersive museum-going experience. It will look at how they worked together and were integrated into the Singapore History Gallery (SHG), along with their use in the DigiMuse programme to assist in learning about Singapore's history and cultural heritage by making it engaging, enriching, and exciting.

This thesis examines and covers these IM specifically as examples for the case study:

- **Singapore History Gallery (2006-2014)**
    - *Singapore 360º* - Karen Kathleen Cai, GSM Design (Glass Rotunda)
    - *Sejarah Singapura* - Ho Tzu Nyen, M'Go Films, GSM Design
    - *The Building Remembers/Remembering the Building* - Matthew Ngui (outside the SHG)

- **Singapore History Gallery (2015 – present-day)**
    - *The Lands Below The Winds* projection – M'Go Films
    - *Sejarah Singapura* (excerpts) - Ho Tzu Nyen, M'Go Films
    - *Story of the Forest* and the smartphone app - teamLab (Glass Rotunda)

- **DigiMuse programme (2018)**
    - *Museum Experiential Guide* - DigiMagic & NTU ADM
    - *An Excavation Through Time* - iMMERSiVELY

The thesis also acknowledges that even within the same time frame, the SHG was constantly changing, with the curatorial team making minute adjustments every so often. The constant renewal of the exhibition site was more evident in 2020 and 2021 when the pandemic forced the museum to shut down most of its interactive kiosks to reduce the risk of virus transmission.

This thesis considers the DigiMuse showcase programme one of the many activities organized to entice more visitors. It explores the *Museum Experiential Guide* and *An Excavation Through Time* in DigiMuse 2018 as examples of the programme and how their use augments visitors' experience. It also explores how DigiMuse is different from the SHG's permanent fixtures.

CHAPTER 2: METHODOLOGY

Most research questions involve examining the historical and theoretical aspects of IM and the NMS. Thus, the research mainly uses literature review – published books, journals, conference proceedings, newspapers, government reports, and websites such as *Infopedia*. The information pool was rounded out by oral histories of selected individuals concerned in this study using **semi-structured interviews**.

The thesis identified the three main stakeholders of the NMS as:

1. Museum Visitors
2. Commissioned Consultants / Contractors
3. Museum Staff (Curators, DigiMuse Team, IT and Media staff)

The museum visitors include Singaporeans of different age groups and ethnicities who understand Singapore's general history and foreign tourists who might not be as well aware. Unfortunately, due to the museum's closure during the Covid-19 pandemic, this research paper could not collect data and visitor feedback; thus, this research paper is not positioned in the area of 'visitor's studies'.

The commissioned consultants and contractors involved people commissioned by the NMS to create media and technology-related works. They include known artists or technologists, and external companies hired to aid with the design or media production of the installations. Examples include Lionel Chok of iMMERSiVELY for his work in the DigiMuse project and M'Go Films, which did part of the film and animation installation in the SHG.

Lastly, the museum staff in this thesis focuses mainly on the NMS curators and the DigiMuse team, who are involved in planning the use of IM in the NMS through exhibitions and programming. Other NMS and NHB staff, such as their Design and Innovation department, IT department, and Comms and Digital department, are also loosely considered in this category.

The approach to the literature review and interviews will mainly revolve around groups 2 and 3. It will involve questions regarding the NMS, its history, and its use of IM in the museum. For group 1, interviews with academics on VR and history will be conducted instead of visitor's studies.

2.1 Literature Review

The foundation of this research project was built from these three books: *National Museum of Singapore Guide* (2007); *Dome in the City* (2016); and *(Re)Presenting Histories* (2017). As the NMS publishes these books, they contain valuable information before and after the 2015 renovation and refreshment of the galleries. They also provided insights on the NMS exhibition planning, design, and strategy and how digital media plays a role in them. A notable observation is the museum's distinction between contemporary art commissioned by the NMS which uses digital media and digital media as a tool in the museography process. Within that digital technology and media umbrella contains works considered IM, using technologies such as VR, AR, MR, and IE.

The three NMS books were complemented by journal articles, essays, and published interviews written by notable members inside and outside the NMS and the NHB. These included writings by historian Kwa Chong Guan; then-NMS director Angelita Teo; and director of Asian Civilisations Museum Kennie Ting. Contributing to this is the book *Questioning Museums: Art Institutions in Singapore* (2019), a collection of transcribed interviews with Ting; Teo; Kwa; and Peter Lee; published by NTU School of Art, Design and Media. Like the three NMS books, these interviews offered valuable information on the operation of museums in Singapore (specifically the ACM and the NMS) from the perspective of the museums' directors. It provides an overview of the organisational structure, how they fit into Singapore's heritage ecosystem; and how each museum reacted to the changes in visitors' lifestyles and expectations as digital technology became more commonplace.

The information pool was rounded off by local journals such as *MuseSG* and *Cultural Connections*; as well as conference proceedings and post-symposium publications such as *Reforming Museums for the 21st Century* (2000)[9]; *Making Museums Matter* (2008)[10]; *The Past in the Present: Histories in the Making* (2009)[11]; *Museum-Community Partnerships* (2010)[12]; *The Digital in Cultural Spaces* (2016)[13]; and *Appropriate Museology*

[9] Magnusson, Karl. Reforming Museums for the 21st Century: Report on the Stockholm Asia-Europe Conference on Museums 2000, Singapore: National Museums of World Culture, 2000.
[10] Heng, Noi Loh; and Teh, Eng Eng. Making Museums Matter: A Post Symposium Publication. Singapore: National Heritage Board, 2008.
[11] Chua, Pricilla, ed. The Past in the Present: Histories in the Making. Singapore: National Heritage Board, 2009.
[12] Tan, Heidi. Museum - Community Partnerships: The Role of ASEAN Museums in the 21st Century, Singapore: National Heritage Board, 2010.
[13] Thangamma, Karthigesu; Tan, Chui Hua; and Low, Mei Gek Cheryl-Ann. Digital in Cultural Space. Singapore: Culture Academy Singapore, 2016.

– *Appropriate Language* (2018)[14]. They include local, regional (ASEAN), and international museum conferences. These journals and conference proceedings were written by relevant staff members of the NMS and the NHB. They provide the audience with the thought process and reflections on what the NMS and the NHB have done. They provided an overview of how the NMS attract new audiences and engages existing visitors by incorporating digital technology in their exhibitions and programming.

The thesis will attempt to piece together the history of the NMS and its use of digital and new media; it will look at reports by government agencies such as NHB Annual Report and *Our SG Heritage Plan* (2018)[15]. It also scouted through *The Straits Times* and *Channel NewsAsia* websites, together with Singapore newspaper database *Newspaper SG* (https://eresources.nlb.gov.sg) for archival news articles related to the revamp and redevelopment of the NMS, as well as crucial VR-related exhibitions and programmes hosted in the NMS. Other National Library Board (NLB) online resources were used as well, such as *Infopedia* and *History SG,* to deliver the background context of the local government and organisations.

For the history of IM and digital museum in the global context, the thesis relied heavily on academic books; journal articles; and web articles from sources such as The Economist, The Open University, Smithsonian Magazine, Britannica, and the technologists' websites. The references were cross-checked to ensure that the information was as accurate as possible. Regarding academic books that discussed the use of digital technologies in museums, books published in the past fifteen years were consulted. As these sources only provide an 'instiution-orientated' perspective, web conferences, video interviews, and blog entries will also be consulted with some of the commissioned artists and developers to look at the artistic and technical issues in implementing IM in the museum.

[14] Avenarius, Gundula; Deemas, Aisha; Kamel, Susan. Museology - Appropriate Language: Essays on Translation and Communication in the Museum. Berlin: Hochschule für Technik und Wirtschaft, 2018.
[15] National Heritage Board. "Our SG Heritage Plan." Singapore: National Heritage Board, 2018.

2.2 Semi-Structured Interviews

The semi-structured interviews were conducted to collect interviewees' experiences and expert knowledge about the topic. The interviews were split into three different groups:

1. Academics and Researchers
2. Commissioned Consultants / Contractors
3. Museum Staff (Digital Media & IT)

Each group had its own set of guiding questions, and additional questions were asked depending on the flow of the conversation. Due to the ongoing pandemic, most interviews took place over video conferencing.

Interviewees

- **Academics and Researchers**
  - *Asst. Prof Li Junting Benjamin* – NTU Wee Kim Wee School of Communication and Information
  - *Asst. Prof Koh Keng We* – NTU School of Humanities

- **Commissioned Consultants / Contractors**
  - *Michelle Ng* – DigiMagic Communications
  - *Lionel Chok* – iMMERSiVELY
  - *Eugene Soh, Tan Shao Yun* – Dude.sg

- **NMS and NHB Staff (Digital Media & IT)**
  - *Jervais Choo* – Programme Director of NMS DigiMuse
  - *Iskander Mydin* – NMS Curatorial Fellow

In addition to written publications (such as newspaper interviews) and interviews done explicitly for this project, this thesis also made use of video interviews that were publicly available, such as the *'Yours Virtually'* video series done by the Culture Academy[16].

Figure sources and interviewees' profiles are located in the Appendix.

[16] "Yours Virtually". Culture Academy. Feb 2021. https://www.mccy.gov.sg/cultureacademy/resources/digital-training/Yours-Virtually

CHAPTER 3: HISTORICAL OVERVIEW

This chapter will look at the key innovations of immersive media (IM) histories, before going in-depth into Singapore and the NMS and its history with digital technology.

3.1 Historical Overview of Immersive Media

Precursor of Immersive Media (Pre-WWII)

Despite being a relatively new digital media, the concept behind IM can be traced back to the late 18th century[17]. In the historical context, these ancestors to modern digital IM could be seen as the roots that branched out to what we now know today as VR, AR, MR, IE. Crucially, this was more about "the establishment of an idea, rather than the invention of a specific technology"[18].

An example of one of the earliest attempts in an immersive environment began with painter Robert Barker, who patented and coined the term "panorama" in 1787[19]. It was a 360-degree painted landscape on a circular canvas surrounding the viewer[20] (fig. 1).

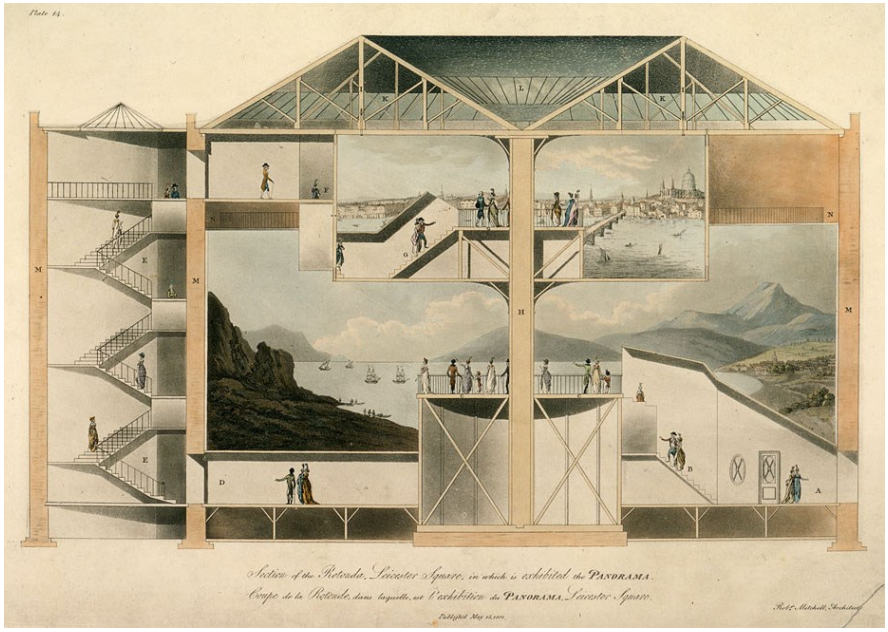

Fig. 1. Cross-section of the Rotunda *in Leicester Square exhibition of Barker's panorama of London (1801).*

[17] Virtual Reality Society. "History of Virtual Reality," 2019. https://www.vrs.org.uk/virtual-reality/history.html.
[18] Ibid.
[19] Ford, Lily. "Virtual Reality, 19th Century Style: The History of the Panorama and Balloon View." The Open University, 2017. https://www.open.edu/openlearn/history-the-arts/visual-art/virtual-reality-19th-century-style-the-history-the-panorama-and-balloon-view.
[20] Ibid.

The rooms in the *Rotunda* were almost entirely covered with panorama paintings, immersing the viewers inside the painting's location. Later iterations following the Rotunda concept are more dynamic,and the diorama was introduced in 1822[21].

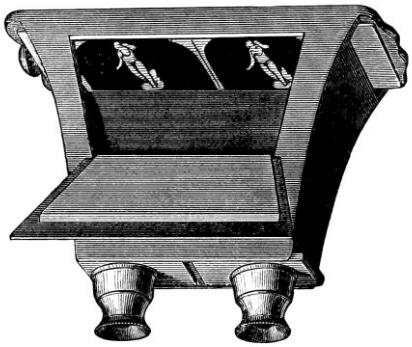

Fig. 2a and b. The Wheatstone stereoscope in King's College London, 2016 (left). The Brewster stereoscope (right), 1849.

Later in the decade, in 1838, Sir Charles Wheatstone's research into stereopsis led to the invention of the earliest prototype of the stereoscope (fig 2a)[22]. Stereopsis essentially is how the human brain processes two-dimensional images from each of our eyes to form a sense of depth and three-dimensionality. In 1849, Wheatstone's long-time rival[23] David Brewster refined the concept and created the lenticular stereoscope, a lens-based portable device[24] (fig 2b). The device became so popular that many companies released their inexpensive version of the portable stereoscope.

Fig. 3a and b. Stereo-view of a man in the Singapore Botanic Gardens (left), 1890s-1900s. Glass stereoscopic negative showing a steamship docked along a river (right), c. 1910s.

[21] Greengard, Samuel. Virtual Reality. Cambridge, Massachusetts: The MIT Press, 2019. 22.
[22] Barnard, Dom. "History of VR - Timeline of Events and Tech Development." Virtualspeech, 2019. https://virtualspeech.com/blog/history-of-vr.
[23] Wade, Nicholas J. "Ocular Equivocation: The Rivalry between Wheatstone and Brewster." Vision (Switzerland) 3, no. 2 (2019).
[24] Barnard, Dom. "History of VR".

There are several sets of stereoscopic images of Colonial Singapore dated between the 1890s to 1910s in the Singapore national collection (fig 3), suggesting that stereoscopic photographs were widespread among the population who could afford such devices.

Stereoscopic photograph viewers provide the user with a passive experience of an artificial visual illusion by isolating the user and changing their perception of their surroundings. It would not be far for science fiction writers to assume other similar possibilities. Moving into the 1930s, the concept of an extended reality materialized in science fiction short stories such as "Pygmalion's Spectacles."[25] Written by Stanley G. Weinbaum, the story showcased the idea that a pair of goggles can project three-dimensional images that augment the wearer's sight, sound, taste, smell, and touch[26]. The stereo-view images were an early inspiration for modern-day virtual reality headsets and provided an early understanding of telepresence and virtuality.

While the futuristic science fiction writers painted what might be possible, the foundation and groundwork provided by the panorama and stereoscope made within the last century allowed inventors to push the limit on what could be achieved in the future[27].

Rise of Immersive Media (Pre-1980s)

It was not until the late 1950s and 1970s that a significant leap in technological advancement enabled some of the speculative technologies for IM described in science fiction. The rise of IM began with conceptualizing and implementing suitable hardware before working on the software to support them.

[25] BCC Research Editorial. "The History and Evolution of Virtual Reality Technology." BCC Research, 2018. https://blog.bccresearch.com/the-history-and-evolution-of-virtual-reality-technology.
[26] Virtual Reality Society. "History of Virtual Reality,"
[27] Greengard. Virtual Reality. 22.

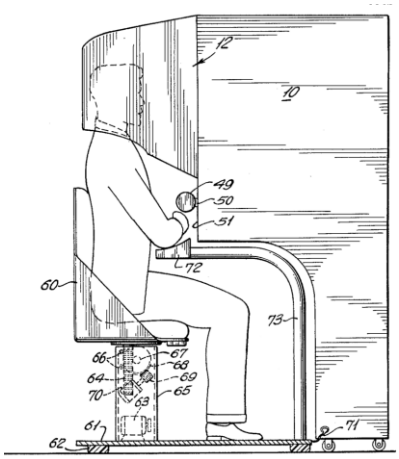

Fig. 4. A diagram of the Sensorama from the patent document.

In 1957, cinematographer Morton Heilig designed the *Sensorama*[28] (fig. 4), which was later patented in 1962[29]. It was a multi-sensory cabinet-like device that worked by combining "three-dimensional motion pictures, peripheral vision, binaural sound, aromas, and tactile sensations"[30] to provide a non-interactive filmic experience for the viewer.

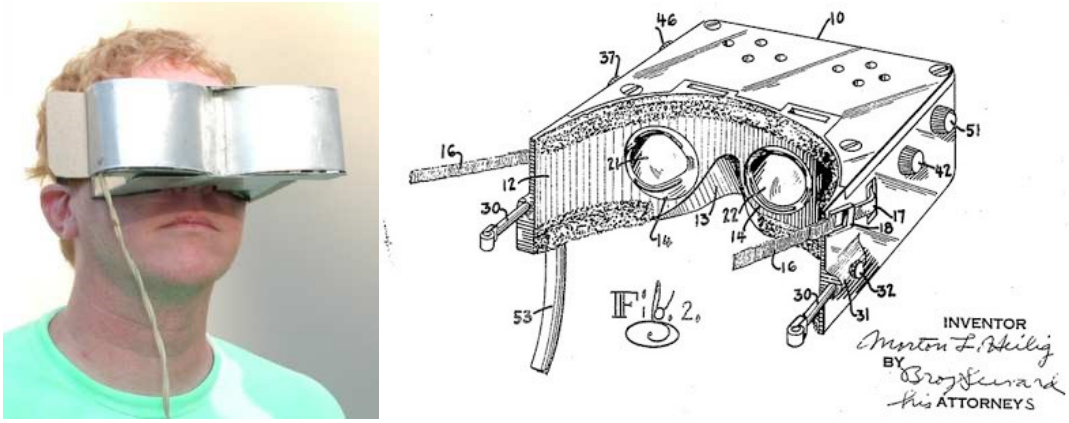

Fig. 5a and b. Photo of a person wearing the Telesphere Mask (Top). A diagram of the Telesphere Mask from the patent document (Bottom).

In 1960, Heilig submitted a patent for a head-mounted display (HMD) device called the *Telesphere Mask*[31] (fig. 5). It can output stereoscopic 3D images with a broad vision and stereo sound[32]. Much like the *Sensorama*, the *Telesphere Mask* is made for non-interactive film and lacks motion tracking[33].

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[28] Mazuryk, Tomasz, and Michael Gervautz. "Virtual Reality - History, Applications, Technology and Future." Vienna University of Technology, 1999.
[29] Everett, Dino. "Morton Heilig: Inventor of VR." USC Hugh M. Hefner Moving Image Archive, n.d. https://www.uschefnerarchive.com/morton-heilig-inventor-vr/.
[30] Ibid.
[31] Dino. "Morton Heilig".
[32] Ibid.
[33] Virtual Reality Society. "History of Virtual Reality,"

The first motion tacking HMD arrived in 1961 as the *Philco Headsight* (fig. 6), it has a helmet-like design that reacts accordingly to the wearer's head movement[34]. This device was not developed for virtual reality applications[35] but for use in military situations such as assisting in landing aircraft by using "infrared camera to produce night vision" [36].

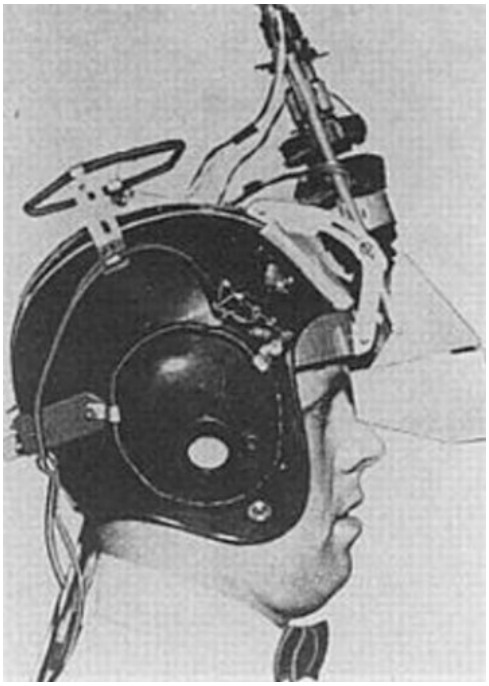

Fig. 6. Philco Headsight headset with CRT display.

Moving forward to 1965, Dr Ivan Sutherland, an associate professor at Harvard University, published the seminal essay titled "The Ultimate Display"[37], from which the blueprint of how AR and VR are developed today[38]. In it, he described the presence of a virtual world simulated reality so convincingly that it would be difficult to differentiate it from actual reality. He explained that navigating this virtual world could be done via several methods such as a keyboard, stylus (or "light pen"), knobs, and joysticks, and a computer would power the device. This essay also introduced the concept of body-tracking and eye-tracking that became available in the following decades[39].

During the middle of the Cold War in 1966, Thomas Furness, an American military engineer, drove the development of human interface technology[40]. Some of his well-

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[34] Greengard. Virtual Reality. 25.
[35] BCC Research. "Virtual Reality Technology."
[36] Greengard. Virtual Reality.
[37] E. Sutherland, Ivan. "The Ultimate Display." Proceedings of the IFIP Congress 2 (1965): 506--508. http://citeseer.ist.psu.edu/viewdoc/versions?doi=10.1.1.136.3720.
[38] Greengard. Virtual Reality. 26.
[39] Ibid.
[40] Dom. "History of VR".

known works involved designing an immersive 3D cockpit system that projected real-time information[41]. Sometimes known as “the grandfather of VR”[42], his contributions continue to inform the development of VR even now.

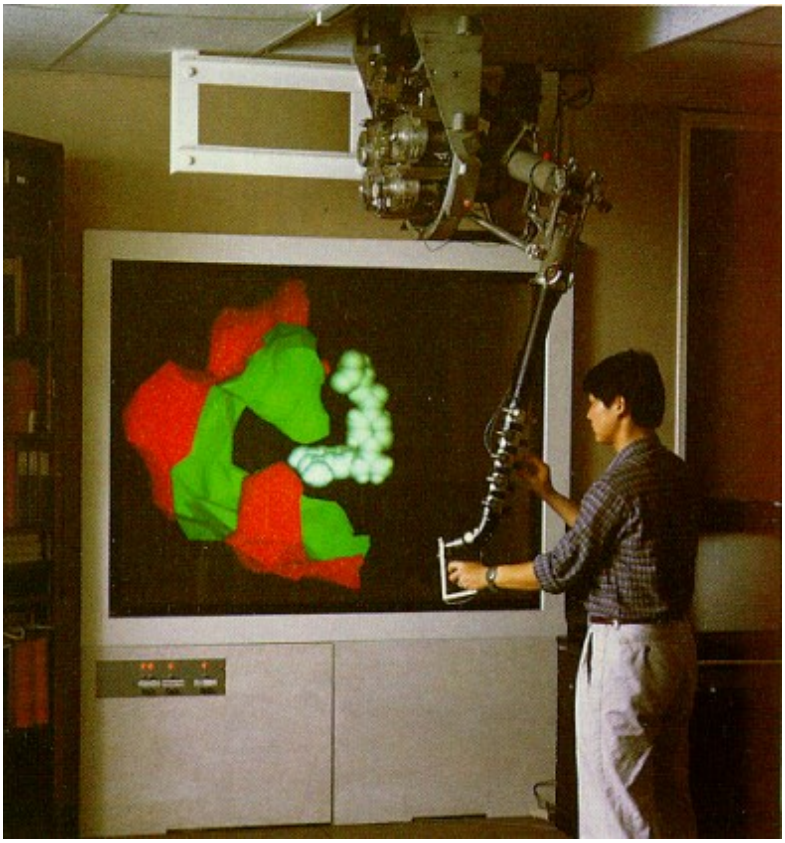

Fig. 7. GROPE-HI haptic display system in use.

In 1967, influenced by Sutherland’s “The Ultimate Display”, Dr Frederick Brooks started *Project GROPE* at the University of North Carolina[43] (fig. 7). The project drove the development of interactive graphics and haptic display[44]. In a retrospective research published in 1990, Brooks and his group noted the technology were ahead of their time as the technical system of the 1960s and early 1970s were inadequate, and predicted that entertainment and “not scientific visualization, will drive and pace the technology”[45].

[41] Lowood, Henry E. “Virtual Reality.” Britannica, 2020. https://www.britannica.com/technology/virtual-reality.
[42] Virtual Reality Society. “History of Virtual Reality”.
[43] Henry E. “Virtual Reality.”
[44] Brooks, Frederick P., Ouh Young Ming, James J. Batter, and P. Jerome Kilpatrick. “Project GROPE. Haptic Displays for Scientific Visualization.” Computer Graphics (ACM) 24, no. 4 (1990): 177–85.
[45] Ibid.

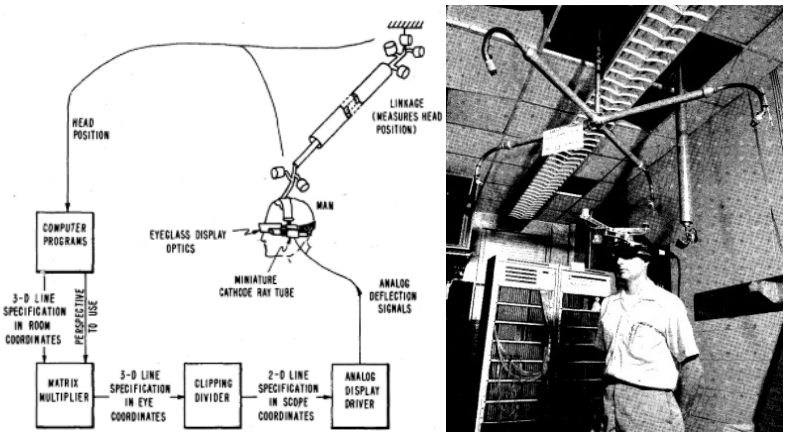

Fig. 8a and b. Diagram of the three-dimensional display system (Left). The mechanical head position sensor (Right).

Building from the foundation made in "The Ultimate Display", Sutherland and his student researcher made a breakthrough in 1968 when they developed *The Sword of Damocles* (fig. 8). It was an HMD wired to a device on the ceiling that could project computer-generated graphics to the stereoscopic glasses inside the headset[46]. Still, they also noted that no commercially available general-purpose computer was fast enough to handle the dynamic perspective display[47].

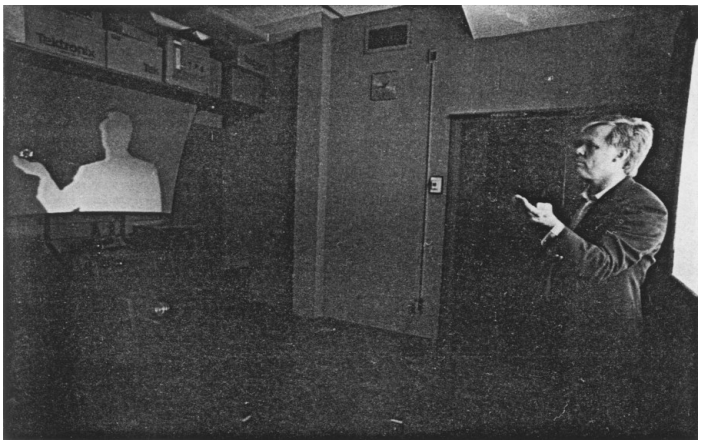

Fig. 9. Krueger's VIDEOPLACE*, developed in the ARTIFICIAL REALITY Laboratory.*

Early application of IM in the arts and exhibition space started in 1969 when computer artist Myron Krueger began a series of interactive "computer art" (as he called them, the term virtual reality did not exist back then). He later devised the term "artificial reality", as he developed more experiments that reduced the boundaries between humans, the virtual space, and the physical environment. His motivation came from other computer-based

[46] Greengard. Virtual Reality. 26.
[47] Ibid.

artworks that failed to exploit their most unique attribute: "its ability to respond in real-time"[48]. His first well-known work was called *GLOWFLOW* in 1969[49]. He later created two more artworks – *METAPLAY* in 1970, and *PSYCHIC SPACE* in 1971, before making the first iteration of *VIDEOPLACE* (fig. 9) in 1974[50].

Unlike the *Sensorama*, *VIDEOPLACE* was fully computerised, showing computer-generated images (CGI) instead of analogue film. It used general-purpose computers to calculate, interpret and react to the attached sensor and output them through the attached projector[51].

VIDEOPLACE was also unique as an IM of that time, as it could accommodate multiple audiences within the same space, rather than just one person. Henry E. Lowood, the Curator for History of Science & Technology Collections at Stanford University, noted that the VIDEOPLACE "system reversed the emphasis from the user perceiving the computer's generated world to the computer perceiving the user's actions" [52].

Much like Weinbaum's short story "Pygmalion's Spectacles", this period of progress was marked by theoretical concepts outpacing the actual technological and engineering development, hampered mainly by the computational power of that time. Regardless, significant advancement was laid for future improvements with literature such as "The Ultimate Display". The backdrop of the Cold War and the Vietnam War was the catalyst in rapid technological development and influenced how future IM would turn out to be.

Evolution of Immersive Media (late-1970s to 2000s)

One of the developments of IM was in the different ways to input data for the computer system to recognise. Specialised gloves for gesture control are known as data gloves, wired gloves or cyberglove[53]. The first prototype was *Sayre Glove* (fig. 10), developed in 1976 and further refined in 1977[54]. Created by Thomas de Fanti, Daniel Sandie, and Rich Sayre[55] in the University of Illinois at Chicago, it was a cheap and lightweight glove that can monitor hand movements using flexible tubes with a light source and a photocell on

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[48] Krueger, Myron W. "'VIDEOPLACE': A Report from the ARTIFICIAL REALITY Laboratory." Leonardo 18, no. 3 (1985): 145–51. https://www.jstor.org/stable/1578043.
[49] Ibid.
[50] Ibid.
[51] Ibid.
[52] Henry E. "Virtual Reality."
[53] Jon. Augmented Reality. 273.
[54] Ibid.
[55] Ibid.

opposite ends. It tracked the user's hand movement by measuring the intensity and value of the light source[56].

Fig. 10. Diagram of the Sayre glove.

Other development of data gloves included the Massachusetts Institute of Technology *(MIT)-LED Glove* in the early 1980s, the *Digital Entry Data Glove* in 1983, and *VPL DataGlove* in 1987[57] (fig. 11). The *MIT-LED Glove* used a camera-based LED system to record the person's position[58]. This glove was used primarily for motion capture and was discontinued shortly after. Meanwhile, the *Digital Data Entry Glove* was developed by Gary Grimes and was able to detect specific hand movements[59]. It was created as an alternative to "large, bulky, and complex" keyboards and typewriters of that time[60]. Unfortunately, the *Digital Data Entry Glove* was never made commercially available[61] , and the patent ultimately expired in 2001[62].

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[56] Sturman, David J, and David Zeltzer. "A Survey of Glove-Based Input." IEEE Computer Graphics and Applications 14 (1994): 30–39.
[57] Ibid.
[58] Ibid.
[59] Grimes, Gary J. Digital Data Entry Glove Interface Device. US4414537A. United States: United States Patent, issued 1983. https://patents.google.com/patent/US4414537A/en.
[60] Ibid.
[61] David J, et al. "Survey of Glove-Based Input."
[62] Gary J. Digital Data Entry Glove.

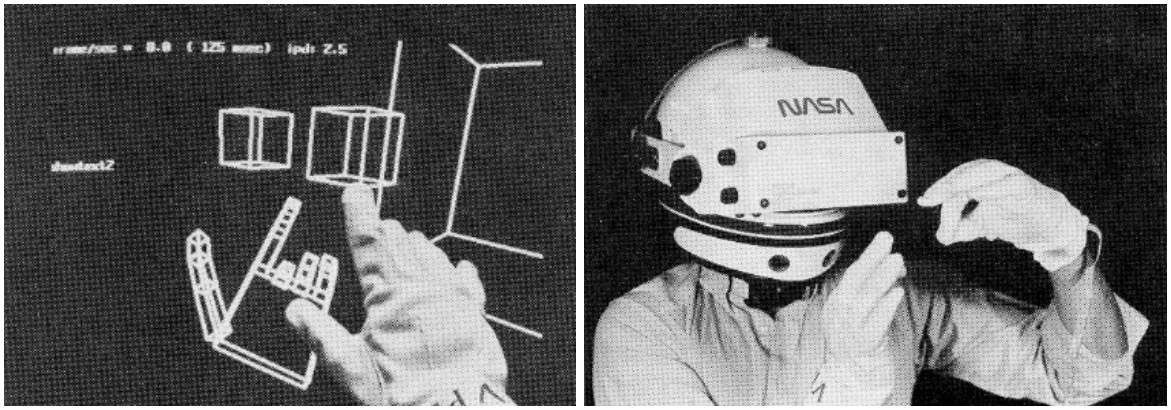

Fig. 11a and b. View of the 3D projection when using the Data Glove (Left). The Virtual Visual Environment Display HMD and glove (Right).

While at the video game company Atari (specifically the Atari Research Center), computer researcher Thomas Zimmerman met fellow VR researchers such as Scott Fisher, Brenda Laurel, and Jaron Lanier. Starting in 1983, Zimmerman and Lanier would collaborate and improve on the optical flex sensor glove. By 1985 they founded their own company VPL Research with shipped their first product, the *VPL DataGlove*[63], in 1987. Unlike the other data gloves, the *VPL DataGlove* found commercial success with research institutions for being "light-weight, comfortable to wear, unobtrusive to the user, and general-purpose"[64].

Concurrently in 1985, Fisher left Atari to join the National Aeronautics and Space Administration, U.S.A. (NASA) Ames Research Center. He became the founding Director of their Virtual Environment Workstation Project (VIEW) project. One of their products was a workstation called the *Virtual Visual Environment Display* (fig. 11). This product standardised VR hardware to include "a stereoscopic head-coupled display, head tracker, speech recognition, computer-generated imagery, data glove, and 3-D audio technology"[65].

Lanier and VPL Research would later create a motion-tracking system named *DataSuit*, and the *EyePhone* HMD in the late 1980s[66]. It was also during this time that the term "virtual reality" became popularised by Lanier[67]. Against the backdrop of the booming technology revolution in the 1990s, many VR and technology companies were founded,

[63] Henry E. "Virtual Reality."
[64] David J, et al. "Survey of Glove-Based Input."
[65] Henry E. "Virtual Reality."
[66] Ibid.
[67] Greengard. Virtual Reality. 28.

concentrating mainly in Silicon Valley[68]. Sadly, most companies would not turn a profit, and VPL Research filed for bankruptcy in 1990 and all its patents sold[69].

Fig. 12. 3 Virtuality 1000DS from W-Industries.

Much like what Brooks and his group have predicted, commercial mass entertainment was the logical next step for VR and IM to develop and evolve. The Nintendo/Mattel *PowerGlove* in 1989 and the Nintendo *VirtualBoy* game console in 1995 were some of the video game industries' earlier (failed) attempts at capitalizing VR and IM for mass-market video games[70]. Sega's VR headset for the Sega Genesis console remained a prototype after its debut at the Consumer Electronics Show in 1993, citing the technical challenges of development[71]. More successful was the line of video game arcade machines named *Virtuality* by W-Industries (fig. 12). First appearing in 1991, it was noted for introducing the idea of "real-time interaction" where two or more players "could compete in the same space with near-zero latency"[72].

[68] Henry E. "Virtual Reality."
[69] "The Virtual Curmudgeon." The Economist. London, September 2010. https://www.economist.com/technology-quarterly/2010/09/04/the-virtual-curmudgeon?story_id=16909935.
[70] Henry E. "Virtual Reality."
[71] BCC Research. "Virtual Reality Technology."
[72] Greengard. Virtual Reality. 32.

Fig. 13. The 'Glasstron' allows viewing realistic video equivalent to a 52-inch screen.

Besides gaming, amusement park rides in the 1990s, such as Disneyland's *Star Tours,* also successfully incorporated elements from Hollywood films and military flight simulators[73]. 1996 would see the release of Sony's first HMD device, the *Glasstron*[74] (fig. 13). Equipped with two LCD screens, the *Glasstron* was an early look at commercial HMD for general consumers and is considered the predecessor to the *PlayStation VR* in 2016. Early films such as *The Lawnmower Man* in 1992 helped the masses to familiarise the concept of VR. In it, an intellectually disabled gardener was experimented with inside VR by a scientist to enhance his intelligence[75]. Soon after, the landmark film *The Matrix* in 1999 showcased the idea of people living inside a dystopian virtual world[76].

In 1992, one of the more exciting developments of IM and VR was the creation of the *CAVE Automatic Virtual Environment* (CAVE) by the Electronic Visualization Laboratory of the University of Illinois[77]. CAVE itself is a recursive acronym, and it was described as an "immersive virtual reality theatre where 3D images are rear-projected to between three and six of the walks of a room-sized cube"[78]. Created mainly for use in scientific and professional communities, it contains elements from *VIDEOPLACE* (1974) and the use of stereoscopic glasses. Some CAVE systems allow multiple users, with the virtual environment projected onto walls or surfaces, while users wear LCD shutter glasses to

[73] Henry E. "Virtual Reality."
[74] Jon. Augmented Reality. 73.
[75] Henry E. "Virtual Reality."
[76] Ibid.
[77] Cipresso, Pietro, Irene Alice Chicchi Giglioli, Mariano Alcañiz Raya, and Giuseppe Riva. "The Past, Present, and Future of Virtual and Augmented Reality Research: A Network and Cluster Analysis of the Literature." Frontiers in Psychology 9, no. NOV (2018): 1–20.
[78] Jon. Augmented Reality. 43.

synchronize with the display's refresh rate, thereby creating stereoscopic images. Other CAVE systems also included a tracking system to reflect what the user sees on the walls[79]. Like *Project GROPE,* this VR theatre was widely used by engineers, scientists, and students to explore digital information's representation in innovative ways[80].

Following Krueger's *VIDEOPLACE* and the general technological advancements, many artists began experimenting more thoroughly in digital art (including VR and extended reality) as IM equipment became more mainstream and accessible. As curator Dr Christiane Paul wrote on the theme of VR art, "issues of embodiment vs. disembodiment and the perception of space" was a fundamental theme in artistic exploration and expression of VR[81]. Reflecting the curiosity of new media and digital technology, museums and galleries began hosting digital artworks. Some notable computer artists who incorporate VR technologies include Jeffrey Shaw, Charlotte Davies, Michael Naimark, and Agnes Hegedüs.

Fig. 14a and b (top), c and d (bottom). Jeffrey Shaw's Virtual Museum *(top). Jeffrey Shaw's* EVE, *both exterior and interior (bottom).*

[79] Aukstakalnis, Steve. Practical Augmented Reality: A Guide to the Technologies, Applications, and Human Factors for AR and VR. Crawfordsville, Indiana: Pearson Education, Inc., 2017. 180.
[80] Greengard. Virtual Reality. 45.
[81] Paul, Christiane. Digital Art. Third. London: Thames & Hudson Ltd., 2015. 125.

In 1991, Jeffrey Shaw created the *Virtual Museum* (fig. 14a and b) to showcase "immaterial artistic fabrications"[82]. The artwork was an installation made up of an interactive "three-dimensional computer-generated museum comprising an immaterial constellation of rooms and exhibits"[83]. Viewers controlled their movement via the chair they are sitting on, and the virtual environment was modelled after the physical space of the installation (fig14b). Shaw would later create the first iteration of the *EVE* dome (fig. 14c and d), short for "Extended Virtual Environment", in 1993. It was as much artistic research as technical research to explore "new forms of interactive, immersive visualization and VR applications"[84]. Inside the dome, a pair of projectors on a robotic arm synchronize with a tracking device hat which pan and tilts according to the wearer; it projects a stereoscopic image on the screen while viewers (the hat wearer and other audiences) inside the dome wear a pair of polarizing spectacles[85]. Shaw later created other ground-breaking works such as the panoramic installation *Place – A User's Manual* in 1995 and co-create a CAVE-based installation *reConFIGURING the CAVE* with Bernd Lintermann and Agnes Hegedüs in 2001.

In contrast to being grounded in the physical world, VR artist Davies opted for a fully immersive digital environment in 1995. Osmose's digital environment was created using an HMD and motion-tracking vest. It tracks the user's breathing and balance by bringing them into a CGI forest with a cyber-aesthetic[86].

As important as it is for the commercialization of IM and VR as mass media for the average consumer, digital art highlighted computer artists were also carrying out that important research. They examined the technical development of using and making IM hardware and explored the more significant philosophical meaning of embodiment and the perception of a physical and virtual world. Their exhibition presentation also helped commodify IM technologies and equipment in museums and galleries.

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[82] Shaw, Jeffery. "Virtual Museum". In Jeffrey Shaw Compendium. https://www.jeffreyshawcompendium.com/portfolio/virtual-museum/
[83] Ibid.
[84] ZKM Hertz-Lab. ""EVE Dome", the Extended Virtual Environment explained". In Google Arts and Culture. https://artsandculture.google.com/asset/eve-dome-the-extended-virtual-environment-explained-jeffrey-shaw/uAHHRUZ3uHRiqA?hl=en
[85] Shaw, Jeffery. "Extended Virtual Environment". In Jeffrey Shaw Compendium. https://www.jeffreyshawcompendium.com/platform/eve/
[86] Paul, Christiane. Digital Art.126.

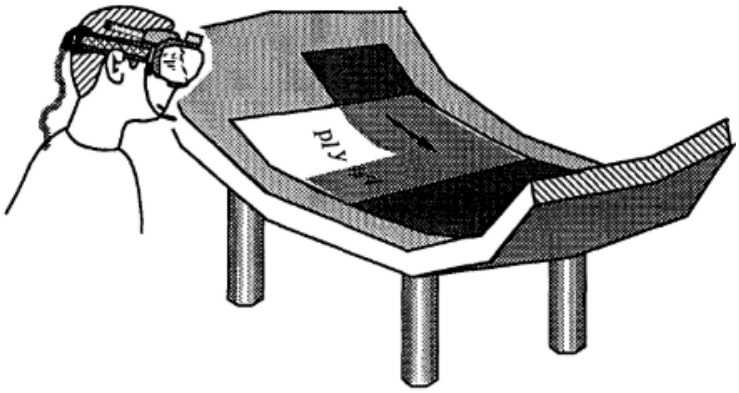

Fig. 15. An example of using the HUDset to project information to the viewer when looking at certain things.

Moving away from VR, the term "augmented reality" was coined in the early-1990s by Boeing Corporation researchers Thomas P. Caudell and David Mizell[87]. They proposed improving the HMD (known as the *HUDset* as seen on fig. 15) for use in aviation by aiming to "improve efficiency" and work performance[88] through augmenting their view "with which a diagram can be "projected" onto a real-world position"[89]. On the differences between VR and AR, they wrote[90]:

> *"A primary difference between virtual reality and "augmented reality" is in the complexity of the projected graphical objects. In our system, only simple wire frames, template outlines, designators, and text are displayed. An immediate result of this difference is that augmented reality systems can be driven by standard and inexpensive microprocessors."*

These differences suggest that AR started as a much more modest technology than VR, which, as mentioned previously, required specialised computers that had not existed at that time.

In 1992-1993, a new gesture-based system called the *Artificial Life Interactive Video Environment* (*ALIVE system*)[91] was developed at MIT Media Laboratory. Using a digital camera to capture the surroundings, it mixed computer graphics and video overlays, allowing the user to interact with "virtual agents" (such as a virtual dog) within the same display area[92].

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[87] Jon. Augmented Reality. 70.
[88] Caudell, T.P., and D.W. Mizell. "Augmented Reality: An Application of Heads-up Display Technology to Manual Manufacturing Processes." System Sciences, 1992. Proceedings of the Twenty-Fifth Hawaii International 2, no. February (1992): 659–69.
[89] Ibid. 662.
[90] Ibid. 669.
[91] Levin, Goland. "ALIVE Project (MIT), ca. 1992". Vimeo video. Posted 2011. https://vimeo.com/18824784
[92] Jon. Augmented Reality. 277.

Fig. 16. The Touring Machine consists of a backpack holding the computing system, the HMD, a tablet, and a stylus.

Much like how VR flourished, AR innovation came primarily from their entertainment use. *Dancing in Cyberspace* in 1994 was considered the first AR theatre production[93], combining actual performers interacting with virtual objects. In 1996 a group of researchers from Columbia University started developing a prototype dubbed the *Touring Machine*[94] (fig. 16). It was a project investigating the potential of mixing augmented reality and mobile computing. It was an early attempt at exploring mobile wearable technology and how AR can "support users in their everyday interaction with the world"[95].

In 1999, computer researchers Dr Hirokazu Kato and Mark Billinghurst developed the *ARToolkit*[96], an open-source software library for creating AR applications.

This period of evolution of IM from established concepts earlier showed that while high-end IM products such as those from VPL Research may not be as successful commercially, they nevertheless introduced the idea of a virtual world beyond the physical world to the masses. They also helped to popularize IM in entertainment, such as theme park rides and video games. They also remained popular in major corporations engaged in engineering businesses and universities looking to explore beyond what is possible.

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[93] Jon. Augmented Reality. 5.
[94] Feiner, Steven, Blair MacIntyre, Tobias Höllerer, and Anthony Webster. "A Touring Machine: Prototyping 3D Mobile Augmented Reality Systems for Exploring the Urban Environment." Personal and Ubiquitous Computing 1, no. 4 (1997): 208–17.
[95] Ibid.
[96] Jon. Augmented Reality. 75.

Exponential Development of Immersive Media (Present-day)

The development of digital technology during the early-2000s shifted away from VR and AR hardware as their novelty and curiosity subsided. Despite that, traces of innovations were made during this period, some of which directly impacted the advancement of IM.

For example, in 2007, *Google Maps* launched *Street View*, which allowed users of *Google Map* to get into an interactive 360-degree-panorama of the location they were viewing[97]. The development of *Street View* also intersects with the development of fully digital 360-degree spherical cameras, which will become increasingly more affordable and accessible to the masses in the next decade.

An immersive high-tech museum called the Museo Archeologico Virtuale or Virtual Archaeological Museum (MAV) was opened in 2008[98]. Italy's first purposed-built virtual archaeological museum did not contain any artefact, instead of using multimedia, interactive and immersive technologies exclusively.

The development of IM, VR, AR, and other related technologies went into high gear from the 2010s onwards. The *Google Art Project* was launched in 2011 and would later morph into the current *Google Arts and Culture*[99]. Working with various cultural institutions globally, they provided high-resolution images and videos of museum exhibits, as well as 360-degree virtual tours accessible from a computer, a smartphone, or a tablet.

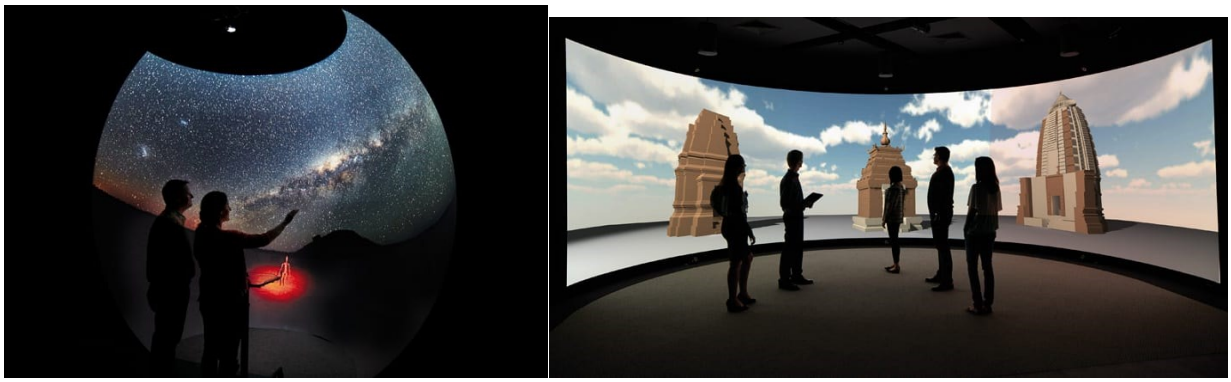

Fig. 17a and b. The Dome and the Cylinder at Curtin University - HIVE.

[97] Virtual Reality Society. "History of Virtual Reality".
[98] Scala, Paola La. "Museums Presenting Past through Digital Technologies: MAV (Museo Archeologico Virtuale) of Ercolano and Site-Museum of Pont Du Gard Case Studies." MWF2014: Museums and the Web Florence 2014, 2014. https://mwf2014.museumsandtheweb.com/paper/museums-presenting-past-through-digital-technologies-mav-museo-archeologico-virtuale-of-ercolano-and-site-museum-of-pont-du-gard-case-studies/.
[99] Anna Somers, Cocks. "How Google Became a Major Producer of Cultural Content." The Art Newspaper. Accessed June 15, 2021. https://www.theartnewspaper.com/feature/how-google-became-a-major-producer-of-cultural-content.

In the educational field, Curtin University opened its new multimedia visual facility, *Hub for Immersive Visualisation for eResearch* (HIVE), in 2013[100]. The facility hosted a range of IM equipment such as 3D video screen, Dome projection, and the panoramic Cylinder. It was intended for artistic research and data visualization and is in line with their new Visual Technologies undergraduate degree major for students.

Fig. 18. The Sony EyeToy for the PlayStation 2. Manufactured by Logitech, the PlayStation Eye would succeed it for the PlayStation 3, and PlayStation Camera for the Playstation 4.

In terms of hardware, video games and home entertainment drove much of the development in the 2000s and 2010s. The Sony *EyeToy* was released in 2003 as a webcam accessory for the Sony *PlayStation 2* (fig. 18). This webcam used computer vision, motion, color detection, and sound for players to interact with supported video games[101]. Similar technologies for tracking users' actions would be employed by Sony's rivals, such as the Nintendo *Wii Remote* wireless handheld controller in 2006, which uses motion-sensing accelerometers, and the Microsoft *Kinect* camera device for their Xbox 360 game console in 2010[102]. The *Kinect* later progressed beyond gaming and found utilization in engineering, healthcare, and volumetric capture workflow[103].

[100] Ibacache, Jessica. "Researchers Abuzz over HIVE and Immersive Visualisation." Curtin University, 2013. https://news.curtin.edu.au/stories/researchers-abuzz-over-hive-and-immersive-visualisation/.
[101] Jon. Augmented Reality. 277.
[102] Ibid.
[103] Zacks Equity Research. "Microsoft Lures Investors with Azure Kinect & Partner Updates". Yahoo! Finance. 2019. https://finance.yahoo.com/news/microsoft-lures-investors-azure-kinect-140402563.html

Fig. 19a and b. Photos of museum visitors using the Louvre audio-visual guide on a Nintendo 3DS.

There was a renewed interest in immersive technology as consumer lifestyles changed and the reliance on the Internet and smartphones increased. At the same time, general-purpose computer and entertainment devices (such as video game consoles and televisions) became increasingly more powerful and sophisticated. For example, in 2011, Nintendo released their critically acclaimed portable gaming device, the *Nintendo 3DS*. One of its main selling points was the ability to display stereoscopic 3D effects without needing any 3D glasses and the AR games it support. The following year would see the Louvre Museum in Paris partnering with Nintendo to create an audio-visual guide using the *Nintendo 3DS*[104]. The guide allows for a self-guided tour, containing over "700 audio commentaries and photos" and "3D models of major works" viewable in stereoscopic 3D, using "Nintendo's location estimation technology" to identify the user's location in the museum.

In 2012, AR found its way into multiple museum exhibitions. For example, the Royal Ontario Museum in Toronto used AR and *Kinect* to breathe life into their dinosaurs projections (fig. 20a). Similarly, California's Laguna Beach Art Museum used AR to animate still photographs (fig. 20b). In Los Angeles Getty Museum, there was the 3D model manipulation of the exhibits (fig. 20c). Lastly, the London's Science Museum utilised a television celebrity as a virtual AR museum guide (fig. 20d)[105].

[104] Cooper, Daniel. "Nintendo puts 3DS in the Louvre, France remains generally indifferent." Engadget. 2012. https://www.engadget.com/2012-04-12-3ds-louvre.html (accessed 22 Jun 2020)
[105] Rieland, Randy. "Augmented Reality Livens up Museums." Smithsonian Magazine, 2012. https://www.smithsonianmag.com/innovation/augmented-reality-livens-up-museums-22323417/.

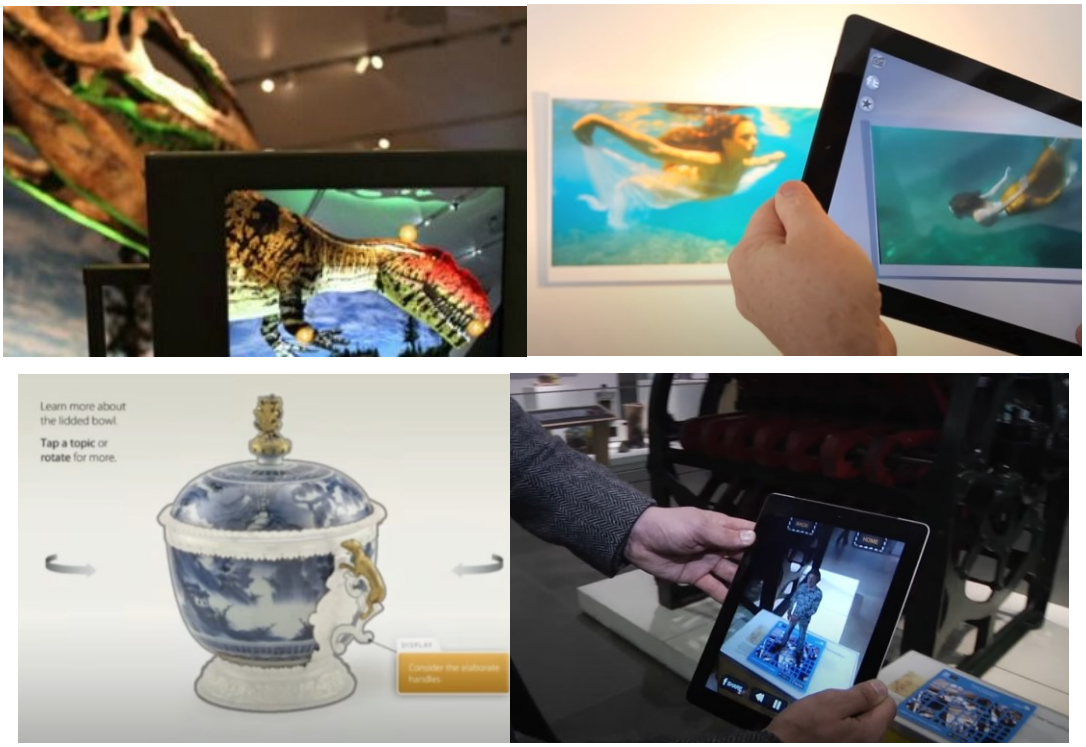

Fig. 20a and b (top), c and d (bottom). The AR application of the respective exhibitions. 20a is from the Smithsonian Magazine, while the rest are from the exhibition's respective YouTube channel.

In 2014, Google developed *Tango*, an Android-based AR platform. Later in 2016, AR company Niantic released *Pokémon Go,* a spin-off game from the *Pokémon* franchise that combines GPS location tracking and AR capabilities of the smartphone[106]. It became a worldwide phenomenon, where different *Pokémon* (cartoon creatures with mystical powers) appear based on where the player is. In a way, the smartphone became a portal to the unseen virtual world of these creatures. The popularity of *Pokémon Go* also made it into a featured demo when Apple announced its new *ARKit* AR framework in 2017[107]. Google *Tango*, Android's equivalent AR framework, was replaced by Google *ARCore* the following year[108].

Outside of gaming, Google began developing the AR-enabled *Google Glass,* which would be released around 2014[109]. Their rival Microsoft would release the first *Microsoft Hololens* in 2016[110], creating the foundation for their Windows Mixed Reality (MR) platform. In 2017, Facebook launched the *Camera Effects Platform* for content creators to

[106] Greengard. Virtual Reality. 91.
[107] Hollister, Sean. "Here comes Pokemon Go's ARKit mode. Is your battery ready?" CNET. 2017. https://www.cnet.com/news/pokemon-go-apple-arkit-iphone-ipad-pro/
[108] Robertson, Adi. "Google ARCore Gives Android Users Augmented Reality Without Tango". The Verge. 2017. https://www.theverge.com/2017/8/29/16219696/google-arcore-augmented-reality-platform-announce-release-pixel-samsung
[109] Jon. Augmented Reality. 79-80.
[110] Ibid.

develop and publish their AR filters[111]. It was later renamed *Spark AR* in 2018 and became compatible with the Instagram app[112].

The 2010s also saw the emergence of consumer-grade VR headsets. They were generally categorised into two: tethered, high-end, and expansive, or mobile, entry-level, and economical. That was the norm until the late-2010s, with the decline of mobile VR and high-end headsets becoming wireless and more affordable.

In 2012, the *Oculus Rift* VR headset went into a Kickstarter campaign by creator Palmer Luckey. The Oculus headset and brand would later be acquired by Facebook, Inc in 2014. During the same year, Anantarupa Studio, a digital content company based in Jakarta, created Indonesia's "first virtual reality museum"[113]. Using a pre-commercial *Oculus Rift* headset, viewers can look at virtual statues from the Majapahit era scattered in various museums worldwide. The *Oculus Rift* was released commercially in 2016[114].

Fig. 21. An example of a Google Cardboard with a smartphone inserted inside the cardboard visor. It was Google's way of introducing VR to the masses with an inexpensive cardboard container and plastic lens.

[111] Kirkpatrick, Ficus. "Introducing Camera Effects Platform". Facebook for Developers. 2017. https://developers.facebook.com/blog/post/2017/04/18/Introducing-Camera-Effects-Platform/
[112] Chandhok, Nikhil. "Camera Effects Platform is now Spark AR". Facebook for Developers. 2018. https://developers.facebook.com/blog/post/2018/10/05/camera-effects-platform-is-now-spark-ar/
[113] Hans David Tampubolo. "Virtual Museum Brings Indonesia's Heritage Closer to Home." The Jakarta Post. May 16, 2014. https://www.thejakartapost.com/news/2014/05/16/virtual-museum-brings-indonesia-s-heritage-closer-home.html.
[114] McCarthy, Cecilia Pinto. How Virtual Reality Will Impact Society. San Diego: ReferencePoint Press, Inc, 2019. 5.

During the same period, Google leveraged on the large number of smartphones in circulation by releasing the *Google Cardboard* (fig. 21) in 2014, a VR platform that used a smartphone and a cardboard container to view 360-degree images and videos.

It should be noted that most entry-level headsets, especially those without controllers, such as *Google Cardboard*, only offer passive VR content – 360-degree images and videos. As pointed out by David Zelter, true VR would also need to provide "autonomy, interaction, and presence"[115]. As these 360-degree contents are consumed passively, they would not be considered true VR. Chapter 4.1 in Immersive Media and Virtuality will cover more on this topic.

Smartphone manufacturer Samsung would release their Samsung *Gear VR* headset in 2015[116] , and Google would release the Google *Daydream View* headset in 2016. Much like *Cardboard*, both devices are powered by the smartphone inserted into them, but they come with added functionalities than simply working as a viewing device. These headsets are not considered room-scale VR headsets.

Another distinction that separates VR headsets is the 'Degree of Freedom' (DoF). Headsets such as *Cardboard, Daydream View,* and *Gear VR* only offer 3DoF, as the headset only tracks the rotational movement. Higher-end or newer headsets such as the *Oculus Rift* supports 6DoF. This effect is done by combining 3DoF rotational tracking with translational tracking, enabling the user to feel like they are moving in a virtual world as opposed to the virtual world moving with them as they move.

2016 would also see many high-end VR devices released, including the beforementioned *Oculus Rift*, the Sony PlayStation VR, HTC Vive, and less conventional brands such as the *Pimax 4K*[117]. Although significantly more powerful than mobile VR devices, they must be connected to high-end computer hardware. They boast additional sensors to track the headset's position and controllers, allowing for true room-scale VR interaction but also making the barrier of entry much higher.

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[115] Zeltzer, David. "Autonomy, Interaction, and Presence." Presence: Teleoperators and Virtual Environments 1, no. 1 (1992): 127–32. https://doi.org/10.1162/pres.1992.1.1.127.
[116] Ibid.
[117] Zhao, Tingting. "Pimax launches 4K VR device in Beijing". China Daily. 2016. http://www.chinadaily.com.cn/business/tech/2016-04/09/content_24398258.htm

Oculus Quest 2	**31.07%**	+0.95%
Oculus Rift S	18.48%	-0.70%
Valve Index HMD	16.68%	+0.19%
HTC Vive	11.24%	+0.12%
Windows Mixed Reality	5.48%	-0.17%
Oculus Rift	5.40%	-0.54%
Oculus Quest	5.23%	-0.08%
HTC Vive Pro	2.01%	-0.01%
HTC Vive Cosmos	1.75%	+0.57%
Riftcat Vridge	0.56%	+0.05%
iVRy	0.34%	-0.06%
Pico Neo 3	0.27%	+0.21%
Sony PlayStation VR	0.18%	+0.01%

Fig. 22. A chart from Steam Hardware and Software Survey *for June 2021. It shows most of Steam's VR users are using the Oculus Quest 2.*

Standalone mobile VR devices would arrive in 2018 in the form of *Lenovo Mirage Solo*, which runs on the Google *Daydream* platform, and *Oculus Go*, which Facebook Technologies developed in partnership with Qualcomm and Xiaomi. Google and Samsung would slowly shift their focus from VR to AR by discontinuing the *Daydream View*[118], and dropping Samsung *Gear VR* support in 2019[119].

Meanwhile, Oculus discontinued both the *Oculus Go* and *Oculus Rift* devices as they work on merging them into an all-in-one device known as the *Oculus Quest* and its successor, the *Oculus Quest 2*. The *Oculus Quest 2* was rebranded to *Meta Quest 2* in late 2021 when Facebook changed its corporate name to Meta Platform, Inc. as Meta focuses on their long-term metaverse project.

It is worth noting that the current historical canon of immersive media is very much Western-centric. With a few exceptions, there is not much literature and research into non-Western contributions to the development of modern-day IM. Regardless, this short chapter does help to illustrate and give an introductory historical overview of where IM originated from and how it has evolved to the present day. Knowing this background context will help exhibition planners and staff choose appropriate IM technology and understand the pitfalls, origins, and trends of using such technologies.

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[118] Robertson, Adi. "Google is discontinuing the Daydream View VR headset, and the Pixel 4 won't support Daydream". The Verge. 2019. https://www.theverge.com/2019/10/15/20915609/google-pixel-4-no-daydream-support-view-vr-headset-discontinued

[119] Robertson, Adi. "Oculus CTO John Carmack says 'we missed an opportunity' as the Gear VR dies". The Verge. 2019. https://www.theverge.com/2019/9/26/20885685/oculus-cto-john-carmack-samsung-gear-vr-headset-missed-opportunity

3.2 National Museum of Singapore – Case Study, History, and Technology

In this section, we will first examine why the NMS was chosen as a case study before taking a quick look at the museum's history and how it became what it is today. This will be followed by looking at the digital technology landscape of Singapore and the NMS, including exhibitions and programmes using IM from the early 1990s till the present day.

National Museum of Singapore as a Case Study

Fig. 23. The current-day National Museum of Singapore is located at Stamford Road.

The NMS (fig. 23) was chosen for this thesis case study after an initial review among prominent museums opened to the public within Singapore - NMS, National Gallery Singapore (NGS), Singapore Art Museum (SAM), Asian Civilisations Museum (ACM), ArtScience Museum (ASM), The Peranakan Museum, Lee Kong Chian Natural History Museum, NUS Museum, and the Singapore Philatelic Museum.

Even though the NMS is Singapore's oldest museum with a permanent collection, it was chosen for using digital technology and new media as an essential part of its exhibition design philosophy[120]. The use of digital and non-digital technology is positioned as a valuable core tool in the storytelling component of the exhibition design philosophy rather than just an afterthought. The usage of said technology enables the museum's audiences to be immersed and engaged with the narrative the exhibition tries to convey[121]. The

[120] Phua, Jay, and Chung May Khuen. "Chapter 7 - An Immersive History: The Use of Technology in the Life in Singapore Galleries." In (Re)Presenting Histories: Experiences & Perspective from the National Museum of Singapore, edited by Stephanie Yeo, 126–133. Singapore: National Museum of Singapore, 2017.
[121] Ibid.

museum also utilizes IM in some of its public programming, with its annual DigiMuse programme being the main highlight.

This thesis zooms in on the Singapore History Gallery (SHG) and the 2018 edition of the DigiMuse programme. The SHG is the main permanent exhibition gallery in the NMS; as such, it also has a secondary function of serving as the NMS exhibition standard. Even though the use of IM in the NMS can be traced as far back as 1995, the thesis narrows it down to 2006, when the first major renovation of the museum was done. This overhaul includes changing the name from the Singapore History Museum to the current NMS, serving as a starting point to look at the modern-day institutional trend of the NMS.

Another significant milestone was in 2015 when the museum was closed in 2014 and revamped in time for the Singapore Golden Jubilee SG50. These revamp made notable changes to the SHG, which the research paper will examine in detail in the later chapters.

Lastly, the reason to include the 2018 edition of the DigiMuse programme is to look at how the contemporary NMS experiments with incorporating IM elements into their exhibitions. The 2018 edition was the first time an open call to local artists and technologists was issued to showcase commissioned projects to test out in the museum space. The research paper investigates two specific examples (*Museum Experiential Guide* and *An Excavation Through Time)* as they are used in the SHG rather than in other galleries.

Historical Overview of the National Museum of Singapore

Name of the Museum throughout History:

1. Raffles Library and Museum (1874-1942)
2. Syonan Hakubutsukan (1942-1945)
3. Raffles Library and Museum (1945-1960)
4. National Museum (1960-1993)
5. Singapore History Museum (1993-2006)
6. National Museum of Singapore (2006-Present)

Early History of the Museum (Pre-WWII)

The idea of a library and museum can be traced back to a meeting of distinguished scholars in Singapore in 1823 by Sir Stamford Raffles[122]. In 1845, the Singapore Library was opened and was part of the Singapore Institution (present-day Raffles Institution), but the museum section would not be realised until the next few years[123]. Moving forward to 1874, the Singapore Library and Museum was transferred to the colonial government and renamed the Raffles Library and Museum[124].

The official opening of the present-day location of the museum at Stamford Road was completed in 1887 and served as "a repository for artefacts deemed relevant to the flora, fauna, and peoples of the region"[125]. The museum's collection would continue to grow steadily. By 1910, it included "zoology, botany, geology, ethnology and numismatics" collections[126]. The first Singapore history collection was started in 1918 by the then-library and museum's director, Dr Karl Richard Hanitsch, to coincide with the centennial of the founding of Singapore. In 1926, the museum building saw an extension on the east side as the collections expanded[127].

In 1942, despite the Japanese Occupation of Singapore, work in the museum continued as usual, albeit more slowly, and it remained open to the public[128]. A few months into the invasion, it was renamed the Syonan Hakubutsukan, or the Syonan Museum and Library[129]. After the war in 1945, the British Military Administration took back control of the museum[130].

Museum during Post-War Period (1945-1990s)

This period saw the museum coming into its own as it navigated its new role and purpose under the turbulent backdrop of Singapore, shedding off its colonial identity, the merger

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[122] Lim, Sharon, Shihui Ong, and Stephanie Yeo, eds. Dome in the City: The Story of the National Museum of Singapore. Singapore: National Museum of Singapore, 2016, 12.
[123] Ibid.
[124] Ibid.
[125] Lenzi, Iola. National Museum of Singapore Guide. Singapore: Editions Didier Millet, 2007, 12.
[126] Preservation of Sites and Monuments, National Heritage Board. "National Museum of Singapore." In Singapore Infopedia. Singapore Infopedia, 2015. https://eresources.nlb.gov.sg/infopedia/articles/SIP_2015-08-31_132917.html. (accessed 17 Jun 2020)
[127] Lim, et al. Dome. 19-20.
[128] Lenzi. National Museum. 16.
[129] Lim, et al. Dome. 23.
[130] Ibid. 25.

with Malaya and subsequent independence of the nation, and the metamorphosis into a globalised city-state.

The museum and library became administratively separated in 1955, and by 1960 the museum would be renamed the National Museum, while the library would be called the National Library and have a separate building beside the museum[131]. From 1963 to 1966, the directorship of the museum would be helmed by the Permanent Secretaries of the Ministry of Culture. By Singapore's independence in 1965[132], the museum's focus began to gravitate towards "the nation's culture and history"[133].

In 1968, the museum was transferred to the Ministry of Science and Technology[134]. The struggles of declining entrepot trade, massive unemployment, and rapidly growing population prompted the government to shift its focus towards industrialization[135]. The *Museum School Service* was introduced in the following year "with the aim to establishing close partnerships with schools"[136]. It was not until 1972 that the museum was transferred back to the Ministry of Culture as plans for the Science Centre Singapore (SCS) were announced. The museum aimed to focus solely on the "history, ethnology and art" of Singapore[137]. During this time, the museum's natural history collection got transferred to the National Museum of Malaysia and the newly formed University of Singapore (present-day National University of Singapore)[138].

Fig. 24a. Minister for Culture at the official opening of the National Museum Art Gallery in 1976.

[131] Ibid. 26-27.
[132] Ibid. 27.
[133] National Heritage Board. "National Museum of Singapore."
[134] Lim, et al. Dome. 28.
[135] Chua, Priscilla. "Chapter 6 – Building an Economy: Getting Down to Work." In (Re)Presenting Histories: Experiences & Perspective from the National Museum of Singapore, edited by Stephanie Yeo, 90. Singapore: National Museum of Singapore, 2017.
[136] Lim, et al. Dome. 28.
[137] Ibid, 29.
[138] Lenzi. National Museum of Singapore Guide, 16-17.

As part of the museum's focus on local art, the Young People's Art Gallery was formed in 1973 as an extension of *the Museum School Service,* and the National Museum Art Gallery was opened in 1976 (fig. 24a)[139].

During the 1980s, the Singapore government took a more long-term approach to the museum. In 1981, Mr Lee Wai Kok, then-Deputy Secretary of the Ministry of Culture, took over as the museum's director[140] , and under his leadership, the museum underwent an extensive refurbishment in 1984. One year later, the National Museum was reopened with four new galleries[141], including the first SHG[142].

At the tail-end of 1986, the Minister for Community Development, Mr Wong Kan Seng, appointed the National Museum Task Force to guide the museum into the foreseeable future[143]. Their main recommendation was to distance the museum from "being a treasure house full of butterflies, stuffed animals and strange smells" and instead becoming a "living museum linking our past with our present and the future"[144]. As a national museum, it would serve as a reference point for "Singapore's collective memory and identity" and its multicultural heritage. The museum would promote how Singapore is also intrinsically tied to "the historical events in the region around it and the cultures of the region"[145].

The task force became instrumental in the modern Singapore museum landscape as the museum continues to change, adapt, and evolve to serve the needs of her community. Other recommendation includes the establishment of a National Heritage Trust, modelled after the British National Heritage Trust (along with the formation of a National Arts Council)[146]. They also recommended the expansion of the National Museum and redeveloping them into a series of distinct museums to form a large museum precinct to rejuvenate the Civic and Cultural District[147]. The motivation for the proposal was understanding the "vital" economic benefit of having "deep understanding of the cultures and ways of living in the Southeast Asian region and in Singapore"[148].

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[139] Lim, et al. Dome. 29.
[140] Ibid. 30.
[141] Ibid. 30.
[142] Lenzi. National Museum of Singapore Guide, 17.
[143] Guan, Kwa Chong. "Transforming the National Museum of Singapore." In Rethinking Cultural Resource Management in Southeast Asia: Preservation, Development, and Neglect, edited by John N. Miksic, Geok Yian Goh, and Sue O'Connor, 202. London: Anthem Press, 2011.
[144] Ibid.
[145] Ibid. 203.
[146] Ibid. 205.
[147] Ibid.
[148] Ting, Kennie. "Museums in Singapore: A Short History." MuseSG 8, no. 2 (2015): 21.

In the meantime, the National Museum started working on more interactive exhibits as the trend in visitor engagement evolved. The museum was reopened in 1990 after completing a major restoration work that lasted for two years[149].

National Heritage Board, A New Focus, Revamp Period (1990s-2006)

After much discussion for the policy approval and dialogue with an international museum consultant, the "Museum Precinct Master Plan" was completed in February 1991[150]. The National Heritage Board (NHB) was formed in 1993 as a statutory board under the then *Ministry of Information and the Arts* (MITA)[151]. It was established after the Singapore Heritage Society (SHS)[152] submitted a proposal on the "feasibility of a heritage trust for Singapore"[153]. The NHB was formed by combining the National Archives, Oral History Department, and the National Museum.

The NHB would oversee the newly formed Singapore History Museum (SHM, previously National Museum), SAM, and ACM, with each museum managing the different facets of Singapore's history and heritage. The NHB state themselves as "the custodian of Singapore's heritage", tasked with "telling the Singapore story, sharing the Singaporean experience and imparting our Singapore spirit"[154], with the aims of "education, nation-building and cultural understanding"[155]. The NHB later established the Museum Roundtable in 1996; a collective has now grown its membership to "over 50 public and private museums and heritage galleries" in Singapore and aims to promote collaboration on exhibitions, festivals, and programmes to benefit the community[156].

With the national collection finally divided into three museums and a new focus solely on the nation's history, it appears all is well for the Singapore History Museum, at least for the next couple of years[157]. During this turn of the millennium, the museum was actively "exploring new ideas for exhibitions and programmes"[158], as it faced stiffer competition

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[149] Lim, et al. Dome. 31-32.
[150] Guan. "Transforming the National Museum." 205-206.
[151] Tan, Lay Yuen. "National Heritage Board". Singapore Infopedia. https://eresources.nlb.gov.sg/infopedia/articles/SIP_94_2005-01-27.html (accessed 17 Jun 2020)
[152] SHS is a non-profit independent organization on Singapore heritage conservation.
[153] Guan. "Transforming the National Museum." 207.
[154] "About NHB". National Heritage Board. https://www.nhb.gov.sg/who-we-are/about-us (accessed 17 Jun 2020)
[155] "Our Mission & Vision". National Heritage Board. https://www.nhb.gov.sg/who-we-are/about-us/mission-and-vision (accessed 17 Jun 2020)
[156] "Museum Roundtable". National Heritage Board. 2020. https://www.nhb.gov.sg/what-we-do/our-work/sector-development/museum-roundtable (accessed 17 Jun 2020)
[157] Lenzi. National Museum of Singapore Guide, 17.
[158] Lim, et al. Dome. 44.

from its newer siblings[159]. It was thought that by combining the challenges faced by Singapore's historical "Great Man" (e.g., the nation's political leaders during Singapore's independence) and melding them with empathetic ground-up stories of the "little men" (the working-class citizens), it would make for an appealing tale for younger Singaporeans[160].

The year 2000 was also when the government unveiled its first Renaissance City Masterplan. Building up from the National Museum Task Force, one of its visions was to nurture local art and a cultural "renaissance" economy[161]. It led to two paradigm shifts; a recognition that museums and the arts "were critical to urban vibrancy and quality of life"; and to "recognise museums as an industry in its own right"[162].

Fig. 24b. Foundation Stone Laying Ceremony of the National Museum of Singapore at Fort Canning, November 2004.

In 2002, Lee Chor Lin became the museum's first female director and reimagined the place as a "lifestyle destination"[163]. The Stamford Road building closed for three years from 2003 onwards, and the SHM was temporarily housed at a disused cinema space inside Riverside Point. The idea behind the large-scale overhaul was due to the museum's need to "continue narrating Singapore's history in a meaningful and appealing way" by rethinking "both its physical display and conceptual framework" and its approach to showcasing Singapore's history [164]. The broader curatorial focus resulted in an expanded building to house the new permanent gallery – the Singapore History Gallery (SHG).

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[159] Wong, Hong Suen, and Jason Toh. "Imagining Singapore: Musings of a 120-Years-Old Dame." In The Past in the Present: Histories in the Making, edited by Priscilla Chua, 42–51. Singapore: National Heritage Board, 2009.
[160] Guan. "Transforming the National Museum." 211.
[161] National Library Board. "Renaissance City Report is Issued: 9th March 2000". In History SG. 2015. https://eresources.nlb.gov.sg/history/events/d0504b41-06f4-4f4b-80d2-f7d84aa2086d (accessed 17 Jun 2020)
[162] Ting. "Museums in Singapore." 23.
[163] Lim, et al. Dome. 34.
[164] Lenzi, Iola. National Museum of Singapore Guide. Singapore: Editions Didier Millet, 2007, 17.

In December 2006, the museum returned to the original Stamford Road site and was renamed the National Museum of Singapore (NMS). The overall renovation and expansion were handled by W-Architects, while Lightemotion did the lighting design[165]. The design and execution of the SHG exhibition (fig. 25) and digital IM experiences were commissioned to GSM Design and GSM Media[166] (presently known as GSM Project).

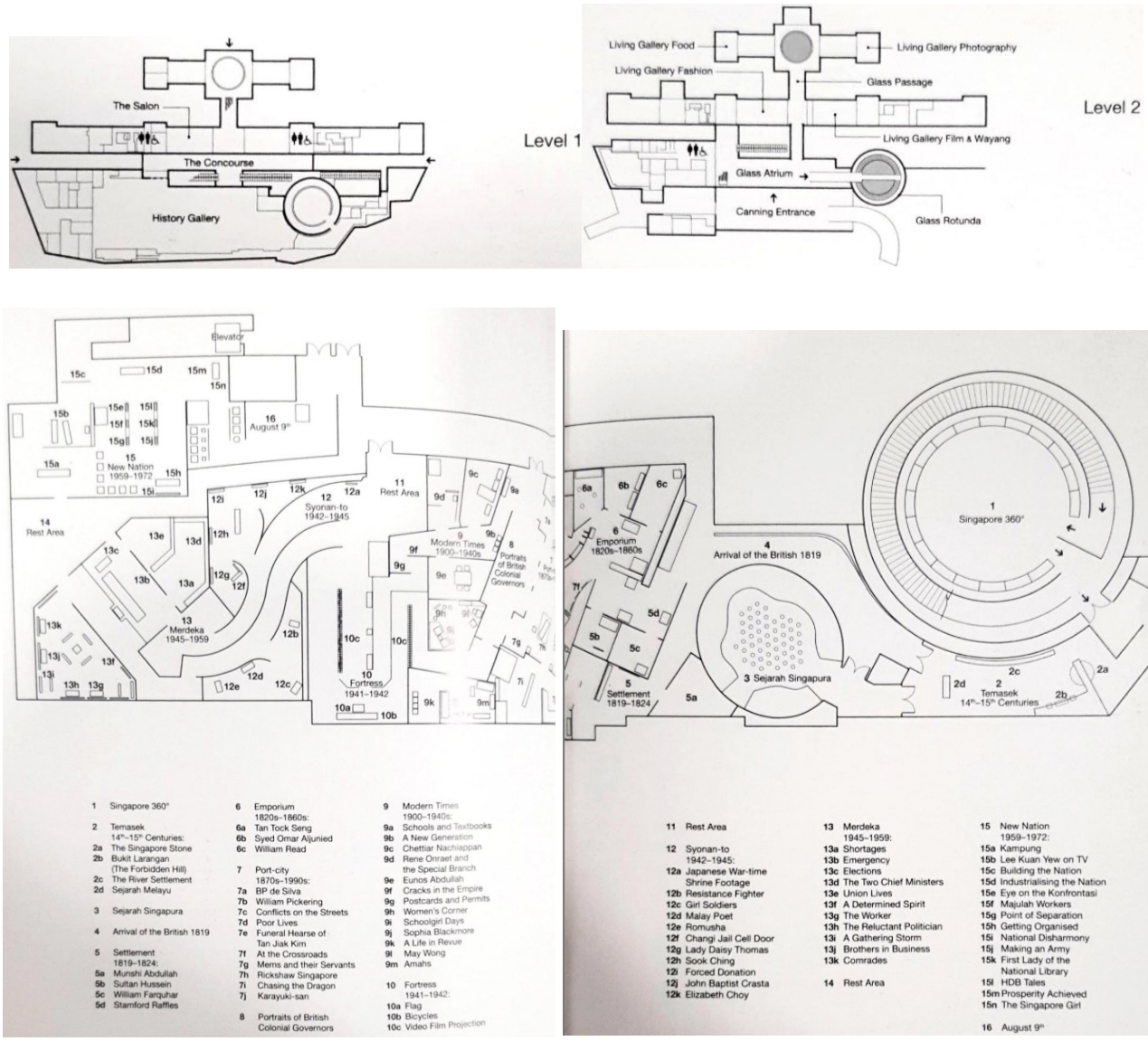

Fig. 25a, b (top), c, d (bottom). Floor plan of the SHG, which starts from level 2 Glass Rotunda.

Inside the SHG, visitors first enter through the Glass Rotunda at level two to view the *Singapore 360°* IM work. After walking down to level one, the exhibition continues with a linear path of the Pre-Colonial Singapore section, where the *Sejarah Singapura* 270-

[165] Sokol, David. "National Museum of Singapore Collection". In Architectural Record. (accessed 14 July 2022)
[166] "Singapore". GSM.

degree film was shown. Afterwards, the pathway separates into two, each chronicling Singapore's political and social histories[167], dubbed the 'Event Path' and 'Personal Path', respectively[168]. This design choice by the exhibition design team engaged the visitors actively by allowing them to pursue whichever story they fancied. It was also designed to enable the visitors to follow both paths if desired. The sections would intersect at the Rest Area (number 14 in fig. 25c), before combining and ending with the 'New Nation 1959-1972' section.

Besides the SHG and the Round Rotunda, new exhibition halls and a gallery theatre were also added. It refreshed the old galleries in the original building into the four Living Galleries that examined "Singapore's socio-cultural history through film, photography, food, and fashion.[169]"

The museum was also home to several commissioned artworks interspersed throughout. The NMS touts itself as Singapore's oldest museum with a "progressive mind" that uses "cutting-edge and multi-perspective ways of presenting history and culture to redefine conventional museum experience"[170]. As explained by then-NMS director Lee Chor Lin[171]:

> *"Our philosophy of history is that it is always in the making, and part of the present. We are dealing with history from a contemporary perspective… Through multiple prongs such as exhibitions, activities, films, and performances, we suggest history is a way of looking at events from multiple perspectives – and our audiences are left to form their own opinion of historical 'facts'."*

Learning from their time at Riverside Point, the museum assayed with different ways to cater to and attract new audiences. These include using more digital technologies and media and adding "curated programmes and film screenings alongside its exhibitions"[172].

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[167] Sokol. "National Museum". Architectural Record.
[168] Lenzi. National Museum. Singapore. 109.
[169] Ibid. 35.
[170] "About Us". National Museum of Singapore. https://www.nationalmuseum.sg/shared-content/exploremuseumtopmenu/about-us-top-menu/overview (accessed 24 Nov 2019)
[171] Nayar Parvathi. "Seeing old things with new eyes". The Business Times. 5 Jan 2007, 28.
[172] Lim, et al. Dome. 44.

Public Response, SG50, Bicentennial and the Pandemic (Present-day)

As this is the period the thesis is examining, extra attention was given to this section, especially regarding the NMS philosophy, how they curate exhibitions and programmes, and why the current NMS function in a particular way in the present day.

Fig. 26a and b. Each visitor was given an audio-visual guide known as The Companion. Photo is taken in 2008 and 2009, respectively.

Evolving from just a storage space for natural and man-made curiosities in the region during the 19th century to a tool in national education post-independence and now a leisure and lifestyle destination, the 2006 brand new NMS brought about many changes. Unfortunately, not all of them were well-received.

The changes include a new extension building housing the new SHG, while the second level of the original structure hosted the four Living Galleries (Food, Photography, Fashion, Film & Wayang). Many digital technology and media were incorporated into these galleries, such as interactive kiosks, animated video screens, and The Companion audio-visual guide (fig. 26). It was also presented in a modernistic façade. The interior design used straight geometric lines, utilising materials such as stainless steel and metal, and deliberate use of lighting that is very different from how traditional museums were presented.

Clara Chow, an arts correspondent for The Straits Times, pondered if the newly reopened NMS was "too 'Disney'", referring to a phrase to the Walt Disney company for simplifying and commercialising media products for mass consumption[173]. Praising the NMS for shedding its "musty, cluttered domains of artefacts" past identity and making it entertaining and accessible, Chow also urged for the museum to be more educational so

[173] Chow, Clara. "Is the museum too 'Disney'?" The Straits Times. 21 Dec 2006, 4.

it could be “a valuable resource that is useful for scholars and laymen alike”[174]. Similarly, a commentator in Singapore’s Mandarin newspaper, Lianhe Zaobao, mentioned that she “was distracted by the attractive colours and display”, noting that it “does not fulfil its function of being educational” as “it is designed for the young”[175].

On the contrary, an NUS history student praised the NMS as “the most interesting and engaging Singapore History ‘lesson’”, being able to learn “personal histories” in addition to the “usual grand narratives”[176].

Fig. 27a, b (top), c and d (bottom). The NMS Food Gallery (top left), and Film and Wayang Gallery (top right), Fashion Gallery (bottom left), Photography Gallery (bottom right), collectively known as the Living Galleries, in 2012.

Jumping to 2011, a string of commentaries and debates took place in The Straits Times, as the public started to scrutinise many aspects of the NMS (and Singapore’s museum landscape in general), from the way exhibitions were presented to the exhibitions’ theme and concept, and spending on artefacts and exhibits. A commentator felt that the NMS functioned more like a contemporary lifestyle museum than a national one. She felt the

[174] Ibid.
[175] Wong, et al. “Imagining Singapore.”
[176] Wong, et al. “Imagining Singapore.”

SHG, while “aesthetically pleasing”, lacks “emotional resonance and connection”[177]. Likewise, a senior writer for The Straits Times, Clarissa Oon, wrote that the SHG “feels small” for a gallery devoted to 700 years of history[178]. She also mentioned that the SHG “gives a largely textbook account”.

On the other hand, Oon felt that, like many contemporary museums, the NMS “engage and entertains viewers rather than talk down to them”. That has also left many visitors to think that it has become anti-intellectual and a “production of multi-sensory experiences that can be easily consumed”[179], a sentiment shared by her colleague Chow 5 years prior. It should be noted that the NMS did succeed in making itself a popular arts and lifestyle destination as visitorship has increased “nearly tenfold since 2004”, which was not easy due to the number of competing entertainment venues[180]. Oon concluded that the next step would be to grant “maturing citizenry the intellectual engagement it craves”[181].

Dr Kevin Y.L. Tan, the then-SHS president, released an essay on the same day echoing a similar concern[182]. Dr Tan was perplexed about the transformation of the SHM into the NMS after the three-year renovation. He understood that the NHB and the NMS wanted to “adopt a storytelling approach” by walking “through stories, not exhibitions”. Tan argued that this had made the NMS “an interpretive centre, not as a museum” as multimedia and videos take centre stage while “artefacts become mere props”. He cited changes to the SHG, such as using an audio-visual guide and the lack of written text panels on the artefacts. He ends the article by saying the NMS must return to the core of its business and not be “a historical gallery with artistic and fashionista pretensions”, presenting actual objects and not a mere simulacrum reproduced through multimedia[183].

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[177] Lui, Rose Hasumi. “National Museum or fashion show?” The Straits Times. 12 Jun 2011, 28.
[178] Oon, Clarissa. “Time for Museum to Dig Deeper.” The Straits Times. 5 Jul 2011, 2.
[179] Ibid.
[180] Ibid.
[181] Ibid.
[182] Tan, Kevin Y.L. “Museums Should Show Real Artefacts.” The Straits Times. 5 July 2011, 22.
[183] Ibid.

Fig. 28. One of the NHB and NMS strategy was to invite local celebrities to be an ambassador to the museum to attract locals through the Explore Singapore campaign, here is local actor Mark Lee inside the Food Gallery. Photo is taken in 2007.

Prof Tommy Koh, the then-chairman of the NHB, responded to both comments on The Straits Times the following day. Acknowledging these comments, he mentioned that the museum would review the use of written texts for artefacts to aid visually and technologically challenged visitors. It is also noted the museum would try to curate more Singapore-related exhibitions "in a creative and inspiring manner"[184].

Ironically, those were similar concerns that the then-Chief Executive Officer (CEO) of NHB mentioned 11 years prior in a 2000 museum conference between Asia and Europe[185]. He discussed the challenges of running multiple museums under the NHB's purview and spoke about the theory of going textless in a museum. Still, visitors expected text, especially those who are not IT-literate and those who prefer not to use any guide. He also mentioned the NHB encourages the use of their "museums as a teaching resource," and the mass media, such as TV production houses, allowed the museum curators to be "actively involved in knowledge production" using 'edutainment' mass media[186].

Less than two weeks later, a group of students wrote into the newspaper's youth voice section to suggest improvements they would like to see in the NMS. Feedback includes

[184] Ibid.
[185] Kim, Lim Siam. "The Experience of the National Heritage Board, Singapore." In Reforming Museums for the 21st Century: Report on the Stockholm Asia-Europe Conference on Museums 2000, edited by Karl Magnusson. Singapore: National Museums of World Culture, 2000.
[186] Ibid.

adding a comment board within an exhibition, having the NMS engage directly with students, volunteering in the museum, and creating an interactive smartphone app[187].

It can be summarised that the NMS succeeded in attracting young Singaporeans as a trendy hangout place. On the other hand, it is also viewed negatively by the older generations that prefer or were used to a more traditional mode of presentation in a museum, especially when it is the country's national museum. The flashy visuals, IM elements such as The Companion, and the immersive 360 and 270-degree films might have been too alienating for some visitors. The museum found itself in a tight spot as it grappled with both ends of the public's opinions[188]. These comments do seem to suggest that the museum is aware of the issue that their exhibitions, especially the SHG, might be too "Disneyfied" in terms of presentation. The museum appears to be cutting down on using new media and reintroducing dropped features, such as text panels, so that the focus could be regained back to the presentation of the artefacts.

Moving to 2012, the NHB was subsumed under the Ministry of Culture, Communication and Youth[189]. It currently manages several museums and heritage institutions, including the NMS; ACM; Peranakan Museum; Singapore Philatelic Museum (revamped to the Children's Museum Singapore from end-2022 onwards); Sun Yat Sen Nanyang Memorial Hall; Reflections at Bukit Chandu; Changi Chapel and Museum; Malay Heritage Centre; and Indian Heritage Centre. In the same year, Angelita Teo became the next director of the NMS, where she continued her predecessor's strategy of emphasising meaningful storyline engagement while also encouraging "conversations about Singapore's diverse cultures"[190].

The museum underwent another refurbishment from 2014 to 2015 as part of the nation's campaign to celebrate Singapore's Golden Jubilee, SG50. This time the overall design was given to GSM Project; the filmic IM experience was provided by M'GO Films, while Kingsmen Creative headed the project management and execution[191].

The presentation format remained the same as the previous iteration, with the Singapore History Gallery on the ground floor providing "the broad stroke of Singapore history" with an updated layout. At the same time, the Life in Singapore galleries explores specific

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[187] YouThInk writers. "Promote exhibits directly to students". The Straits Times. 16 July 2011.
[188] Ibid.
[189] Lim, et al. Dome. 34.
[190] Lim, et al. Dome. 36.
[191] McDonald. "Retelling". InDesignLive.

aspects of Singapore's history[192]. The museum worked with external consultants, the SG50 sub-committees, and their academic advisory panel on the "seed narrative" to guide the content development of each gallery[193]. The SHG was refreshed, with the theme recontextualised and redesigned by GSM Project, M'Go Films, and Kingsmen Creative. At the same time, the second-floor permanent galleries were handled by the local design firm FARM[194]. The artefacts were shuffled to update the "historical narrative"[195] and to create "greater emotional connections with visitors"[196]. Several comments and suggestions were also considered. For example, the SHG has dropped the "compulsory" use of the audio-visual guide; the museum offers dialogue sessions with students and the public during the exhibition planning phase; feedback forms can be found at the end of most temporary exhibitions.

The SG Heritage Plan was officially announced in 2018 by the Ministry of Culture, Community and Youth (MCCY) as "the first master plan for the future of Singapore's heritage and museum sector"[197]. This initiative served as a stop-point to re-evaluate what the government has done and what could be done next. It highlights its importance and commitment to improving the heritage and museum sector.

Fig. 29. Screenshot of An Old New World: Digital Edition.

For Singapore's Bicentennial commemoration in 2019, the NMS put up an immersive blockbuster exhibition titled *"An Old New World: From the East Indies to the Founding of*

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[192] Burris, Jennifer, and Adrian Tan, eds. "Angelita Teo." In Questioning Museum: Art Institutions in Singapore, 88. Singapore: School of Art, Design and Media, Nanyang Technological University, 2019.
[193] Teo, Angelita. "A Golden Opportunity: Revamping the National Museum of Singapore for the Golden Jubilee Year". Edited by Thangamma Karthigesu and Marcus Ng. Culture Connection, 1, (2016): 19.
[194] "National Museum of Singapore Galleries." FARM. https://www.farm.sg/projects/details/national_museum_galleries (accessed 16 July 2022)
[195] "Digital Technology And The Museum Experience: A Case Study Of The National Museum Of Singapore." In *The Digital in Cultural Spaces Conference Publication*, edited by Thangamma Karthigesu, Chui Hua Tan, and Cheryl-Ann Low, Mei Gek, 60. Singapore: Culture Academy Singapore, 2017.
[196] Lim, et al. Dome.
[197] National Heritage Board. "Our SG Heritage Plan."

Singapore, 1600s–1819", which explored the history of the island two hundred years before Sir Stamford Raffles set up a trading port in Singapore[198]. This temporary exhibition was later converted into a virtual online exhibition (fig. 29) using IM technologies[199].

Moving to 2020, much like the rest of the world, the NMS was negatively impacted by the global COVID-19 situation. The pandemic became a catalyst for rethinking the use of digital technology in the museum, the use of touch interactivity in exhibition design, and audience interaction beyond the physical space of the museum building.

Immersive Media Development in Singapore and the Museum

This section examines the historical relationship between the NMS and IM technology by first looking at the background of Singapore and information technology and how that influenced the NMS to incorporate digital technologies in their exhibitions. It will also look at the lessons learned from past experiences to better shape the understanding of using IM in the NMS.

The Singapore Computer Society was established in 1967[200], highlighting Singaporeans' early interest in information and communication technology (ICT) and digital media. The society was followed by the opening of the Institute of Systems Science at the National University of Singapore (NUS-ISS) in 1981 to focus on developing IT talents through graduate and professional development programmes[201].

The NUS-ISS would become a vital cornerstone in developing and promoting VR technologies in Singapore.

On the governmental front, the *Ministry of Communications and Information* (MCI) was established in 1985[202]. The *Ministry of Information and the Arts* (MITA) was formed in 1990, and it took over some of the roles from MCI, in addition to the management of the arts and heritage sectors which includes the NHB, National Library Board (NLB), and

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[198] "An Old New World: From the East Indies to the Founding of Singapore, 1600s–1819". In National Museum of Singapore. 2020. https://www.nhb.gov.sg/nationalmuseum/our-exhibitions/exhibition-list/an-old-new-world (accessed 5 July 2021)
[199] "An Old New World: Digital Edition". In National Museum of Singapore. 2020. https://www.nhb.gov.sg/nationalmuseum/our-exhibitions/exhibition-list/aonw-digital (accessed 5 July 2021)
[200] "About Us." Singapore Computer Society. 2021. https://www.scs.org.sg/about (accessed 5 July 2021)
[201] "Our Story." National University of Singapore. N.d. https://www.iss.nus.edu.sg/about-us/our-story (accessed 5 July 2021)
[202] "Ministry of Communications and Information (MCI)." National Archives of Singapore. 2018. https://www.nas.gov.sg/archivesonline/government_records/agency-details/42 (accessed 5 July 2021)

National Arts Council (NAC)[203]. MITA expanded its function in 2001 to include ICT as it was renamed to the *Ministry of Information, Communications and the Arts* (MICA). MICA would again be renamed to the Ministry of Communications and Information (MCI) in 2012, while the NHB, NLB and NAC were moved to another ministry. The *Infocomm Media Development Authority* (IMDA) statutory board was formed in 2016 to oversee digital-related policies, programmes, and the development of Singapore's digital landscape. They are a child agency of MCI[204].

Moving back to 1990s, after VR and related technologies gained traction and popularity, Singapore showed interest in learning about them when the country hosted several ICT and digital technology conferences, some with a dedicated VR section. The first would be the 1990 8th International Conference of Computer Graphics Society (CG International '90), held at the NUS-ISS in June 1990[205]. While no section was dedicated to VR, Dr Mark Green, an Associate Professor at the University of Alberta presented his paper on VR user interface that year. The next VR-related conference held in Singapore would be the 1994 Virtual Reality Software and Technology (VRST) conference, also hosted by the NUS-ISS. This conference was conceived to counter other VR conferences at that time, "highly commercial" and "essentially detailed advertisements for specific products"[206]. Rather, this conference was aimed at international cooperation and high-quality research contribution.

The following year, the Nanyang Technological University (NTU) organised and hosted the Second Asian Conference on Computer Vision (ACCV'95). In this three-days conference, there were dedicated sessions devoted to VR technologies[207]. Moving to 1998, Temasek Polytechnic (TP) hosted the Virtual Reality Technology and Internet Applications Conference. It was a technical conference on VR technologies, with papers presented mainly by NUS academics, TP lecturers and industry partners, such as Motorola and Silicon Graphics[208]. Despite the 2000s being a relatively dry period in VR technology development, Singapore hosted the Cyberworlds International Conference

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[203] "Ministry of Information and the Arts." National Archives of Singapore. 2018. https://www.nas.gov.sg/archivesonline/government_records/agency-details/31 (accessed 5 July 2021)
[204] Loke, Kok Fai. "Parliament passes Info-communications Media Development Authority Bill." ChannelNewsAsia, via Internet Archive Wayback Machine. 2016. https://web.archive.org/web/20160826220615/http://www.channelnewsasia.com/news/singapore/parliament-passes-info/3048966.html (accessed 5 July 2021)
[205] Chua, Tat-Seng, and Tosiyasu L. Kunii, eds. "C G International '90 - Computer Graphics Around the World." In VG International '90. Singapore: Springer-Verlag Tokyo, 1990.
[206] Gurminder, Singh, Steven Keith Feiner, and Daniel Thalmann, eds. "Virtual Reality Software And Technology - Proceedings Of The VRST '94 Conference." In VRST '94 Conference. Singapore: World Scientific, 1994.
[207] Second Asian Conference on Computer Vision. Singapore: Nanyang Technological University, 1995.
[208] Temasek Polytechnic. Proceedings of the Virtual Reality Technology & Internet Applications Conference. Singapore: Temasek Polytechnic, 1998.

(CW) in 2003, 2005, and 2010, all taking place in NTU[209]. This conference covered topics that included human-computer interaction, virtual environment, simulation, VR, AR, and MR. These conferences indicated that Singapore was not just interested in learning IM technologies but highlighted Singapore as an active partner in cooperating with industry leaders and other countries in advancing the technology.

1994 to 1996 was an exciting period for VR in Singapore as VR became mainstream in multiple industries. As mentioned in the previous sub-chapter, the VRST conference was held in August 1994, and it received the attention of local media by sharing possible applications. This included a VR computer network for sharing 3D models; a truck driving simulator; and real-time drawing and sketching through a virtual workbench[210]. Later that year, Kim Michael Fairchild, technical staff at NUS-ISS, wrote to The Business Times highlighting NUS-ISS goal for VR's early arrival in Singapore was to take advantage of the development[211]. In September 1994, the *VIRTEX '94* exhibition was officially opened by the Minister of State for Education at the Science Centre. The public was able to try out various VR products, such as a haptic vest and a virtual walkthrough of the upcoming Esplanade theatre using a pair of 3D spectacles[212]. 1994 was also the year two immersive motion simulator theatre opened in Singapore (with more planned in the future). They are the *Virtrek* at Clarke Quay's festival village and *CineMania* at Fantasy Island Sentosa[213].

In February 1995, The Straits Times reported that Ngee Ann Polytechnic installed VR systems in most of their lecture theatres to teach abstract concepts that are thought to increase productivity[214]. In the following month, the *Megabugs* exhibition was held in SCS. It included a VR video game co-created by *Alliance Multimedia Corporation* and NUS-ISS where the visitor had to put on an HMD to play the game[215]. As one of the star attractions for the exhibition's Family Carnival, it was a fun and engaging way to entice young people to learn about insects.

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[209] "Cyberworlds International Conferences". Nanyang Technological University. N.d. https://www3.ntu.edu.sg/home/assourin/CW/cw-conferences.htm (accessed 6 July 2021)
[210] Yeo, Heidi. "Virtual reality programs being prepared for home computers". The Straits Times. 25 Aug 1994, 23.
[211] Ibid.
[212] "VIRTEX '94 Exhibition". The Straits Times. 4 Sept 1994, 21.
[213] "Family entertainment a virtual reality". The Straits Times. 23 Dec 1994, 3.
[214] "Poly launches virtual reality lecture system". The Straits Times. 9 Feb 1995, 22.
[215] "Getting into the insect world via Cyberbug". The Straits Times. 20 Feb 1995, 2.

Fig. 30a and b. Visitors tried out an interactive model at the virtual reality exhibition held at the Singapore History Museum, 1995.

Later in September, the SHM held a blockbuster VR exhibition titled *VR: Dawn of a New Reality* (fig. 30). This exhibition features "30 different VR displays for visitors to immerse themselves in computer-generated environments"[216]. It was presented by the NHB and *Imagine Interactive Inc*, a local VR consumer product company[217], and was marketed to showcase an overview of "affordable and practical" VR applications[218]. It was thought to be the largest and most expansive VR exhibition in Singapore and the first time an entire exhibition was dedicated to VR[219]. Considerable media coverage was given for this exhibition. Lim How Seng, the then-director of the NHB, said that one of the reasons for this exhibition was to alter the negative connotation of being "old and musty". Dr Gurminder Singh, Imagine's director and the head of a research team at NUS-ISS hoped that this exhibition "can educate the common man to make him see how VR will affect him everyday in five years time (*sic*)"[220]. Education Minister Lee Yock Suan, who visited the exhibition, mentioned that schools could use VR technology in the future when it becomes more affordable[221]. The exhibition was also very popular with students, reportingly over 45 per cent of the visitors were primary and secondary school students since it opened one-and-a-half months prior[222]. However, the exhibition does have detractors, with complaints such as blurry images inside the HMD, the lack of explanatory notes, and guidance on equipment usage[223].

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[216] Lim, et al. Dome. 43.
[217] Koh, Boon Pin. "Imagine that! Museum tampers with reality". The Straits Times. 16 Oct 1995, 3.
[218] Koh, Boon Pin. "Some hits, some misses at VR show". The Straits Times. 25 Oct 1995, 3.
[219] Koh. "Imagine that!".
[220] Ibid.
[221] "Schools may use virtual reality if costs drop". The Straits Times. 23 Oct 1995, 1.
[222] Foo, Lilian. "Museum abuzz with virtual reality activity". The Straits Times. 9 Nov 1995, 39.
[223] Koh. "Some hits, some misses".

The NUS-ISS and its associate partner companies, *Alliance Multimedia* and *Imagine Interactive,* continued to focus on VR technology as they anticipated the boom for practical use in companies and individuals.

Along with the general advancement of computing and IT technology, some VR technologies would influence the SHM/NMS museography for years to come, even when the hype for VR subsided in the following decade, and the value of using VR in museums dwindled. Moving forward to the SHM redevelopment period of 2003-2006, the museum's galleries situated at Riverside Point presented the Singapore story using a mix of "interactive technology, dioramas" and "multi-sensory activities" that appeals to "visitors of all ages and levels of historical knowledge"[224]. The NHB also took this time to develop and launch their online and new media presence, with web portals such as (the now-defunct) yesterday.sg, and museums.com.sg[225]. They also developed the *Integrated Museum Display System* (IMDS), a personal digital assistant (PDA) with interactive multimedia narration known as the *Museum eGuide*[226].

Before the SHM reopened as the NMS in 2006, it worked with external contractors such as GSM Design, GSM Media, M'Go Films, and media artists to commission new multimedia content for the SHG. Examples of IM works include *Singapore 360º* (fig. 31a), *Sejarah Singapura: Picture of 14th Century Singapore* (fig. 31b)[227], and *The Building Remembers/Remembering the Building* (fig. 31c)[228]. Each of the works has its own conception history, which will be examined in details in Chapters 5 and 6.

The Exhibition Galleries 1 and 2 in the basement were touted as "one of the city's largest and most technologically versatile exhibition spaces". It is capable of hosting "overscale three-dimensional works of art as well as technologically sophisticated new media forms"[229].

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[224] Lenzi, Iola. 2004. "Singapore History Museum." In Museums of Southeast Asia, edited by Marilyn Seow and Laura Jeanne Gobal, 132–33.
[225] National Heritage Board. "National Heritage Board Annual Report 2005/2006: Living Heritage." Singapore, 2006.
[226] National Heritage Board. "National Heritage Board Annual Report 2006/2007: Muse in Vogue." Singapore, 2007.
[227] Ibid, 56-60.
[228] Ibid, 36-37.
[229] Ibid, 110-112.

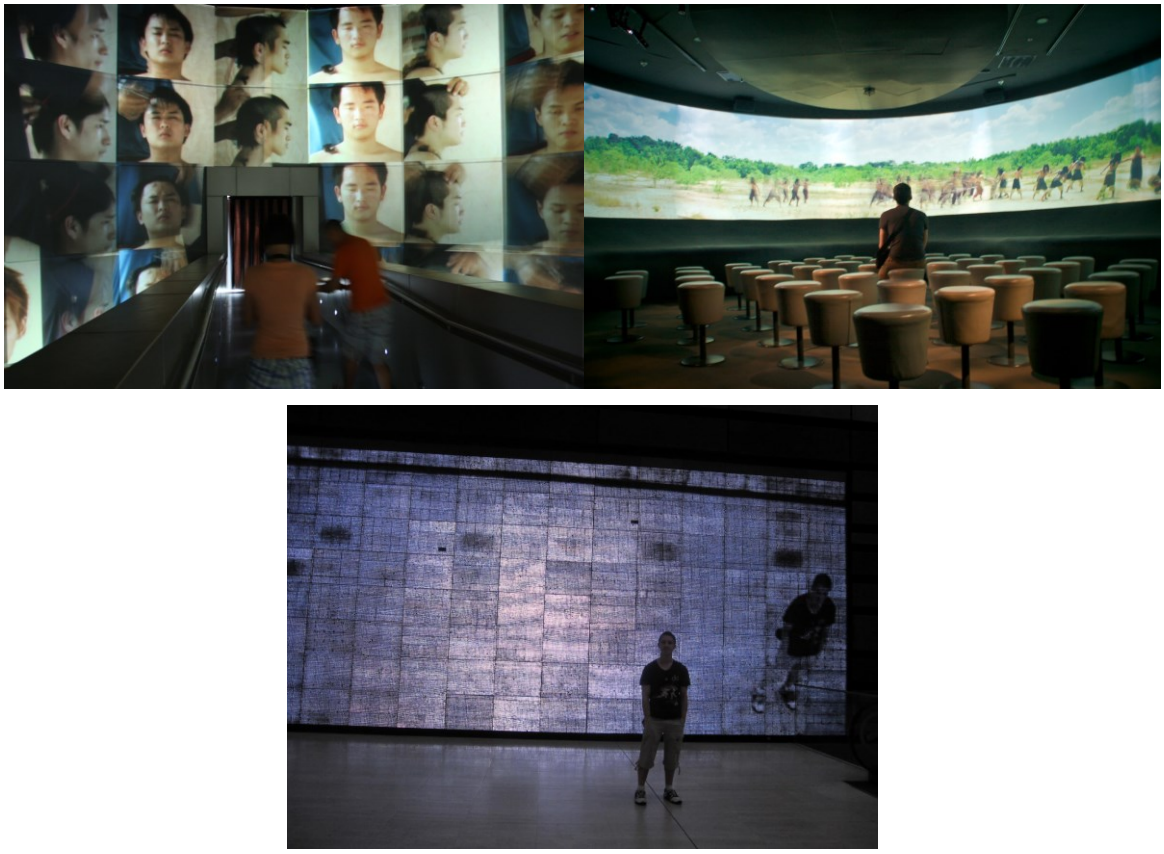

Fig. 31a, b (top) and c (bottom). Singapore 360º *at the Glass Rotunda (left),* Sejarah Singapura: Picture of 14th Century Singapore *in the SHG (centre), and the video wall (right), photo taken in 2011, 2012 and 2010 respectively.*

The NMS continued to include dynamic and interactive displays in their other exhibitions. The museum underwent partial modification with the SHG changing its exhibition circulation. *Singapore 360º* has been removed and the SHG can be entered via level 1 instead of level 2. It was done as part of the SG50 Singapore Golden Jubilee from 2014 to 2015. The museum partnered with the exhibition design firm, *GSM Project,* to update the SHG and reopened in September 2015. The main adjustments were in the movement flow and circulation, which altered some IM experiences. On the topic of digital enhancement for 2015 revamp, then-NMS director Angelita Teo said[230]:

> *"The museum-going experience has changed from a personal one to a social activity… The use of technology in the galleries was thus a careful consideration, in that technology and digital enhancements should serve the purpose of adding layers, texture and content, but not to define and overwhelm the experience."*

[230] Teo. "A Golden Opportunity". 19–26.

One example of change was the addition of the Global City section, which explored Singapore's global position and relations with other countries at the end of the SHG. Previously, the SHG would end its narrative in the early 1970s, but for the revamp, the museum expanded to include Singapore's international relations in the 21st century[231]. Part of this segment was the addition of the interactive map kiosk that the curatorial team worked with the *Singapore Memory Project,* where visitors explored curated memories and shared their memories to be stored in the kiosk database for other visitors. This section serves as a way for the museum to use digital media for visitor engagement, making the experience more personal and interactive.

Story of the Forest by Japanese art collective teamLab, an immersive interactive digital installation, was introduced in 2016[232]. It took over the Glass Rotunda that once housed *Singapore 360º*. Visitors can download the (now defunct) accompanying AR app to interact with the art space. In early 2017, the NMS *Gallery10* was also introduced. The NMS's first digital-only gallery aimed to be an "experimental digital space equipped with advanced projection technology" for the museum to collaborate with creatives and artists[233].

During the same period in 2016, Singapore caught the attention of American news channel CNBC when a local start-up, Hiverlab, planned to preserve heritage sites in VR by recreating them as virtual content[234]. The news article also noted that while the VR space was primarily geared towards video games and entertainment, companies were also looking into expanding into areas such as "education, social interaction, and tourism"[235]. Hiverlab was the sponsor and VR system partner for the DigiMuse Virtual Reality Showcase in December 2017, while presenting their original 360-degree short film, *Beach Road*, in that event[236].

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[231] Lim, Sharon. "Chapter 6E – More than a Little Red Dot: Becoming a Global City." In (Re)Presenting Histories: Experiences & Perspective from the National Museum of Singapore, 120-25.
[232] "Story of the Forest". teamLab. N.d. https://www.teamlab.art/w/story-of-the-forest/ (accessed 18 July 2021)
[233] Ho. "The National Museum of Singapore launches first dedicated digital space".
[234] Choudhury, Saheli Roy. "VR to Make Couch Potato Tours of the World's Landmarks a Click Away." CNBC, 2016. https://www.cnbc.com/2016/12/07/hiverlab-creating-a-virtual-heritage-of-the-worlds-most-historic-sites.html.
[235] Ibid.
[236] "National Museum Of Singapore International VR Content Showcase". Hiverlab. https://www.hiverlab.com/national-museum-of-singapore-international-vr-content-showcase (accessed 18 July 2021)

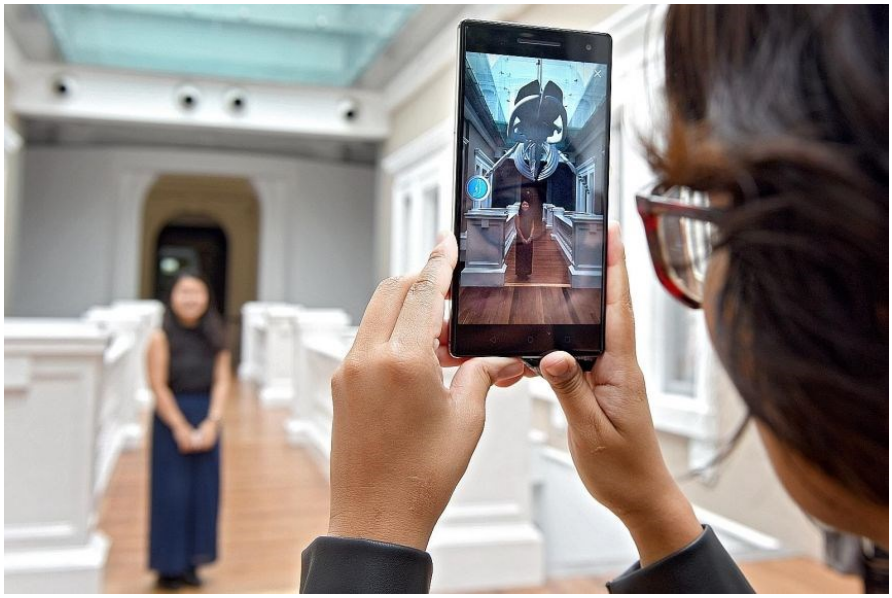

Fig. 32. Visitors trying out the AR function of the whale skeleton where it used to be displayed.

The museum renewed its exploration of VR and AR technology in 2017. In April of that year, the museum partnered with Google and developer GuidiGo to create an hour-long architectural tour where visitors were given Tango-enabled[237] smartphones and guided to six points of interest within the museum[238] (fig 32). The project was done to commemorate the museum's 130th year. On the use of technology for this project, Jervais Choo, the then-NMS senior assistant director said[239]:

> *"The museum is primarily a collection-based museum. How we introduce technology always has to be focused on how it helps to tell the story of the collection or, in this case, of the building better."*

Later that year in December, the museum launched the DigiMuse programme (fig. 33), which aimed "to engage the wider technology sector to crowd source ideas to enhance museum experiences and build a vibrant cultural sector"[240] by blending history, art, and technology. Artists, technologists, and cultural professionals were invited to work on projects with the museum, which will later be shown to the public for around one month. For the 2018 edition, the museum launched an open call to attract potential partners in developing digital applications from two categories – 'Museum Experience' and 'Art and

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[237] Tango was Google's AR platform before it was replaced with Google ARCore.
[238] Said, Nabilah. "National Museum of Singapore Uses Augmented Reality to Tell Building's History." The Straits Times. 14 April 2017. https://www.straitstimes.com/lifestyle/arts/national-museum-of-singapore-uses-augmented-reality-to-tell-buildings-history.
[239] Said, Nabilah. "Take a Selfie with a Whale at Museum." The Straits Times, 18 April 2017. https://www.straitstimes.com/lifestyle/arts/take-a-selfie-with-a-whale-at-museum.
[240] "DigiMuse: Circuit Breaker Edition." National Museum of Singapore. https://www.nhb.gov.sg/what-we-do/our-work/community-engagement/public-programmes/digimuse (accessed 3 Jun 2020)

Creatives'[241]. Many of the accepted DigiMuse projects made use of VR and AR technology. The DigiMuse 2020 edition, dubbed the "Circuit Breaker Edition" (named after Singapore's COVID-19 pandemic preventive measure) will be the first time the DigiMuse programme goes fully online[242].

Fig. 33. Visitors trying out the VR headsets in DigiMuse 2017.

The NMS launched "An Old New World" temporary exhibition in 2019 and was later converted into a 360-degree-virtual online exhibition, aptly titled "An Old New World: Digital Edition," in April 2020, when the physical exhibition ended[243]. In addition to the free-moving virtual tour, the Digital Edition also comes with three guided audio tours.

In summary, this chapter provides crucial contextual knowledge of how IM came about, vital developments in modern IM in both international and local contexts, and the history of the museum, which provides clues on how the NMS plan its exhibitions and its attitude towards digital technology and IM.

[241] "DigiMuse Open Call for Digital Art and Innovative Concepts". National Museum of Singapore. https://www.nhb.gov.sg/nationalmuseum/our-programmes/programmes-list/digimuse-open-call-2018?sc_lang=en (accessed 13 July 2021)
[242] Ibid.
[243] "An Old New World: Digital Edition".

The permanent galleries and exhibitions in the museum are (as of July 2021):

- **Singapore History Gallery**
    - *Singapura (1299 – 1818)*
    - *Crown Colony (1819 – 1941)*
    - *Syonan-To (1942 – 1945)*
    - *Singapore (1945 – present)*
- **Life in Singapore: The Past 100 Years** galleries:
    - *Modern Colony (1920s-1930s)*
    - *Surviving Syonan (1942-1945)*
    - *Growing Up (1950s-1960s)*
    - *Voices of Singapore (1970s-1980s)*
- **Goh Seng Choo Gallery**
    - Rotating exhibit of the William Farquhar Collection of Natural History Drawings.
    - Currently: *A Voyage of Love and Longing (*2021)
    - Previously: *Magic and Menace* (2017)
    - Previously: *Desire and Danger* (2015)
- **Glass Rotunda**
    - *Story of the Forest* by teamLab
    - *Singapore, Very Old Tree* by Robert Zhao
- **Other Contemporary Artworks**
    - *Moving Memories* by the NMS (LED Wall, next to the gift shop)
    - *History of the National Museum of Singapore* by Tip Yew Chong (Grand Staircase)
    - *Wings of a Rich Manoeuvre* by Suzann Victor (Glass Atrium)
    - *GoHead/GoStan* by Brandon Tay and Safuan Johari (SHG)
- **Digital Exhibitions and Offerings**
    - *An Old New World: Digital Edition* (https://www.nhb.gov.sg/media/exhibition-online/aonw-new/index.html)
    - *Home, Truly: A Digital Experience* (https://www.roots.gov.sg/home-truly)
    - *Every Body Plays a Part – A Showcase of Public Health Crises and Responses in Singapore* (https://www.nhb.gov.sg/nationalmuseum/our-exhibitions/exhibition-list/ebpap)
    - NMS Dome Bot chatbot

CHAPTER 4: IMMERSIVE MEDIA, STORYTELLING, AND THE THEATRE-MUSEUM

This chapter examines the theoretical and conceptual ideas behind IM and the museum relating to the NMS. It attempts to understand the differing definition of IM as a loaded term while defining it for this thesis, followed by examining the classic concept of virtuality as a basis for understanding IM and its related technology. It will explore the relationship between storytelling, theatre, and the museum.

4.1 Immersive Media and Virtuality

Defining Immersive Media

In a journal article on educational media, researchers Regina Kaplan-Rakowski and Kay Meseberg defined IM as media where a person experiences "psychological immersion", or "telepresence", also known as the state of "being there" in a synthetic or mixed media environment. In contemporary IT and media contexts, immersive media is also an analogous term to "extended reality" or XR. According to a Forbes article, XR is an umbrella term for AR, VR, and MR[244].

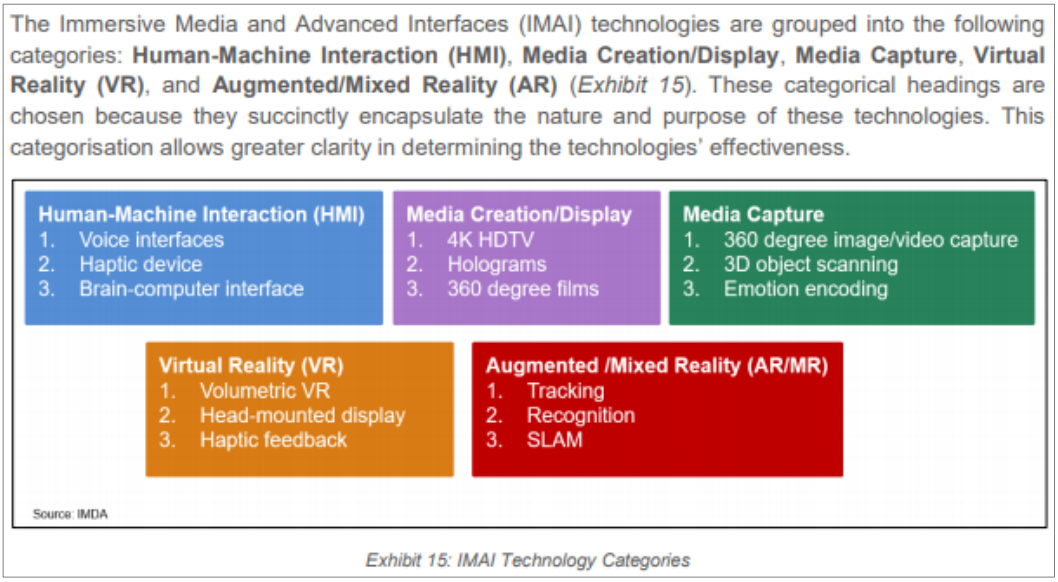

Fig. 34. Screenshot from "ANNEXES A-2 IMMERSIVE MEDIA AND ADVANCED INTERFACES" in Technology Roadmap, published in Nov 2018.

[244] Marr, Bernard. "What Is Extended Reality Technology? A Simple Explanation for Anyone." Forbes, 2019. https://www.forbes.com/sites/bernardmarr/2019/08/12/what-is-extended-reality-technology-a-simple-explanation-for-anyone/

Separately, the Infocomm Media Development Authority (IMDA) looks at IM at a more technical level in their “Immersive Media and Advanced Interfaces” annexes report. It uses a classification based on the five basic senses - Vision (sight); Tactile (touch); Gustation (taste); Auditory (hearing); Olfaction (smell). They are then categorised into five different components (fig 34).

While that categorisation is suitable for their in-depth market and technology report, a more simplified categorisation will be used for the thesis (fig 33). The focus here is not on the technology itself but its utilisation in a museum setting. In this case, the experience rather than the technology is more helpful for this research. The simplified categories help separate and distinguish the different types of media used in the museum (e.g., the “immersive-ness” of an interactive kiosk compared to a VR HMD).

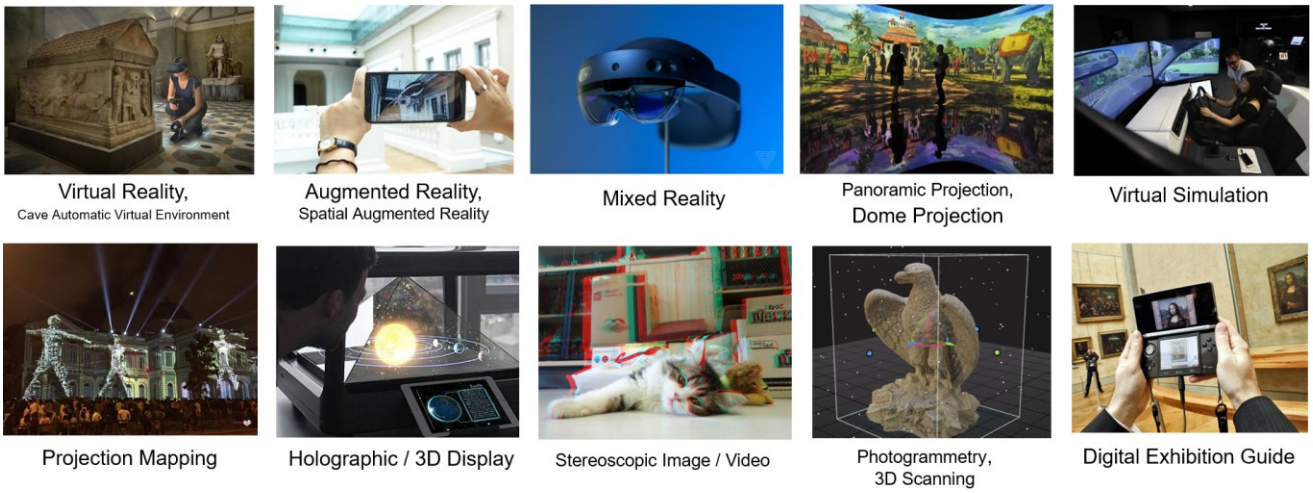

Fig. 35 A list of immersive media as defined for this research.

They are separated into standard media usually associated with IM and XR, except for the *Digital Museum Guide*, which combines cameras (e.g., QR code scanning), map tracking, high-resolution imaging, and 3D models into the hardware. Regardless, IM is a form of new media that relies on the computational processes for either input or output.

It should be noted that the NMS does not actively employ mainstay IM, such as VR, AR, or 3D display as part of their exhibition design. Those are usually reserved for more experimental programmes such as DigiMuse. Thus, IM will be more loosely defined in the exhibition space by including mediums such as immersive multiscreen projection.

Reality-Virtuality Continuum

Before using IM in an exhibition, it helps to understand the level of digital immersion through the Reality-Virtuality Continuum.

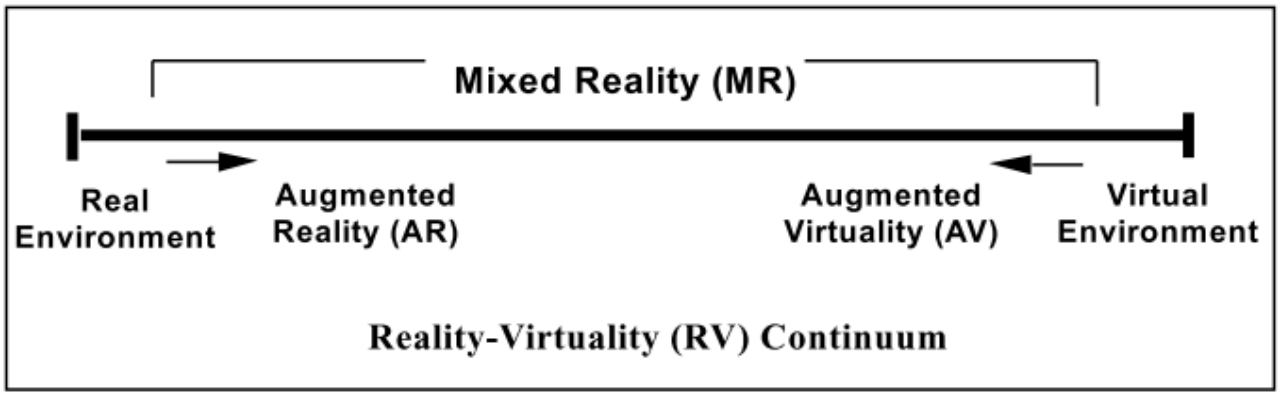

Fig. 36a. Simplified representation of the RV Continuum according to Paul Milgram.

First described by Prof Paul Milgram and his research partners in 1994, the '*Reality-Virtuality Continuum'* (fig. 36) is a scale that ranges from a completely virtual environment to actual reality[245]. It was initially proposed as a taxonomy for categorising AR and MR display systems of that time. Their definition of MR was "one in which real-world and virtual world objects are presented together within a single display"[246], which serves as an umbrella term for both VR and AR. It should be noted this is an antique definition of MR as the term has evolved and changed since the paper was first published.

On one end, the actual environment consists of "real objects" with a physical presence in our three-dimensional existence that can be touched and affected by this world's physics. Moving on is AR, where virtual objects are superimposed or layered onto the natural environment, are commonly viewable, and can be interacted with through a physical medium such as a digital screen. Continuing is augmented virtuality (AV), a currently unused term that would help describe future technology[247]. Unlike AR, AV is primarily virtual, with some real-world objects or data imported into the digital realm.

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[245] Milgram, Paul, and Kishino Fumio. "A Taxonomy of Mixed Reality Visual Displays." IEICE Transactions on Information and Systems E77-D, no. 12 (1994).
[246] Milgram, Paul, Haruo Takemura, Akira Utsumi, and Fumio Kishino. "Augmented Reality: A Class of Displays on the Reality-Virtuality Continuum." In Proceedings Volume 2351, Telemanipulator and Telepresence Technologies, edited by Hari Das, 282–92. Boston, 1994..
[247] Abdullahi, Khullani M. "The Reality-Virtuality Continuum: Understanding Augmented and Virtual Reality for Marketing." Medium, 2016. https://khullani.medium.com/the-reality-virtuality-continuum-db166a704c01. (accessed 5 July 2021)

This paper would like to propose AV as the combination of using an immersive display (such as a CAVE or dome projection) and heightening its immersion using real-world elements such as props and lighting. This proposition originated from how modern museums use stage elements to augment the immersion of the experience. Lastly is the virtual environment or virtual reality.

Virtual Reality: Autonomy, Interaction, and Presence

The words 'virtual reality' is defined as "a computer-generated digital environment that can be experienced and interacted with as if that environment were real"[248]. The ideal VR system would allow users to interact with these digital representations of objects as if they were present in the physical world.

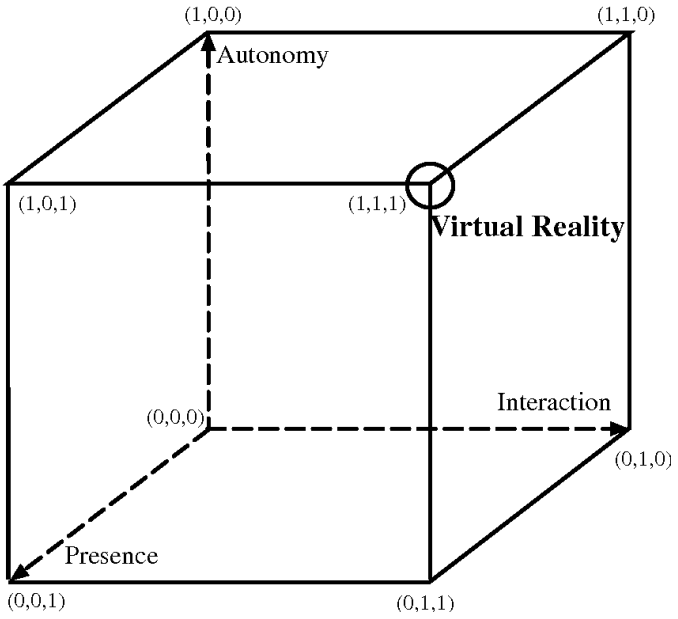

Fig. 36b. Autonomy, interaction, presence in VR – Zeltzer's cube..

True VR requires the medium to provide "autonomy, interaction, and presence"[249]. This distinction filters out 360-degree images and contents as true VR, as they only offer a passive experience. The three components - autonomy, interaction, and presence, forms the 'AIP Cube', coined by David Zelter of the MIT Media Lab. It is a "qualitative tool for describing, categorising, comparing, and contrasting virtual environments"[250].

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[248] Jerald, Jason. "Chapter 1: What is Virtual Reality". In The VR Book: Human-Centered Design for Virtual Reality. Edited by M. Tamer Özsu. First. Association for Computing Machinery and Morgan & Claypool Publishers, 2016. https://doi.org/https://doi.org/10.1145/2792790.
[249] Zeltzer. "Autonomy." 127-132.
[250] Ibid. 127.

Autonomy refers to the qualitative measurement of the "computational model to act and react to simulated events and stimuli". On the other hand, interaction refers to "the ability to define and modify states of a model with immediate response". Lastly, presence refers to the sensory input that grounds us in our physical reality. In essence, it relates to the user reacting, interacting, and feeling immersed through sensory channels.

The VR in the RV Continuum refers to true VR (also known as room-scale VR), a virtual environment with a high level of autonomy, interaction, and presence. It would ideally be able to respond to the user's actions and inputs (such as moving the user's field of view as they turn their head). It should also allow real-time manipulation of virtual objects using the physical controllers and make the user feel like they are part of that virtual world. It should be understood that this paper refers to VR as one that fulfils all three components, as passive 'cinematic VR' experiences such as 360-degree images and videos do not qualify them as true VR. Their productions and hardware requirements are also different, with true VR necessitating much more powerful hardware to power the real-time interactions, while cinematic VR content is often pre-recorded.

VR experiences should also not be seen as binary but as a scale, an example being a VR rollercoaster app. In this instance, no direct input from the user can alter the virtual environment, yet the experience is rendered in real-time. This situation blurs the line between cinematic and true VR experiences. Thus the use of the autonomy, interaction, and presence components are helpful indicators of how effective a VR experience is.

4.2 Exhibition Narrative, and Immersion of a Theatre-Museum

As mentioned previously in the history section, after the transformation of the SHM to the NMS in 2006, the NMS uses a form of storytelling (or 'Exhibition Narrative') to guide visitors into making their own interpretations of historical facts. This section will look at that form of storytelling using IM and how it relates to contemporary museography as a 'theatre-museum'.

Defining a Museum from the NHB Perspective

Before moving on, it helps to recap the definition of a museum to get a common understanding for the purpose of this thesis. The International Council of Museums (ICOM) defines a museum as "a non-profit, permanent institution in the service of society

and its development, open to the public, which acquires, conserves, research, communicates and exhibits the tangible and intangible heritage of humanity and its environment for education, study and enjoyment"[251]. The NHB view the museum as a place that "conveys ideas in three-dimensional space" and "apart from text, graphics, and multimedia presentations, objects play an important role"[252].

In essence, a museum functions like a storybook, where the narration is king. The artefacts play an integral role in shaping the story, with the curators acting as the unseen facilitators for audiences visiting the space.

From Object to Artefact

Objects are seen as an essential part of a museum, akin to animals are to a zoo[253]. The NMS notes that the differences between a museum and other "cultural, epistemological and pedagogical establishments" is in the "collection, preservation, storage, documentation, research and presentation of objects"[254].

Apart from the object's physical quality, it needs to be recontextualised with its association with a particularly notable event or person for an object to become an artefact. This method creates a "resonance, drama and story" that link us to "past people, places and events". The NMS argues that an object remains an object until they learn of its background and significance, thus allowing them to be recast as an artefact[255].

Thus, for this thesis, 'object' and 'artefact' are loaded terms with different meaning, with an object being a physical item. In contrast, an artefact is an object that has been carefully analysed, studied, observed, and exhibited in the museum in a specific context. It also highlights the importance of story and narrative in an exhibition that allows museum visitors to make sense of why a specific object is displayed in a particular way.

This approach was very different before the era of 'exhibition narrative' and 'theatre-museum', instead being called "a gloomy mausoleum" and a "dead house". It came at a time when the museum functioned mainly as a storage and display facility rather than a place purposefully built to present carefully crafted exhibitions to educate the public[256].

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[251] "Museum Definition". International Council of Museums. N.d. https://icom.museum/en/resources/standards-guidelines/museum-definition/ (accessed 5 July 2021)
[252] Wong, et al. "Imagining Singapore."
[253] Phua, et al. "Chapter 7".
[254] Phua, et al. "Chapter 7".
[255] Ibid.
[256] Lim, Sharon, et al. Dome. 46.

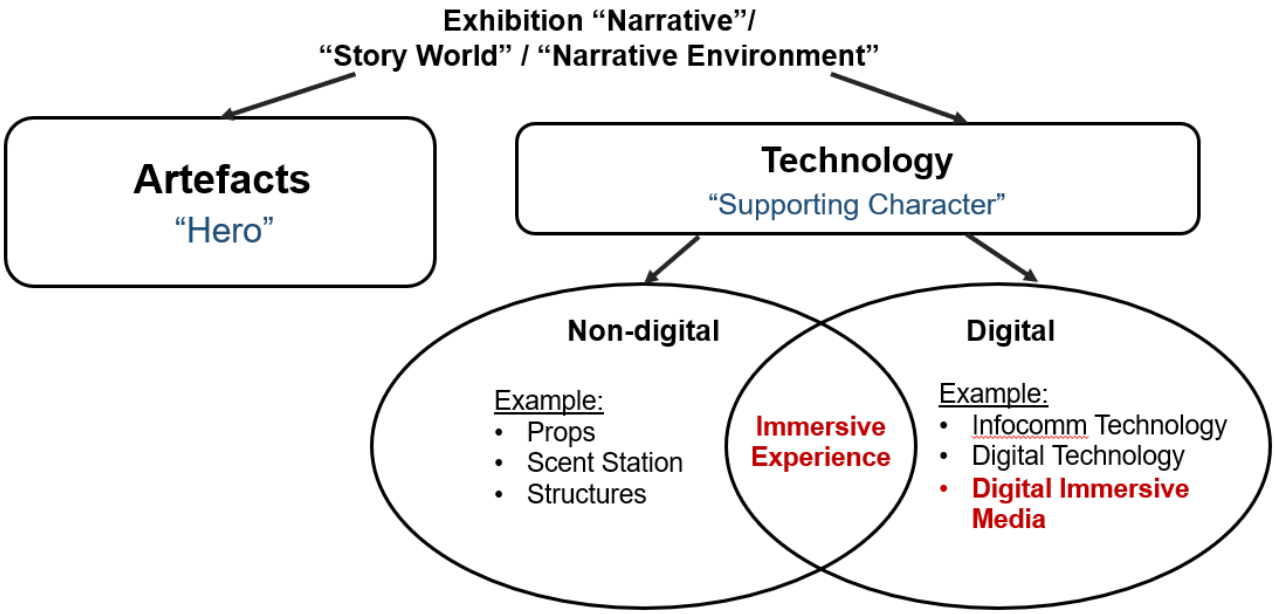

Fig. 37. Diagram of the NMS exhibition design strategy regarding artefacts and technology, based on (Re)Presenting Histories. Created by the author.

Iskander Mydin, the NMS senior Curatorial Fellow, remarked that the museum uses storyline as its starting point in creating exhibitions[257], with the mode of the display as "contextual"[258]. In this way, the NMS exhibition concept, or their museological approach, revolves around "narrative" and "storytelling"[259], with the artefacts as the "hero" and technology as a "supporting character"[260] (fig. 37). As the exhibition narrative, the objects in the gallery function as "witnesses, testimonials, symbols, representations, (and) entry-point". The primary purpose is for the museum visitors to be immersed in the "experience"[261]. The visual presentation of the artefact is also crucial, as "the artefact doesn't exist solely on its own". It interacts visually with other atefacts and the environment to create a "diorama effect"[262].

[257] Phua, et al. "Chapter 7".
[258] Mydin, Iskander. (NMS) in discussion with author, video conference, 14 Oct 2020.
[259] Mydin, Iskander. "Chapter 1 – Towards a Museum Narrative". In (Re)Presenting Histories : Experiences & Perspectives from the National Museum of Singapore. Edited by Stepanie Yeo. Singapore : National Museum of Singapore, 2017, 10-19.
[260] Phua, et al. "Chapter 7".126-133.
[261] Mydin. "Chapter 1".
[262] Mydin, in discussion with author.

Personal Story and Seed Narrative

Dr Mark Frost, one of the academics working on the 2006 revamp of the SHG, remarked that major emphasis was placed on "people, biography and personal drama, particularly through its liberal use of modern multimedia"[263] when redesigning the galleries. Research at the Minnesota Historical Society similarly concluded that "museum visitors most readily connect to history through the personal stories of others"[264]. This theory creates a "process of introspection" that creates guiding questions within their minds, such as[265]:

- What was it like?
- What would I do?
- How would I feel?
- Would I have made the same choice?

During the 2015 refurbishment, the museum staff used a similar tactic of narrative and introspection by raising these questions when they were brainstorming about the 'seed narrative' for the permanent galleries redesign[266]:

- What is the story to be told?
- How is the story to be told?
- What is the setting of the story?
- What is the experience? How will visitors be engaged?
- What is the key take-away for visitors?

Bring History to Life through Design

For the SG50 revamp, the SHG, the four galleries under the 'Life in Singapore: The Past 100 Years' and the Goh Seng Choo Gallery received the exhibition overhaul treatment.

As a collective set of galleries linked to Singapore history, these exhibitions revolved around intimate and personal stories within the 'story world'; and it was done by bringing out the curators' in-depth research using a variety of museographical disciplines (e.g., exhibition design, lighting design, spatial design, graphic design). They were

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[263] Frost, Mark Ravinder. "The Making of the Singapore History Gallery: Some Personal Reflections." In The Past in the Present: Histories in the Making, edited by Priscilla Chua, 61–77. Singapore: National Heritage Board, 2009.
[264] Mouw, Michael, and Daniel Spock. "Immersive Media: Creating Theatrical Storytelling Experiences." In The Digital Museum: A Think Guide, edited by Herminia Din and Phyllis Hecht, 45–56. Washington, DC: American Association of Museums, 2007. 47.
[265] Ibid.
[266] Teo. "A Golden Opportunity."

supplemented using non-digital and digital media technology[267]. This approach was to counter the "ever-decreasing attention span" of museum visitors. The GSM design team opted for a more interactive, less static exhibition by integrating multi-sensory experience using interactive stations (both non-digital and digital), ambient sounds, and scents to engage the visitors "in the stories on a personal level"[268].

Some elements of design utilised in the 2015 museum refresh include "the thoughtful and deliberate use of space"[269], accompanied by visual anchors, sound, and scent to "evoke a scene of time, place and circumstance" in this holistic storytelling experience. The use of distinct textures and colours helps to bring the museum space alive, such as mimicking the interior of a pre-colonial bungalow, "complete with a slow-moving, creaking ceiling fan and a display of newspapers from that time period" [270]. In addition, fragrance developer Givaudan also made unique scents for the permanent galleries to immerse the visitors[271].

This approach can be traced back to the 2006 SHG, where the lighting design team deliberately used lights to reinforce the museum's narrative[272]. An example is the SHG Japanese Occupation section, where the Edison bulbs' filaments were dimmed, causing them to "shake" and evoking the feeling of fragility and helplessness.

Live Interpretation and Object Theatre

Interestingly, NHB staff Wong and Toh wrote in 2009 that while the NMS approach was "story-based", sometimes the objects might "function as a supporting cast"[273] instead of being the 'main character'. They perceive the artefact's role as one that "materialise ideas, triggers thoughts and enables knowledge to be imagined and known". The two also compared the creation of a museum exhibition to that of theatre production, where different groups of people with different visions and styles work together to bring their production into reality[274]. The comparison towards theatre could have been derived from interpretive and object-oriented techniques in theatre productions applied to museum exhibitions starting in the 1970s[275].

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[267] Mydin. "Chapter 1".
[268] Seow. "Retelling the Story of a Nation".
[269] Ibid.
[270] Ibid.
[271] Seow. "Retelling the Story of a Nation".
[272] Sokol. "National Museum". Architectural Record.
[273] Wong, et al. "Imagining Singapore."
[274] Ibid.
[275] Alsford, Stephen, and David Parry. "Interpretive Theatre. A Role in Museums?" Museum Management and Curatorship 10, no. 1 (1991): 8–23.

The techniques had their roots in the 'live interpretation' strategy used by open-air museums of the past by having station staff don in period-appropriate outfits speaking to tour groups in first or third person, along with accurate historical setting recreated to bring a sense of theatricality into the exhibition[276]. This kind of strategy allowed for a scripted dramatisation of past events. It grants role-playing interpreters the freedom to apply their historical knowledge from their character's viewpoints. The museum might also hire theatre companies specialising in historical drama to "serve as company-in-residence"[277]. The idea of using the interpretive theatre spread from America's Science Museum of Minnesota to even the Science Centre Singapore[278].

The key advantage of using interpretive theatre programming was creating an extra layer on top of the traditional museum experience. It helps decode heritage aspects more effectively than static objects and revitalises the museum to promote return visits. In addition, it dispels the notion that the museum is a passive and uninteresting place[279] while also humanising the stories behind the artefacts, building on "fundamental empathy" for the audiences to relate to those characters[280]. This method can be summarised from the ideas conceptualised by author Freeman Tilden[281]:

> *"The interpretive art aims not at instruction but provocation, implying an experience that transcends the mere acquisition of information to something that engrosses and compels the human spirit."*

Besides interpretive theatre strategy, there is also the term "object theater" (or, more accurately, "story theater"), coined by Taizo Miake of Ontario Science Center in 1980s[282]. This exhibition strategy is defined as "any museum-based automated theatrical presentation involving sets, lighting and audio cues"[283]. It also includes advanced technical media such as motion-based simulation, animatronics, or voice-activated interface to create a multi-sensory context for the artefacts on display[284]. Whereas interpretive theatre focuses on people role-playing, story theater deals primarily use multimedia to enhance the museum experience. However, despite the object and media

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[276] Ibid.
[277] Ibid.
[278] Ibid.
[279] Ibid.
[280] Ibid.
[281] Mouw, et al. "Immersive Media".
[282] Ibid. 49.
[283] Ibid.
[284] Bedford, Leslie. "Storytelling: The Real Work of Museums." Curator: The Museum Journal 44, no. 1 (2001): 30.

focus, “story content is ultimately more decisive than any object or theatrical trick of the trade”[285].

These techniques align with 2006 revamp of the SHG, where voice-over dramatisation in the audio-visual guide (as well as interviews with curators)[286] help lead visitors from one artefact to the next. It guides them with accounts from multiple perspectives, set in a theatrical space where the use of props allows for further immersion.

The Musume Companion (App)

Taking these techniques into account, the 2006 iteration of the SHG introduced a digital audio-visual guide known as The Companion[287] (fig. 26). It functions to help museum visitors understand artefacts on display at the SHG through audio, visuals, and text. It is a bulky lime-green device with an LCD screen with glow-in-the-dark keypads and comes with a pair of earphones and a neck strap. It follows the flows of the SHG by going through each artefact one by one.

While the device allows visitors to browse at their own pace as it narrates the story behind each artefact, it is not without issues. It is slow to respond, the buttons are not properly labelled and have a messy layout, and it is also bulky and cumbersome to wear. The device might have also deterred certain groups of people from visiting the museum as they are not technologically savvy, and using such a bulky device may seem intimidating.

The Companion device would not be the last time the NMS experiments with an external device or application to augment the visitor’s experience. The Companion device was eventually discontinued during the refurbishment of the 2015 SHG.

With the commodification of smartphones in the mid-2010s, the museum shifted their attention to commissioning smartphone apps instead of designing new devices. Some examples include the NMS app in 2019 and the Story of the Forest AR app.

In addition, linking back to the idea of the interpretive theatre strategy, in the 2021 temporary exhibition - *Picturing the Pandemic: A Visual Record of COVID-19 in Singapore*, the NMS collaborated with a local theatre company, Checkpoint Theatre, to create a podcast audio narrative to shed light on the struggles faced by Singaporeans

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[285] Mouw, et al. “Immersive Media”.
[286] Teo. “A Golden Opportunity” 22-23.
[287] “Redesigning The Companion”. In SlideShare. 2012. https://www.slideshare.net/kamiyahkimmy/redesigning-the-companion (accessed 16 July 2022)

during the pandemic. The podcast is marketed as a companion audio trail for the exhibition and accessible via the 'NMS Dome Bot chatbot'[288].

All these devices and apps served to fill the role of a 'middle-man', or a possible tour guide, with personalised pacing and allowing the visitors to focus on displays that interest them. It can also help to resolve issues that a real tour group might face, such as the language barrier, by writing descriptions and text in languages other than English.

In either case, the NMS exhibitions are more akin to story theatre than interpretive theatre, likely due to human resources and logistical issues. A kiosk, installation, audio guide, and even just an app on the visitor's phone may appear less daunting than having dressed actors inside a gallery. This approach combines certain aspects of the interpretive theatre, like connecting with the audiences through empathy and dramatising a historical event.

Bringing the Elements Together

Fig. 38. This part of the Singapore History Gallery tries to recreate a typical HDB flat dwelling, making it akin to 'stage' where the visitors become the 'actors' of the play.

An example of using both theatre strategies can be found at the end of the current SHG (fig. 38). This HDB[289] flat replica mergers stagecraft (which includes color, lighting, period-accurate props, and interactive touchscreen kiosks) and the museum's artefacts to create "a space that generate an effective engagement with the past"[290]. In this analogy, the

[288] "Picturing the Pandemic: A Visual Record of COVID-19 in Singapore". National Museum of Singapore. https://www.nhb.gov.sg/nationalmuseum/our-exhibitions/exhibition-list/picturing-the-pandemic (accessed 15 July 2021)
[289] HDB is short for Housing Development Board, a statutory board responsible for public housing. HDB flats are one of the most common form of public housing in Singapore.
[290] Teo. "A Golden Opportunity."

visitors, particularly local visitors, become the 'actor' and 'interpreters' of this historical setting as they "step back" in time and be given the opportunity to "generate historical understanding and meaning"[291].

CHAPTER 5: SINGAPORE HISTORY GALLERY AND DIGIMUSE

This chapter will take a closer look at the three examples of IM in the 2006 and 2015 SHG each, respectively, and two prototype projects for the 2018 DigiMuse programme. It will question if the IM selected for this thesis are considered contemporary art or merely a tool in the eyes of the NMS before exploring how they contribute to the more extensive museum's narrative of Singapore's history and cultural heritage.

5.1 Immersive Media: Digital Art or Digital Tool?

Discussing IM as digital contemporary art or a digital tool could be a potentially complex issue, as the binary line between them is blurred when presented in a history museum such as the NMS. When comparing the presentation of artwork in an art museum compared to a history museum, Iman Ismail, then-assistant curator of the NMS, wrote that contemporary art in the NMS functions to "encourage conversations between the past and the present", which allows for re-interpretation of historical narrative from different viewpoints[292].

It can also be argued that some of the selected works geared more toward one direction, such as the *Museum Experiential Guide* classified more as a tool. This smartphone app can be seen as an evolution of *The Companion* device from the SHG in 2006.

Regardless of the IM status as an art or tool, it helps to go back to the NMS exhibition philosophy, where the narrative is the cornerstone. As such, any use of digital media must aid the understanding of an exhibition's narrative that "the object (the museum artefacts), in itself, may not be able to"[293]. In essence, digital technology should make it easier to "deliver information" and to "facilitate access"[294].

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[291] Ibid.
[292] Ismail, Iman. "Chapter 8 – Using Contemporary Art to Relook at History." In (Re)Presenting Histories: Experiences & Perspective from the National Museum of Singapore, edited by Stephanie Yeo, 136-137.
[293] Teo. "Digital Technology And The Museum Experience".
[294] Burris, et al. "Angelita Teo." 86-87.

5.2 Singapore History Gallery (2006-2014)

The IM examples chosen for this period of the SHG are as follows:

- *Singapore 360º* - Karen Kathleen Cai, GSM Design (Glass Rotunda)
- *Sejarah Singapura* - Ho Tzu Nyen, M'Go Films, GSM Design
- *The Building Remembers/Remembering the Building* - Matthew Ngui (outside the SHG)

Singapore 360º

Fig. 39. Singapore 360º, *viewed from below, the photo was taken in 2007.*

Singapore 360º was a 6-minutes film directed by Karen Kathleen and edited by Katrina Koepker[295] (fig. 31a and 39). This work is part of the SHG; as such, it was conceived by GSM Design and produced by GSM Media, with the company engaging the director to create this work. It was screened directly onto the circular wall of levels one and two inside the Glass Rotunda using projectors. It can be viewed either at the level ramp at the Atrium level or from the ground floor below. The Glass Rotunda was also the entrance to the SHG, making it the first work audiences will encounter as they descend from the second floor to the first.

This installation was a passive IM experience which provided audiences with a "dramatic and impressionistic"[296] view of ordinary life in Singapore. It was accompanied by musical

[295] Lenzi. National Museum. 52.
[296] Lenzi. National Museum of Singapore Guide. 52.

excerpts from '*Singapore. A Geopolitical Utopia'* by Russian composer Vladimir Martynov, which Singapore's Ambassador to Russia initially commissioned.

As the first exhibit the audiences experienced in the SHG, it strived for a positive start to the exhibition by dispelling the notion that the NMS was boring and musty by showcasing such a large piece of work, literally engulfing the audiences to experience it. The work also established the tone for the exhibition and communicated that it was made for the general public. The physical act of walking down the spiral staircase in the Glass Rotunda also makes the audiences feel like they are stepping back into the past on a journey to discover Singapore's history.

Sejarah Singapura: Picture of 14th Century Singapore

Fig. 40a. Sejarah Singapura *inside the SHG in 2007.*

Sejarah Singapura: Picture of 14th Century Singapore was a 10-minute 270-degree panoramic audio-visual projection film directed by film artist Ho Tzu Nyen (fig. 40a). Similar to *Singapore 360°*, it was conceived by GSM Design and produced by GSM Media. It was located in the middle of SHG inside an oval-enclosed space. Multiple projectors screened a portion of the film, while seats were placed in the middle so audiences could watch the film from any angle.

The film was filmed with actors in period-appropriate costumes, acting out iconic scenes that hypothesised the founding of Temasek based on the *Sejarah Melayu (*Malay Annals) - a manuscript compiled and amended by the Malaccan court in the 16th century[297]. The

[297] Ibid. 56.

film also included other accounts, such as 14th-century Chinese traveller Wang Dayuan. It has a very theatrical filming style, with the actors properly laid out in the foreground facing the audiences as if it were a theatre play.

Ho's work combines facts and myths to present different interpretations of Singapore's past, shrouded in mystery even today. Before this, he made a video and oil painting installation, *Utama – Every Name in History is I*, in The Substation in 2003. This work examines the Srivijayan prince and founder of the Kingdom of Singapura, Sang Nila Utama. *Sejarah Singapura* can be seen as an expansion and Ho's continued research into the early histories of Singapore.

As a filmic experience, it helped audiences to understand the history and myths behind pre-Raffles Singapore and provided background context in pre-modern Singapore's history. Two copies of the *Sejarah Melayu* Malay Annals artefacts were displayed inside the SHG. Like the *Singapore 360°*, this IM work was also a passive experience, making it easy to accommodate a big group of visitors simultaneously and interest them in the Singapore narrative and the artefacts on which this film is based.

Fig. 40b. *The circular projection at the beginning of* An Old New World *exhibition in 2019.*

This IM experience would later be reworked as part of an ultra-wide screen projection in the 2015 iteration of the SHG. The concept of circular 270-degree video projection to narrate history would later be revisited in 2019's *An Old New World: From the East Indies to the Founding of Singapore, 1600s-1819* (fig. 40b).

The Building Remembers/Remembering the Building

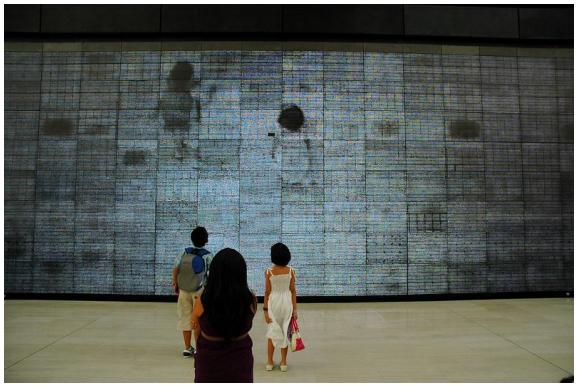
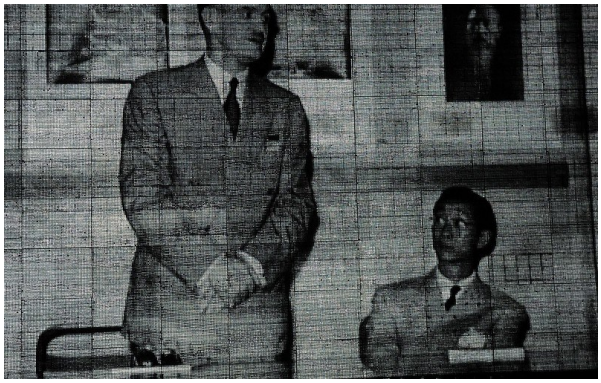

Fig. 41a and b. The Building Remembers/Remembering the Building, *photos taken in 2009.*

The Building Remembers/Remembering the Building was an interactive video installation by multimedia conceptual artist Matthew Ngui (fig 41). The structure was made up of LED panels with embedded acrylic rods and was located on the ground floor of the extension building. It was stationed between the two escalators on the wall, the present-day entrance to the SHG. As noted by Iola Lenzi, this work "is not just about history but also actively documents and creates history"[298].

This work contained three different visual materials screened randomly throughout the day. The first was the projection of archival footage related to the museum in the past, meant to present the museum's story literally. The second was a set of images taken by a camera in a designated space at the Glass Atrium that will be randomly projected later. This work creates an ever-expanding data bank of the museum's history, allowing the work to be "actively involved in transforming present-day reality into history"[299]. The last was a video camera located at the Atrium, live streaming the movement of the museum visitor (but not retaining the video) as they roam around the museum.

This installation evokes the concept of Myron Krueger's 1974 "artificial reality" *VIDEOPLACE* and his series of related digital artwork as the work would "respond", through computerised sensors, to the user rather than the user responding to it.

Ngui's work simplifies the complex idea of "time, history, and the multiple and differing perceptions of reality" that leads to one's understanding of historical 'truth'. And as a work that deals with the history of the museum itself, instead of the national narrative, it showcased the use of contemporary art in a social history museum by making the

[298] Ibid. 36.
[299] Ibid. 37.

museum visitors a part of the building's history[300]. This introduces the meta-narrative of the visitors' place in the museum's history and the larger national history.

5.3 Singapore History Gallery (2015-present)

The IM examples chosen for this period of the SHG are as follows:

- *The Lands Below The Winds* projection – M'Go Films
- *Sejarah Singapura* (excerpts) - Ho Tzu Nyen, M'Go Films
- *Story of the Forest* and the smartphone app - teamLab (Glass Rotunda)

The Lands Below The Wind

Fig. 42. Abraham Ortelius's Map of Southeast Asia *projection.*

The Lands Below The Winds wide-angle projection by M'Go Films is located at the beginning of the SHG (fig. 42), where the text panel for *Abraham Ortelius's Map of Southeast Asia* is located. The work is a large-format video animating a 1570 map of the East Indies by cartographer Abraham Ortelius (fig. 40). Computer graphics are accompanied by realistic seafaring audio of thunder and ocean waves through a sound system above. The caption of this work notes that the map was published half a century after the Magellan-Elcano voyage concluded their first circumnavigation of Earth in 1522. The animation would highlight different locations on the map and inform viewers of the

[300] Ibid.

location's significance. As of mid-2020, when the museum reopened, floor stickers were placed to demark standing areas to facilitate social distancing.

Fig. 43. Abraham Ortelius's Map of Southeast Asia *projection.*

The text panel inside the SHG states:

> *"Abraham Ortelius (1527–1598) was a Flemish cartographer whose Theatrum Orbis Terrarum (Theatre of the World) was regarded as the first modern atlas. In this 1570 map, the Malay Peninsula appears as an elongated extension of mainland Southeast Asia, and Singapore as an appendix, marked "Cincapura", with a cluster of islets. As was common practice for the time, the map also has illustrations of mermaids and imaginary sea creatures."*

This map is one of the many antique maps in the National Museum of Singapore's collection. It predates the establishment of the East India Company (EIC) by thirty years and is inaccurate in many areas as an early attempt to chart the world. As mentioned in the text panel, the map also contains many illustrations of imaginary sea creatures native to the cartographer's culture and myths, exemplifying the seafaring attitude during that era being associated with adventure, exploration, and journeying into the unknown. It is seen as a "milestone map" of Southeast Asia and the East Indies as it embodied seventy years

of cartography knowledge of the 16th century. There are also many editions of this map, making it widely available, primarily through the many versions of Ortelius' *Terrarum*[301].

Much like *Singapore 360°*, this was the first exhibit museum visitors will encounter upon arriving at the SHG. While *Singapore 360°* introduced audiences to a glimpse of modern-day Singaporean life, this animation underlined the pre-Raffles Southeast Asia. This map shows that the SHG was interested in Singapore's history and the island's association with the rest of the region. This historical context was crucial as many of the Temasek-era artefacts point toward a thriving sea trade, meaning that ancient Singapore was not an isolated community but part of a much more extensive global trading network. It was emphasised using the projection and highlighted the prominence of sea charts and maps in many European civilisations.

Much like *Singapore 360°* and *Sejarah Singapura*, this passive filmic experience aims to create relevance between the exhibition narrative and the artefact this multimedia work was referencing. It should be noted that the title of this work, *The Lands Below The Winds,* cannot be found in the SHG but only on the developer M'Go Films' website.

Sejarah Singapura (excerpts)

Fig. 44a (above) and b (below). A Sophisticated Port Settlement *projection, as it appeared in June 2021 (above) and March 2020 (below).*

Sejarah Singapura (excerpts) projection is an ultra-wide-angle projection located near the entrance of the SHG (fig. 44). This IM work is a modified version of the original *Sejarah Singapura*, now presented in a different context. The video loop has been shortened to contain only clips of native villagers in their traditional *kampong* dwellings, and the voice-over narration has been removed.

[301] "Southeast Asia, by Abraham Ortelius. 1584". Sanderus: Antique Maps and Books. https://sanderusmaps.com/our-catalogue/antique-maps/asia/southeast-asia/old-antique-map-of-southeast-asia-by-abraham-ortelius-27046 (accessed 11 July 2021)

This excerpt video is located in the first section of the SHG – 'Singapura'. It is split into three main segments – "Seashores", "River Settlements", and "Sacred Hills"[302]. This section focuses on the indigenous people living in Temasek from the 14th century onwards, highlighted by the artefacts, props, and this projection to recreate a facsimile of 14th-century Temasek. The Orang Laut ("sea people" in Malay) was one of the native communities living in 14th-century Singapore. The exhibition text panels state that the Orang Laut occupied the waters near Longyamen ("dragon's tooth strait" in Mandarin). At the same time, the main settlement was located at the Singapore River, with the royals and elites living in present-day Fort Canning Hill (Bukit Larangan). It was noted in the *Sejarah Melayu* that Temasek was invaded in the late 14th century, with much of the locals chased out, and was subsequently inhabited primarily only by the Orang Laut.

The video showcases different scenes of the people's daily life in their *kampong* ("village" in Malay), with the adults chatting, trading, and working and the children were playing. One scene displayed an open field, while another was within a forested area, both illustrating the people's dwellings and bamboo or rattan baskets filled with sundries such as fruits.

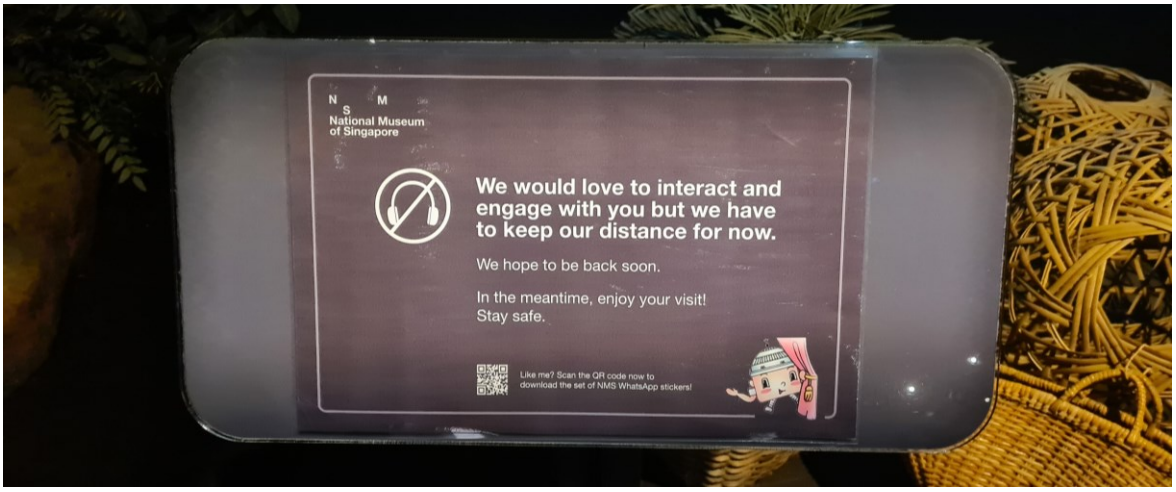

Fig. 45. A Sophisticated Port Settlement *audio station was closed mid-2020 to facilitate social distancing.*

Unlike the 2006 version, this incarnation sees the projection on a flat ultra-wide screen, with the front of the screen decorated with prop bamboo baskets, clay pots, and related artefacts such as coins and ceramic sherds. During the pandemic in 2020 and 2021, the audio-station next to the film projection was disabled (fig. 45). It would have contained audio commentaries by historians Dr John Miksic and Dr Derek Heng describing

[302] Ibid.

Singapura as a trading port in the 14th century. The trading port was associated with the Chinese, Indian, Vietnamese, and Javanese in the Southeast Asian archipelago[303].

As described in the 'Exhibition Narrative and the Theatre-Museum' section in the previous chapter, this projection is only one part of the immersive experience. It was accompanied by artefacts, audio commentaries, props, and other design elements such as spatial and lighting design. The sound of village chatter and simple string instrument playing was also used to complete the experience. Props such as ceramic potteries, bamboo, rattan baskets, and a few artificial wild plants surround the screen.

The use of props creates a diorama effect set against the backdrop of the looping film, calling back techniques used by the 19th century *Rotunda and* incorporating the stagecraft elements from story theatre. This approach allows the museum visitors to be transported back in time among the villagers to be a part of the film. It makes the experience more intimate and ultimately makes learning ancient Singapore history more enjoyable.

Story of the Forest

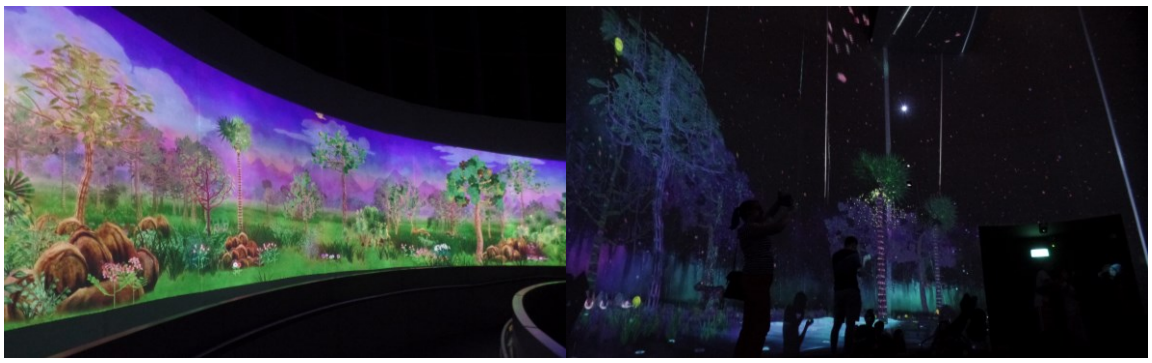

Fig. 46a and b. Story of the Forest *by teamLab.*

Story of the Forest[304] is an immersive digital multimedia installation artwork by digital art collective teamLab that debuted in the revamped Glass Rotunda in December 2016[305] (fig. 46). This installation is inspired by the *William Farquhar Collection of Natural History Drawings. A* portion of the 477 illustrations in the collection can be viewed in the Goh Seng Choo Gallery as part of the rotating exhibit of the whole collection. 69 illustrations were selected to become digital three-dimensional characters in the installation, including both flora and fauna, with the animated backdrop envisioned by teamLab's artists. The

[303] Based on the text panel description describing the audio commentaries before the audio-station was shut down.
[304] A video demonstration of the installation can be found on teamLab's YouTube channel - https://www.youtube.com/watch?v=OMv92DpcgfI&ab_channel=Rila-Channel
[305] Ismail, Fairuz Iman. The Story of the Forest. Roots.sg. Jun 2017. https://www.roots.gov.sg/stories-landing/stories/the-story-of-the-forest/story (accessed 11 July 2021)

installation encompassed the entire Glass Rotunda, from the 15-meter high domed ceiling, a 170-meter passage bridge, and the spiral staircase leading to the basement[306]. It is proposed to contain over fifty projectors from the internal assembly and along the spiral staircase[307]. This installation is also comprised of a (now defunct) smartphone app.

The team was commissioned to work on this installation in 2014 after they had a successful showcase at the Singapore Biennale 2013. They comprise artists, programmers, sound engineers, animators, technologists, and other specialists, making up around three hundred individuals[308].

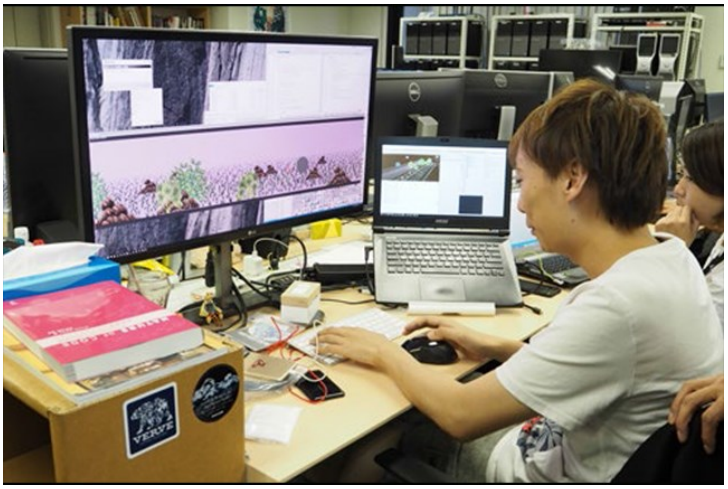

Fig. 47. *A teamLab computer graphics animator was working on the project.*

This installation is an interactive art piece, unlike all other works presented so far. Upon entering the bridge from the Glass Atrium, visitors will be greeted with a dream-like visual of falling flower petals accompanied by serene and calm music.

The spiral passage reveals a stunning continuous panorama of a safari filled with creatures from the natural history drawings collection; as visitors proceed down the passageway, the forest changes daily to night while also taking Singapore's dry and wet seasons into account. This area is also where the visitors can use the optional smartphone app. It blurs the line between augmented reality and augmented virtuality, as the digital creatures exist simultaneously in both the virtual and the physical world via the projection and the visitor's smartphone, where the visitor can snap photos of the virtual creature on the screen for it to be "collected" in the phone. The app also supplies information about the animals collected, such as habitat, diet, and conservation status.

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[306] "Story of the Forest". teamLab.
[307] Ismail. The Story of the Forest.
[308] Ibid.

Specific creatures are also programmed to interact with the audience, some fleeing when approached and others turning their heads to keep looking at the visitors as they walk past them[309].

Walking to the basement, visitors will end up at the base of the bridge they crossed. Attached on the floor are sensors that, when approached, will sprout virtual trees. There is an element of unpredictability as the trees and wildlife that spawn with it is random. The whole artwork uses a unique computer program that reacts in real-time, and the visuals are constantly changing. They can never be replicated, making every visit to the art installation different[310].

One of this work's aims was to ignite interest in the natural history drawings collection by sparking a dialogue between the past and present. This digital artwork reimagined and stylised a forgotten Singapore when it was still bursting with flora and fauna, and the smartphone app provides an additional layer of interactivity and learning. Having the smartphone app was an exciting choice as, much like a museum activity booklet, it offers something fun and hands-on for visitors (especially the younger guests) while personalising their experience. The use of interactivity thus provides better engagement with museum visitors. There was an increased visitorship to the Goh Seng Choo Gallery, likely as more people learned about and compared the installation with the original drawings[311]. It can be argued that this installation successfully applied modern approaches to digital technologies to garner positive results.

5.4 DigiMuse Programme

DigiMuse is an initiative within the NMS that first began in 2017 as a VR showcase and conference on using such technology in a museum. DigiMuse Presents showcase was held from 4th August to 26 August 2018. The IM projects chosen for the 2018 DigiMuse are as follows:

- *Museum Experiential Guide* - DigiMagic & NTU ADM
- *An Excavation Through Time* - iMMERSiVELY

309 Mai, WenYi. "Story of the Forest: An Interactive Exhibition Of William Farquhar's Drawings At The National Museum Of Singapore". Hype and Stuff. 2019.. https://hypeandstuff.com/story-forest-exhibition-singapore/ (accessed 12 July 2021)
310 Ismail. The Story of the Forest.
311 Ibid.

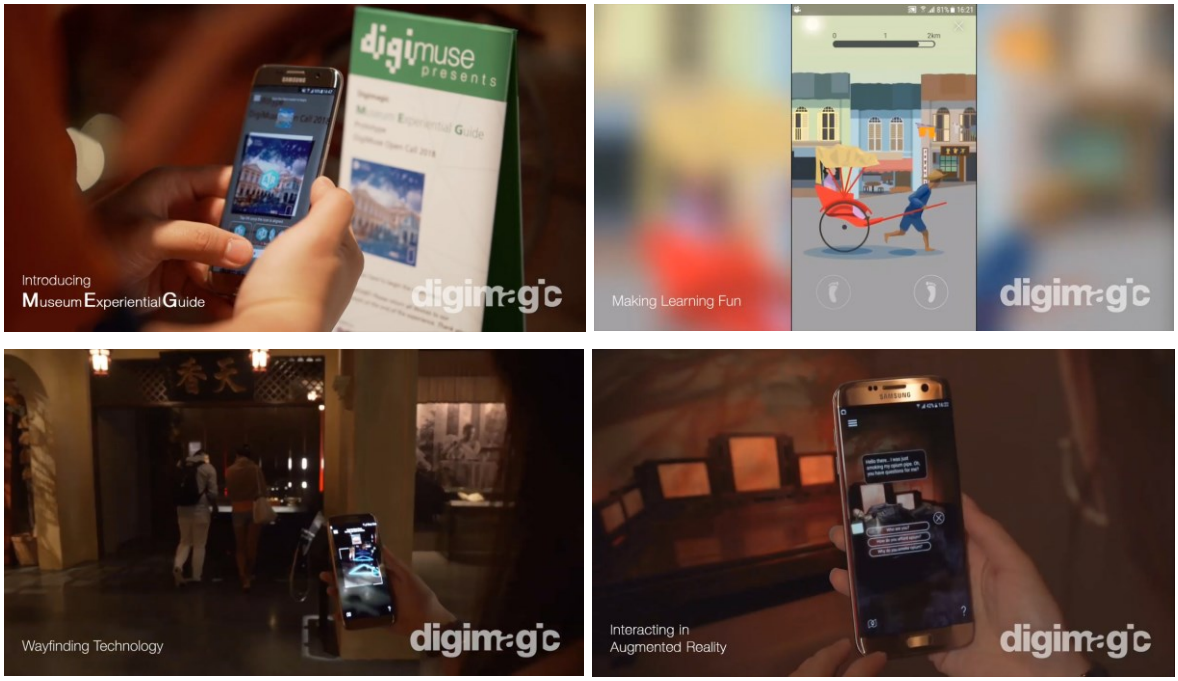

Fig. 48a and b (top), c and d (bottom). The Museum Experiential Guide *by DigiMagic.*

The *Museum Experiential Guide*[312] was an AR-powered digital museum guide smartphone application developed by Digimagic Communications and Dr. Andrea Nanetti from the NTU School of Art, Design and Media (fig. 48). The smartphone app was used inside the SHG during the DigiMuse Presents showcase. According to Donald Lim, the CEO of Digimagic, this smartphone app provides an AR experience, gamification, and a "re-enactment of past incidents", calling it a "mixed reality experience". Their goal was to make the museum-going experience "more immersive, more interactive, and more intelligent"[313], transforming it using "technology and storytelling", and "enhance the interaction of the visitors with the artefact" by "bringing the story to life"[314].

This prototype app was created explicitly for the Crown Colony section of the SHG. By scanning an AR marker (fig. 48a), an image programmed to interact with the app, a holographic AR character named MEG will guide the visitor to the rickshaw artefact beside the marker. By scanning the rickshaw, visitors can play a 2D video game of being a rickshaw rider (fig. 48b). They do this by tapping on the left and right of their phone's

[312] A video demonstration of the app can be found in Digimagic's YouTube channel: https://www.youtube.com/watch?v=wcHA4hfDqi0&t=59s&ab_channel=digimagicians
[313] NationalMuseumSg. "DigiMuse Presents: Museum Experiential Guide". YouTube Video. 1:01, 1 Aug 2018. https://www.youtube.com/watch?v=HRveJ-TkVnU
[314] Michelle Ng (Digimagic – Senior Account Manager) in discussion with author, 14 Oct 2020.

screen alternatively. After the game, the visitors will be presented with facts about rickshaw riders. A Wayfinder then guides the visitors to the opium history section of the gallery (fig. 48c) where a digital 3D model of an opium smoker is superimposed on the opium chair artefact. Visitors can ask questions about this 3D character (fig. 48d). There is also a “Knowledge Tumbler” section in the app used for “knowledge aggregation” that acts like a “mini-Google” that draws relevant information into the app based on what artefact is scanned in the museum[315].

This project seemed to be a test run of layering additional digital technology on top of what was previously done, specifically with the addition of AR, a simple video game, and wayfinding. The NMS is no stranger to using a digital museum guide as they had developed the audio-visual PDA guide known as *The Companion* for the previous iteration of the SHG in 2006. The NMS also has a separate museum smartphone app[316] developed in December 2018 that was discontinued sometime in 2021. The app was replaced by the ‘NMS Dome Bot chatbot’ web application in 2021.

The smartphone app provides an experience that cannot be replicated by passively viewing the exhibits. As evident from case studies in The Museum of Modern Art (MoMA) in New York City, kinaesthetic learners (such as young visitors) benefit the most from physical activity[317].

The rickshaw mini-game is an excellent example of putting the museum visitors into the rickshaw riders' shoes (or lack thereof). While it does not and cannot replicate the hardship the rickshaw riders experienced in the past, the app can still elicit empathy from the visitors and make the experience more meaningful than simply reading a text panel. This app is also an example of the museum’s attempt at “Disneyfiying” the hardship of the rickshaw riders. Similar to the complaints from the 2006 SHG, reducing the suffering and lives of our forefathers to a simple mini-game might aggravate some visitors, especially the older generations. On the flip side, it is also a welcoming first step for younger visitors to learn more about the occupations of their forefathers. Aiding this is the archival video of rickshaw riders stationed near the rickshaw artefact.

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[315] Ibid.
[316] “National Museum of Singapore Mobile App Redesign”. Meet Raph. http://meetraph.com/project/national-museum-of-singapore-app-redesign (accessed 17 July 2021)
[317] McGee, Carrie; and Rosenberg, Francesca. “Art Making as Multisensory Engagement: Case Studies from the Museum of Modern Art”. The Multisensory Museum: Cross-Disciplinary Perspectives on Touch, Sound, Smell, Memory, and Space. Levent, Nina; Pascual-Leone, Alvaro, eds. 2014. Plymouth: Rowman & Littlefield.

The AR opium smoker recalls the concept of interpretive theatre, where a digital copy replaces the actor. One advantage is that the artefact does not get damaged when the 3D model is overlayed on them, and the app developers can get creative with what they can do. This app, unfortunately, limits what could be done compared to an actual person, such as asking them questions outside the scope of what was programmed into them. Regardless, this prototype project does succeed in providing insights into the possibility of technologically extended use of a museum guide and AR opportunity.

It should also be noted that the content and artistic direction, like all media products, should be linked to the target audiences. For example, rich interactivity and catching stylised visuals could entice children, while older audiences could be captivated by more realistic imagery and more mature topics.

An Excavation Through Time

Fig. 49. *A boy trying out* An Excavation Through Time *video game.*

An Excavation Through Time is a VR installation developed by iMMERSiVELY, with the Lionel Chok being the project lead. It was done in partnership with Lim Chen Sian from the Archaeology Unit, ISEAS Yusof Ishak Institute, and the Asian Civilisations Museum. This VR experience was first showcased inside the Singapura section near the entrance.

This VR installation allowed visitors to role-play as an excavator inspired by the local excavation in Empress Place in 1998 and 2015 and the Victoria Concert Hall excavation in 2011. The installation consists of an HTC Vive VR headset wired to a computer running

the software application, dual controllers, base stations, trackers, and a 3-panels projection screen mirroring what the user is looking at inside the headset. It is presented in the first-person view, where the visitor uses the controllers as a proxy for digital archaeology tools to dig up digital 3D renditions of local artefacts.

Fig. 50. First-person view of what the user would see in the headset.

This VR mini-game is divided into a few parts, where the user first needs to separate the soil into cubes before digging it out and dusting it to reveal the artefact (fig. 50). They then put the artefact into a container to complete the task. The interaction is facilitated by the two Vive controllers, with the user picking up the digital tools as they would in real life by physically picking up the controllers and moving them. Optionally, a second player could join in the game by simply picking up a tracker-tagged baton and digging alongside the first player. This second player would look at the screen in front of them instead of viewing it through a VR headset[318].

This VR experience addressed the passive museum experience where the artefacts are all displayed behind glass walls. This experience allows the visitor to "touch" and hold the artefact and look at it up-close, albeit virtually[319]. It was also noted to be a "holistic experience" that "create empathy" towards archaeologist and conservator by putting the

[318] Lionel Chok (iMMERSiVELY Founder) in discussion with author, 22 September 2020.
[319] Viddsee. "Yours Virtually Ep 4: Re-Imagining Exhibition: An Immersive Experience". YouTube Video. 5:17. https://www.youtube.com/watch?v=Ge42YMWWxgQ

visitors in their shoes, using similar tools, and when the visitors are done, they can see the actual artefact that was excavated in the same gallery[320].

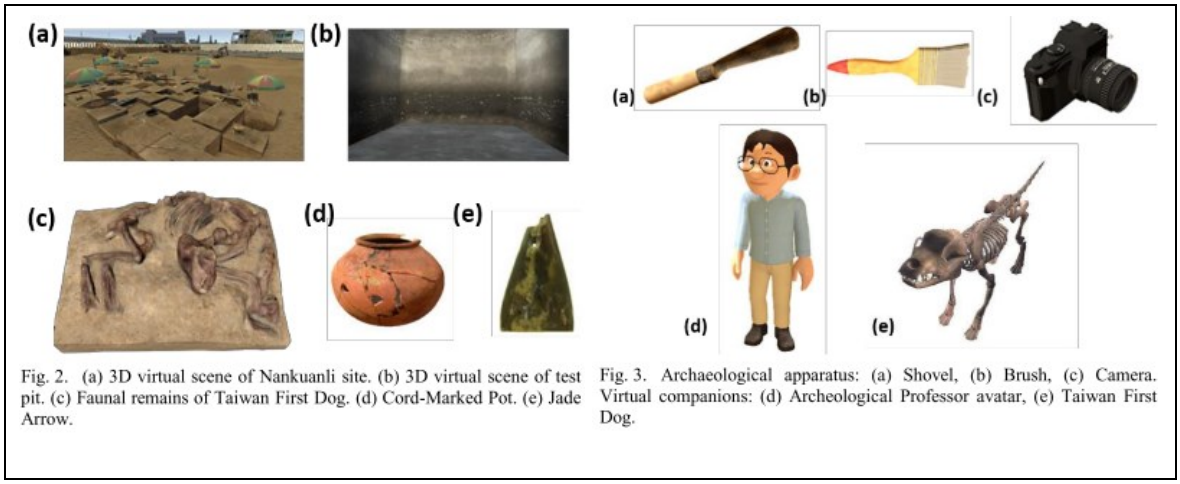

Fig. 2. (a) 3D virtual scene of Nankuanli site. (b) 3D virtual scene of test pit. (c) Faunal remains of Taiwan First Dog. (d) Cord-Marked Pot. (e) Jade Arrow.

Fig. 3. Archaeological apparatus: (a) Shovel, (b) Brush, (c) Camera. Virtual companions: (d) Archeological Professor avatar, (e) Taiwan First Dog.

Fig. 51a and b. Figures extracted from 'Simulating the activity of archaeological excavation in the immersive virtual reality', showing the 3D virtual scene of objects of the project.

Like the previous example, *An Excavation Through Time,* physical activity benefits kinaesthetic learners and makes the museum visit more memorable and meaningful. This VR experience also highlights the importance of local archaeology and conversation about artefacts not usually highlighted in an exhibition. It should be noted that the idea of doing VR excavation is not new. The Tainan National University of the Arts and the National Taiwan University have worked on a similar project in the past[321] (fig. 51). The two universities collaborated to create a VR application that guides users to unearth and excavate relics in a reconstructed virtual archaeological space[322].

[320] Ibid.
[321] Hung, Yi Ping, Tsui Mei Huang, Kuang Ti Li, R. P.C. Janaka Rajapakse, Yang Sheng Chen, Ping Hsuan Han, Iou Shiuan Liu, Hao Cheng Wang, and Da Chung Yi. "Simulating the Activity of Archaeological Excavation in the Immersive Virtual Reality." Proceedings of the 2018 3rd Digital Heritage International Congress, Digital Heritage 2018 - Held Jointly with the 2018 24th International Conference on Virtual Systems and Multimedia, VSMM 2018, no. August 2019 (2018).
[322] Ibid.

CHAPTER 6: ANALYSIS OF THE FINDINGS

This chapter provides a distilled summary of the findings posed by the research questions of this thesis. It will considers the historical context, the museum exhibition philosophy amd strategies, and the chosen examples of IM.

6.1 The Role of Immersive Media in the National Museum of Singapore

> *What can we learn about the National Museum of Singapore's strategy and direction of engaging Singapore's history and heritage by using digital technology and immersive media in the Singapore History Gallery from the first revamp in 2006 and the second revamp in 2015?*

The period between the first revamp in 2006 and the second revamp in 2015 marked a shift in consumers' expectation. According to Angelita Teo, while learning about history, gaining knowledge, and viewing artefacts are the primary motivators for both periods, museum visitors expect a more sophisticated form of presentation than in the past[323]. The paradigm shift runs parallel to the advancement of digital technology and new media from the early-2000s to the 2010s.

Even before the 2006 revamped building was officially opened, the museum (then called Singapore History Museum) was already anticipating the rise of digital technology. This phenomenon was evident in their 1995 *VR: Dawn of a New Reality* exhibition, the largest and most expansive VR exhibition at that time. Even this exhibition was primarily influenced by the local and global advancement of digital media and technology, specifically VR technology. The rapid progress of digital technology overseas prompted the establishment of the NUS-ISS to train IT professionals for Singapore to remain competitive. As a result, the institute's research and development programmes have led to the formation of local VR companies such as *Alliance Multimedia* and *Imagine Interactive*.

When the museum temporarily relocated to Riverside Point in 2003, it had already been experimenting with different forms of media and multi-sensory activities. This experimentation was pushed further when the NMS opened in 2006 with the new SHG, four permanent galleries, and a collection of commissioned digital media artworks.

It was then that the museum began to emphasise storytelling and emotional connection more at the core of its exhibition philosophy, which remained true when the museum

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[323] Teo. "Digital Technology And The Museum Experience".

underwent another revamp in 2015. This way of exhibition design calls to mind the interpretive theatre and story theatre-museum exhibition strategies employed by overseas museums, with its popularity beginning in American open-air museums such as the Skansen Museum[324]. Story theatre (also known as "object theater"), started as an exhibition programme in Canada's Science North museum[325]. Both use elements of theatre, stagecraft and more to create an emotional narrative that makes it more memorable for their museum visitors.

Unfortunately, despite the exhibition philosophy grounded in narrative and emotions, the over-reliance on digital technology seeded the fear that the museum was becoming "Disneyfied" (the simplification of the museum experience in a sanitised manner). Numerous commentaries published in the local newspapers, mainly by the older generations, voiced concerns that the multimedia might have overshadowed the true stars of the museum – the artefacts.

When comparing the IM examples in 2006 and 2015, it can be inferred that extra thoughts and considerations were put into integrating contemporary and digital media in the 2015 iteration of the Singapore narrative that the NMS desired to tell. Although *Singapore 360°* was impressive, it felt out of place as the first exhibit encountered by patrons, while the next presentation was about the 14th and 15th century Temasek[326] caused a disjoint in the flow. In contrast, *The Lands Below The Winds* projection at the *Abraham Ortelius's Map of Southeast Asia* section flows naturally to the Singapore Stone and other 14th to 16th-century artefacts beside the projection. The use of digital media and IM elements was also slightly reduced in the 2015 refresh to bring the focus back to the exhibition narrative and artefacts. The museum curators also reaffirm that technology should play a supporting role and not take the place of what a physical artefact can offer.

When comparing both iterations of the 2006 and 2015 *Sejarah Singapura* projection, the latter has the advantage of allowing the visitors to walk around and immerse themselves using stagecraft elements such as props and mood lighting in 14th-century Temasek rather than just passively viewing a video. The display of relevant artefacts, text panels, and audio stations also provided additional context on the projection's goal.

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[324] Alsford, et al. "Interpretive Theatre"
[325] Bedford. "Storytelling."
[326] Lenzi. National Museum of Singapore Guide. 50-51.

The last two IM examples, although *The Building Remembers/Remembering the Building* and *Story of the Forest* were fundamentally different in terms of concept and execution, both were acknowledged as contemporary art as commissioned by the NMS. The first was a conceptual artwork that dealt with the architectural history of the building itself[327]. At the same time, the latter is an immersive digital installation responding to the *William Farquhar Collection of Natural History Drawings*[328]*.* Their similarity lies in both being a non-passive experiences. While both artworks reacted to the presence of museum visitors, and in *Story of the Forest*, the visitor could respond to the installation using the dedicated smartphone app. This interaction added another layer of engagement that directly ties into learning about the natural history drawings and Singapore's natural history during the colonial period. This was possible as smartphones had become commonplace by the artwork's inception.

Fig. 52a. *The NMS smartphone app, was co-developed by* Cypress Labs Pte Ltd *and released in 2019.*

The use of smartphones draws to mind *The Companion* audio-visual guide from the 2006 iteration of the SHG. The Companion was discontinued in 2015, but elements of it remain in the NMS smartphone app (fig. 52) meant for the general public with varying degrees of proficiency in technology. The NMS app developers focused on simplicity and clarity with responsive design to match the screen sizes of different smartphones.

[327] Ibid. 36.
[328] Ismail. "Chapter 8 – Using Contemporary Art" 136-137.

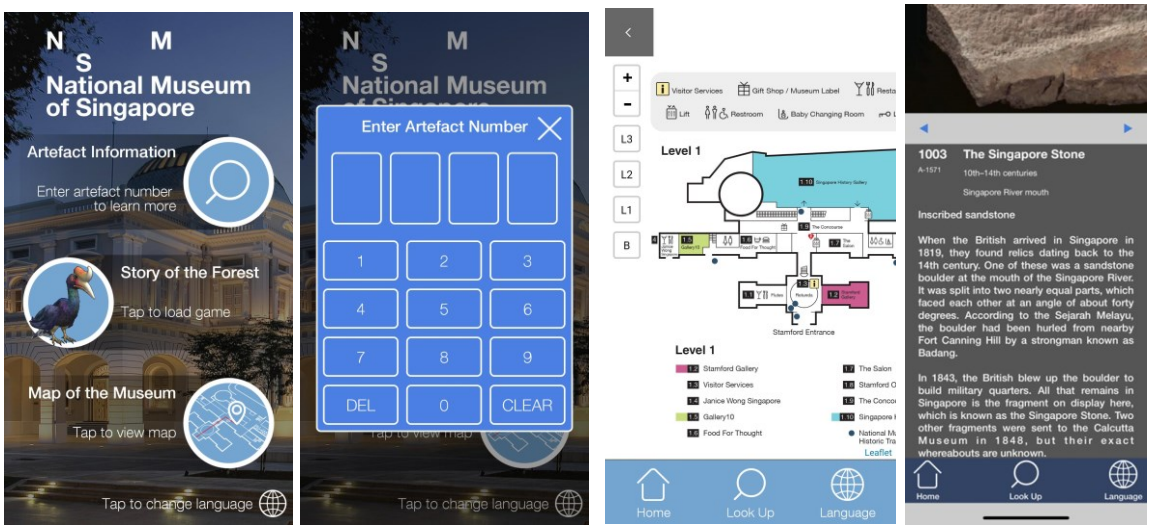

Fig. 52b, c, d, e. *Screenshots of the NMS app.*

This app included translations of the museum artefact in Chinese, Bahasa Melayu and Tamil, the museum map, an AR game based on the Farquhar Collection of Natural History, and an English and Mandarin audio-tour[329]. Eventually, people began to find downloading an additional app bothersome; the NMS shifted to a web-based chatbot. This shift is an example of the technology's evolution within the museum, which adapts to the visitors' lifestyle changes and technological development.

It could be argued that the museum's ambition of having a museum companion never really faded away, even after the criticisms and eventual discontinuation of *The Companion* device in 2015. When personal smartphones gain wide usage, the NMS commissions or partners with various technology companies to create apps that serve different functions in the museum. They include the AR-enabled architectural tour app in 2017, the DigiMuse experimental Museum Experiential Guide app in 2018, and the NMS app in 2019, each with different features in different parts of the building.

As an experience, the museum understood in 2015 revamp that museum visits could be a solo or group experience, which is possibly why companion apps are optional, and text panels were re-inserted. *The Companion* device was pointed out for creating an isolated experience as visitors would need to insert the earpiece to listen to the artefact's description. It was also expensive to maintain, and there were only a limited number of

[329] "National Museum of Singapore". In apkpure, Andriod app archival website. https://apkpure.com/id/national-museum-of-singapore/com.specialistapps.national_museum (accessed 16 July 2022)

devices. Smartphone opens up new and additional ways for visitors to interact with the exhibition, such as a camera to scan, location-tracking, and connection to the Internet.

In summary, there are no significant differences in exhibition strategies employed by the NMS as they have used the artefact-orientated storytelling strategy since 2006. By 2015 the NMS also placed less emphasis on displaying contemporary art in the SHG and instead shifted toward focusing on the main narrative – the history of Singapore. When they did a commission for digital artwork, it was thoughtfully integrated with existing artefacts to create a more substantial connection between using art and learning about Singapore's history[330]. The amount of IM elements was dialled back, and new related catalogues and books were published. All the actions suggest that the NMS desires to make the museum less "Disney" and refocus their efforts on making the exhibition narrative stand out.

This also showed the evolution of digital technology and new media as visitors anticipated a much more immersive and interactive form of engagement to make the museum visits meaningful. These steps are crucial due to visitors' declining attention spans.

6.2 DigiMuse as an Experimental Ground

> *How does DigiMuse, specifically two prototype projects from DigiMuse 2018, fit into the National Museum of Singapore's overall strategy and direction as they were used in the Singapore History Gallery and how do these projects engage in learning about Singapore's history and heritage?*

As mentioned in the previous chapter, the NMS continuously adapts to visitors' shifting demands and lifestyle changes. DigiMuse started bringing together the potential of digital technology in a museum, especially with IM technology such as VR, AR, and MR.

The *Museum Experiential Guide* worked as a proof-of-concept in using AR, gamification, and wayfinding within the established use of a digital museum guide. Developed by Digimagic Communications, in partnership with NTU School of Art, Design and Media, this smartphone app focused on the exhibition narrative by "bringing the story to life"[331]. This approach was in line with the NMS exhibition strategy of focusing on a story around the

[330] Ismail. "Chapter 8."
[331] Michelle Ng (Digimagic – Senior Account Manager) in discussion with author, 14 Oct 2020.

exhibition. This app exemplifies how technology can be incorporated to bring out the exhibition's narrative. But as the technology became more sophisticated, more time and resources were needed to create the digital application.

The *Museum Experiential Guide* attempts to elicit empathy from the users, mainly the hardship faced by the rickshaw workers and the opium addiction that led to a societal decline of the Chinese immigrant community. It was also more engaging than just reading the passive text panel, which leads to better enjoyment and may facilitate better memory of the learning experience[332].

On the other hand, *An Excavation Through Time* focused on the story behind the artefacts excavation, revolving around the excavation projects done in 1998, 2011, and 2015. It was developed by iMMERSiVELY, a VR installation where visitors can role-play as an excavator digging for the artefacts and learning their provenience. It was also strategically located where visitors could view the actual artefacts they had just excavated in the same area, thus promoting learning.

Archaeology and artefact conservation are not usually topics covered by the NMS exhibitions; thus, this installation functions as a complementary work to the exhibition narrative as it highlights the work that went into displaying an artefact. Learning about local archaeology also enhanced one's knowledge of pre-colonial Singapore, especially with the Archaeological Excavation Site at Fort Canning Park, just behind the museum[333].

In addition, future advancements of such IM may contain trackers that allow the developer to monitor the visitors' behaviours. The *Museum Experiential Guide* could have beacons or heat-map trackers to monitor the flow of visitors and examine which aspect of the gallery the visitors spend the most time on[334]. Likewise, eye trackers and other built-in digital trackers in HMD headsets could provide hints on visitors' "habits and motivations" and their preferred content[335]. The data will allow museums to make informed decisions and improve the museum experience accordingly. Unfortunately, this function also tiptoes onto the sensitive aspect of visitors' privacy that the museum needs to address. Museums would likely need to seek permission from the IM user or anonymise the data so that no personal information would be collected.

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[332] Ward, Jamie. "Multisensory Memories: How Richer Experiences facilitate Remembering". The Multisensory Museum: Cross-Disciplinary Perspectives on Touch, Sound, Smell, Memory, and Space. 273-281.
[333] "Archaeological Excavation Site at Fort Canning Park." Roots.sg. https://www.roots.gov.sg/places/places-landing/Places/surveyed-sites/Archaeological-Excavation-Site-at-Fort-Canning-Park (accessed 17 July 2021)
[334] Ng, in discussion with author.
[335] Benjamin Li, in discussion with author, 1 Oct 2020.

These projects showcased the potential of using such digital technology and how leveraging them can help to improve the museum-going experience further. However, it also brings along unique challenges, such as privacy concerns.

6.3 Collaborations and Partnerships

> *What does the National Museum of Singapore's partnership and collaboration with digital technology industries tell us about the museum's attitude in the present-day as compared to pre-2006 revamp period?*

The museum had been working with digital technology industries as early as 1995 with the VR exhibition. It was not the first time the museum partnered with outside organisations, though, as the late-1960s and 1970s saw the museum introducing the *Museum School Service* and the Young People's Art Gallery. The museum worked with local schools to promote science, technology, and art by inviting school groups for exhibition tours and programmes, something the NMS still maintains in the present-day[336].

During the 2006 revamp, contemporary art was incorporated into the museum as it aimed to lift its negative "musty and old" image by commissioning artists to produce artworks that connected to Singapore's history and livened up the place. Some of those artworks unitised IM technology in one way or another. These artworks complement the highly technological setup of the SHG, especially for that time. The museum worked with GSM Media (presently known as GSM Project) to incorporate all these digital media elements.

Like much of Singapore undergoing a technological renovation, the NHB actively pursued digital technology and new media. These include projects like the *Singapore Cultural Resources Online* (SCROL); the *Museum eGuide* – an Internet-enabled PDA used in the SAM, the ACM, "and other museums"; web portals such as yesterday.sg and museums.com.sg[337]; as well as *Museums Collections Management Systems* (MCMS) and *Integrated Museum Display System* (IMDS)[338]. While not directly related to the NMS, it shows that the museum had worked with IT vendors before. They also developed their

[336] "School Programmes". National Museum of Singapore. Last updated 30 June 2021. https://www.nhb.gov.sg/nationalmuseum/our-programmes/programmes-list/school-programmes (accessed 3 August 2021)
[337] National Heritage Board. "Annual Report 2005/2006".
[338] National Heritage Board. "Annual Report 2006/2007".

version of an audio-visual guide and contributed to the museum web portal and the artefact content management system.

Fig. 53. *Gallery10 in 2017 when it first opened.*

The museum continued its emphasis on its IT integration and collaboration from 2015 revamp onwards. They worked with *Singapore Memory Project* for the new interactive map kiosk at the end of the gallery. In 2016, they worked with teamLab to create the *Story of the Forest*. In 2017, the NMS officially opened the *Gallery10* (fig. 53) designed by GSM Project. It was the NMS's first digital-only gallery, where the museum hoped to collaborate with creatives and artists. Afterwards, the NMS partnered with Google and GuidiGo to develop an AR-powered architectural tour. Later in December 2017, the DigiMuse Virtual Reality Showcase showed off over fifteen VR experiences from around the world. It was accompanied by a series of talks and presentations on VR technology and its use in the heritage and cultural sector[339]. The museum would later work with a group of shortlisted companies and individuals on developing projects for DigiMuse 2018.

All these go to show that while the museum is no stranger to working with digital technology and new media companies, it did not actively start to put a considerable focus on them until the museum 2015 revamp. With the annual DigiMuse programme working with locals and the NMS digital offerings such as digital exhibitions, the NMS will likely continue to have good relationships and connections with local and overseas technology companies in the foreseeable future. This symbiotic relationship helps thoughtfully drive the use of digital technology within the museum.

[339] Devi, Reena. “Explore prehistoric sites through VR this December at the National Museum of Singapore.” Yahoo News. 29 November 2017. https://sg.news.yahoo.com/explore-prehistoric-sites-vr-december-national-museum-singapore-093831969.html

6.4 Using Immersive Media in Singapore Museums

How does the National Museum of Singapore's exhibition strategy on using digital technology and immersive media differ from other local museums, and what are some noteworthy milestones of using them in local museum exhibitions?

As this sub-question is very broad, given the large number of museums in Singapore, this section focuses mainly on the ASM and the ACM. It will also briefly talk about the Indian Heritage Centre (IHC).

While incorporating IT and IM in the NMS exhibitions function as supporting roles to the artefacts, they play a different part for the ASM and the ACM.

The ASM is the largest private museum in Singapore and a landmark attraction as part of the Marina Bay Sands Integrated Resort[340]. Situated across the Merlion statue at Bayfront Avenue, they aim to "explore where art, science, culture and technology come together"[341]. The ASM is unique in that it does not have a permanent collection; instead of relying on touring exhibitions, their *Future World: Where Art Meets Science* permanent exhibition and the *VR Gallery*.

The ACM, on the other hand, is an art-historical museum that informs "history through the object", which is a different approach from the NMS, where an object is used to support a historical narrative[342]. Instead of having an exhibition narrative or a storyline, it focuses on the artefact's provenance – its physical characteristics, materials, design, and significance. Much like the NMS, it has its own artefact collection, and they are presented in several permanent galleries. It is located at the Empress Place Building on the north bank of the Singapore River and specialises in China's material and art history and much of Asia.

[340] Zakaria, Faizah bte. "ArtScience Museum". Singapore Infopedia. Last updated 2017. https://eresources.nlb.gov.sg/infopedia/articles/SIP_1816_2011-07-01.html (accessed 21 July)
[341] "About ArtScience Museum". Marina Bay Sands. https://www.marinabaysands.com/museum/about.html (accessed 20 July 2021)
[342] Burris, et al. "Kennie Ting." 23-48.

Fig. 54. *The* Shipwrecked *360-degree virtual tour when viewed on a computer.*

Here is a list of IM milestones in the past decade:

2011

- ASM (with ACM and NHB) *Shipwrecked: Tang Treasures and Monsoon Winds* – online virtual tour
- ACM *Terracotta Warriors: The First Emperor and His Legacy* – online virtual tour and AR app

2015

- ACM App and ACM Tang Shipwreck VR App – interactive app and VR app
- Launch of IHC and the AR-enabled app

2016

- ASM *Future World: Where Art Meets Science* exhibition

2017

- ASM *Into The Wild: An Immersive Virtual Adventure* exhibition – AR app

2019

- ASM *Rewild Our Planet* – AR app

2021

- ACM *thINK* and *Faith Beauty Love Hope* exhibitions; Materials and Design galleries – online virtual tour
- ACM Allie – Virtual Museum Host – online museum guide chatbot
- ACM *Treasures in AR* – web AR
- ASM VR Gallery

In 2011, the ASM presented the *Shipwrecked: Tang Treasures and Monsoon Winds* exhibition, one of the ASM's inaugural exhibitions. In partnership with NHB and Haroko Studio, the exhibition was immortalised as a 360-degree virtual tour using panoramic photography[343]. The collection would later be curated into the *Tang Shipwreck* permanent exhibition at the ACM after this exhibition was over. Haroko Studio would also be the studio that worked on the online virtual tour of the ACM *Terracotta Warriors: The First Emperor and His Legacy* special exhibition later in 2011 and the NMS *An Old New World* exhibition in 2020.

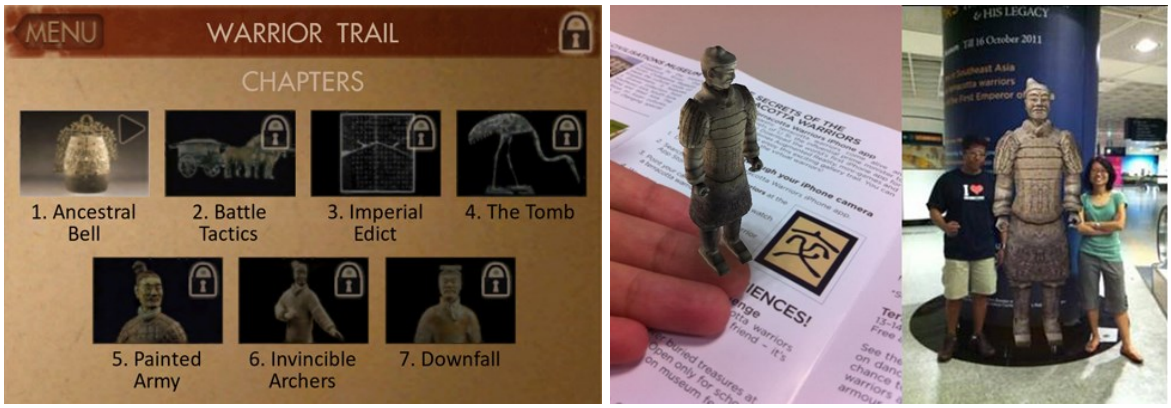

Fig. 55a and b. *Chapter selection screen inside the app (left), and the two promotional AR markers on – one on printed materials such as newspaper and brochures; another on public advertisements (right).*

Besides the virtual tour, the ACM *Terracotta Warriors* exhibition was also accompanied by an iPhone app that combined AR, "location-based gaming", and "interactive features"[344] (fig 55). A noteworthy aspect of the app was the integration of a story chapter system – the app introduced an interactive story called the *Warrior Trail* divided into seven chapters. Promotional material contained an AR marker that unlocked the prologue chapter, with the rest locked until the user unlocks them at specific stations inside the exhibition gallery. This app was an ACM pilot study to understand the implementation of such digital technology within the museum for visitors[345].

[343] "Shipwrecked: Tang Treaures And Monsoon Winds". Haroko Studio. https://www.harokostudio.com/project/shipwrecked-tang-treasures-and-monsoon-winds/ (accessed 2- July 2021)
[344] Thian, Cherry. "Augmented Reality—What Reality Can We Learn From It?" In Museums and the Web. San Diego, 2012. https://www.museumsandtheweb.com/mw2012/papers/augmented_reality_what_reality_can_we_learn_fr.
[345] Ibid.

Fig. 56a and b. *Promotional image of the ACM VR app and what the viewer sees inside (left), with people trying out the Google Cardboard VR headset in the exhibition gallery (right).*

The year 2015 saw the ACM launch mobile and VR-related applications during the first phase of reopening after the revamp. In the *Tang Shipwreck* Gallery, a component featured the Google Cardboard (fig. 56), allowing visitors to use their smartphones with the Google Cardboard Viewer to view the VR app[346]; or they could try it out with a tethered demonstration unit inside the gallery[347]. Besides the ACM VR app, they also unveiled the ACM app with location-enabled capability and additional media content of selected artefacts made up of "self-guided tours, behind-the-scenes views, and interactive maps"[348]. As of 2021, both smartphone apps are obsolete and no longer available.

2015 was also the year that the IHC was opened to the public and was accompanied by an AR-enabled audio guide smartphone app developed by Massive Infinity Pte Ltd[349]. The Indian news channel, *Connected to India*, commented that this was "one of the first museums in Singapore to incorporate technologies such as augmented reality and social media pit-stops in its exhibits"[350]. It is likely referring to the IHC being one of the first Singaporean museums to use AR and social media in its permanent exhibition and not

[346] ACM (Asian Civilisations Museum). 2015. "We are launching our very own ACM VR app!" Facebook. 14 November 2015. https://www.facebook.com/asiancivilisationsmuseum/photos/we-are-launching-our-very-own-acm-vr-app-now-available-for-download-from-the-app/10153472317466749/
[347] Ibid. "ACM Staff Cherry Thian elaborates…" Facebook. 15 November 2015. https://www.facebook.com/asiancivilisationsmuseum/photos/acm-staff-cherry-thian-elaborates-more-on-how-you-can-enjoy-the-tang-shipwreck-i/10153475036816749/
[348] ACM (Asian Civilisations Museum). "Experience Our Asian Civilisations Anew". Media Release. 9 November 2015. https://www.nhb.gov.sg/acm/-/media/acm/document/about-us/media/press-releases/media-release-experience-our-asian-civilisations-anew.pdf
[349] Devi, Reena; Gopal, Nalina. "Indian Heritage Centre". Roots.sg. https://www.roots.gov.sg/stories-landing/stories/indian-heritage-centre-our-community-treasure/story
[350] Iyer, Lakshmy. "Curating a community museum for Indians in Singapore: Nalina Gopal". Connected to India. https://www.connectedtoindia.com/curating-a-community-museum-for-indians-in-singapore-nalina-gopal-7125.html?fbclid=IwAR1JwotZ7mlpFMptv46OYN0THGIlpegnAArEM8-L44EUo8SFAUoyYIzrQG4

just in temporary exhibitions. This is in context to the previous examples mentioned, ACM's *Terracotta Warriors* in 2011 was a temporary exhibition that used AR technology.

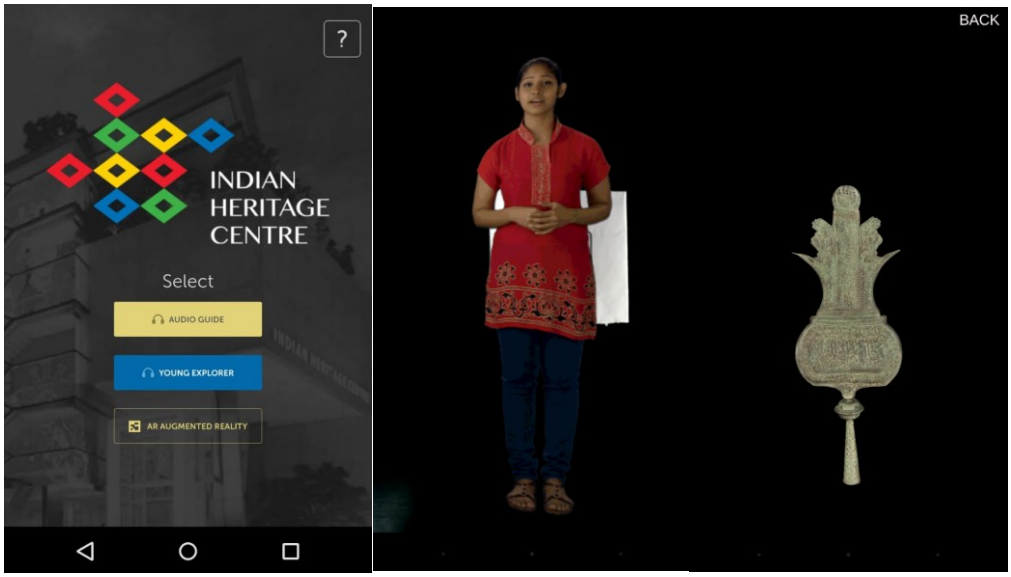

Fig. 57a, b and c. *Screenshot from the IHC gallery app from Goolge Play.*

The IHC galleries are divided into 5 different chronological themes where the "visitors' experiences will gradually shift from material based to digital-based content"[351] as they move through the museum. The museum app (Fig. 57a-c) contains an audio tour guide and an AR scanning function where the visitor can view the artefacts within the app in isolation. In addition to this, the museum also integrated three large interactive devices and over twenty touchscreen kiosks that provided additional content[352].

It is interesting to note how the IHC's media factsheet for its opening refers to the use of IT in the IHC. One is to provide additional content (digital or otherwise) beyond the physical confines of the museum, while the other is to target "younger audiences who appreciate technology based experiences". This seems to suggest that the IHC (and by extension, the NHB, as the IHC operates under the NHB) is shifting towards digitized content and encouraging digital media use within the museum to educate Singapore on its cultural heritage. As a new purpose-built museum, the IHC also had to compete with other museums and attractions. Their strategy appears to be focusing on digital technology to remain relevant and capture the attention of younger Singaporean audiences.

[351] National Heritage Board. "Indian Heritage Centre Media Factsheet", 2015. https://www.nas.gov.sg/archivesonline/data/pdfdoc/20150516001/ihc_and_galleries_factsheet_-_final.pdf (accessed 24 Octo 2022)
[352] "About IHC". Massive Infinity. https://www.massiveinfinity.com/indian-heritage-centre (accessed 24 Oct 2022)

However, the opinion is more divided when it comes to digital technology in the ACM. Dr Alan Chong, the then-ACM director, appeared to embrace the technology, as evident with ACM's *Terracotta Warriors* exhibition in 2011, while his successor Kennie Ting[353] seemed to be more apprehensive, saying in 2019[354]:

> *"We are now exploring different aspects of augmented reality and virtual reality but these are extremely expensive to do well. I would rather direct money towards doing actual exhibitions and acquiring actual objects."*

Ting noted that the ACM had not studied the best approach to using digital content in a museum beyond "spectacularisation" such as a large-scale digital installation built to impress the audiences. And with a limited budget granted to each museum based on how well their key performance indicator was met (usually by physical footfall into the museum), it is understandable Ting will want to focus the money on something more tangible.

In March 2016, the ASM introduced a permanent teamLab gallery. Titled *"Future World: Where Art Meets Science"*[355] – the gallery contained a series of interactive digital artworks comprising multiple zones or areas ranging from a light-based installation to room-scaled interactive projection and playground. The following year, the ASM hosted the *Into the Wild: An Immersive Virtual Adventure* exhibition until 2019[356]. It was an AR and cinematic experience in partnership with Google, Lenovo, and WWF. They are joined by Panasonic, Qualcommm, MediaMonks, and Brian Gothong Tan.

At the museum's basement, visitors use the Tango-enabled phone to scan for virtual animals, learn of their dangers through deforestation, and have a chance to plant a virtual tree. They were then encouraged to make a pledge with WWF, that a real tree would be planted in Rimbang Baling, Indonesia, on their behalf[357].

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[353] Kinnie Ting took over as director of the ACM in September 2016.
[354] Burris, et al. "Kennie Ting." 27.
[355] "Future World: Where Art Meets Science". teamLab. N.d. https://www.teamlab.art/e/artsciencemuseum/ (accessed 23 July 2021)
[356] "Into the Wild: An Immersive Virtual Adventure". Marina Bay Sands Singapore. https://www.marinabaysands.com/museum/exhibition-archive/into-the-wild.html (accessed 29 July 2021)
[357] Ibid.

Fig. 57d. *The stage is a giant AR marker for the smartphone to display the AR images.*

Jumping to 2019, the ASM hosted the *Rewild Our Planet* temporary exhibition (fig. 57d), a "persistent augmented reality (AR) social experience" that brought visitors "to the last wilderness landscape on Earth"[358]. It was a collaboration between the WWF, Google, Netflix, and the ASM, with the app developed by ARUP and Australian IM studio PHORIA. This interactive exhibition used "acoustics, visual projections, theatre staging, smartphones, and advanced AR technology"[359].

The exhibition's goal was to imbue empathy and compassion for planet Earth by letting visitors work together to "clean up" or "rewild" one of the four available biomes, selected through "spatial voting" by physically standing on the zone corresponding to each biome. As the visitors cleared the space, virtual flora and fauna would start to repopulate the area. At the end of the experience, visitors could make a pledge that would persist over time.

Moving forward to the present day in 2021, perhaps spurred by the social distancing restrictions on museums due to the pandemic, the ACM pushed for digital and online applications. They have launched a series of online interactive virtual tours using Matterport's 3D spatial capture developed by Vthere, a Singapore-based spatial scanning company.

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[358] "Rewild Our Planet". WWF. https://rewild.wwf.sg/ (accessed 22 July 2021)
[359] "Designers create inspiring social AR experience 'REWILD Our Planet'". ARUP. https://www.arup.com/projects/rewild-our-planet (accessed 22 July 2021)

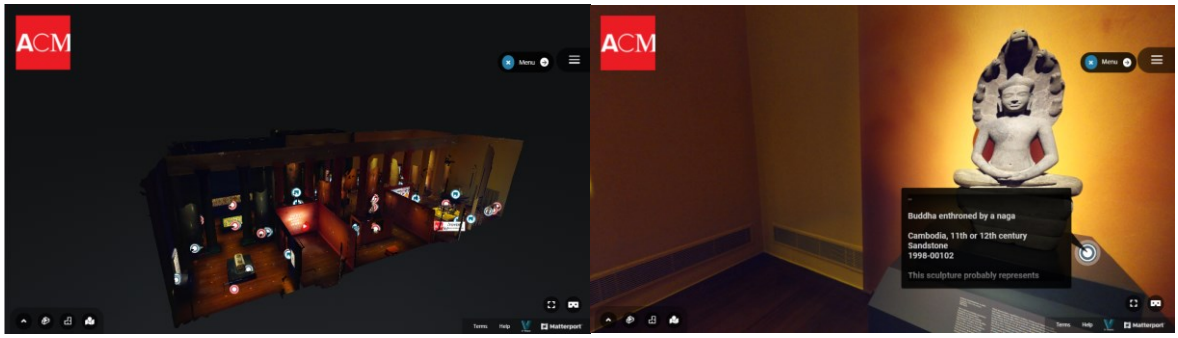

Fig. 58a and b. *Screenshot of the virtual tour seen as a 3D floor plan allowing the user to rotate the virtual gallery architecture (left), view of looking at the artefact with a toggle to display the description text box (right).*

As of December 2021, the ACM had released five virtual exhibitions. They are viewable on both a web browser-compatible device (such as laptop and smartphone) and VR headsets (fig. 58). These exhibitions are the *thINK: Chinese Calligraphy, Connoisseurship, and Collecting*[360] and *Faith Beauty Love Hope: Into 2021*[361] temporary exhibitions and three permanent galleries under the *Materials and Design* heading[362]. *Materials and Design* comprised the *Fashion and Textile* Gallery, the *Jewellery* Gallery, and the *Ceramics* gallery. Besides that, they also implemented a web-based museum guide chatbot named *Allie – Virtual Museum Host*[363]. Like the NMS Dome Bot chatbot, it has functions such as self-guided tours and pre-recorded audio explanations. It replaced the ACM app and does not require museum visitors to download any additional app. In addition, the ACM chatbot was integrated into some virtual tours, allowing users to chat with Allie while navigating the virtual gallery quickly (fig. 58).

[360] "thINK: Chinese Calligraphy, Connoisseurship, and Collecting". Asian Civilisations Museum. https://www.nhb.gov.sg/acm/whats-on/exhibitions/think (accessed 23 July 2021)
[361] "Faith Beauty Love Hope - Into 2021". Asian Civilisations Museum. https://www.nhb.gov.sg/acm/whats-on/exhibitions/faith-beauty-love-hope-2021 (accessed 23 July 2021)
[362] "Virtual Tour of Materials and Design". Asian Civilisations Museum. https://www.nhb.gov.sg/acm/whats-on/tours/virtual-tour-of-materials-and-design (accessed 23 July 2021)
[363] "Allie - ACM's Virtual Museum Host". Asian Civilisations Museum. https://www.nhb.gov.sg/acm/whats-on/tours/allie (accessed 23 July 2021)

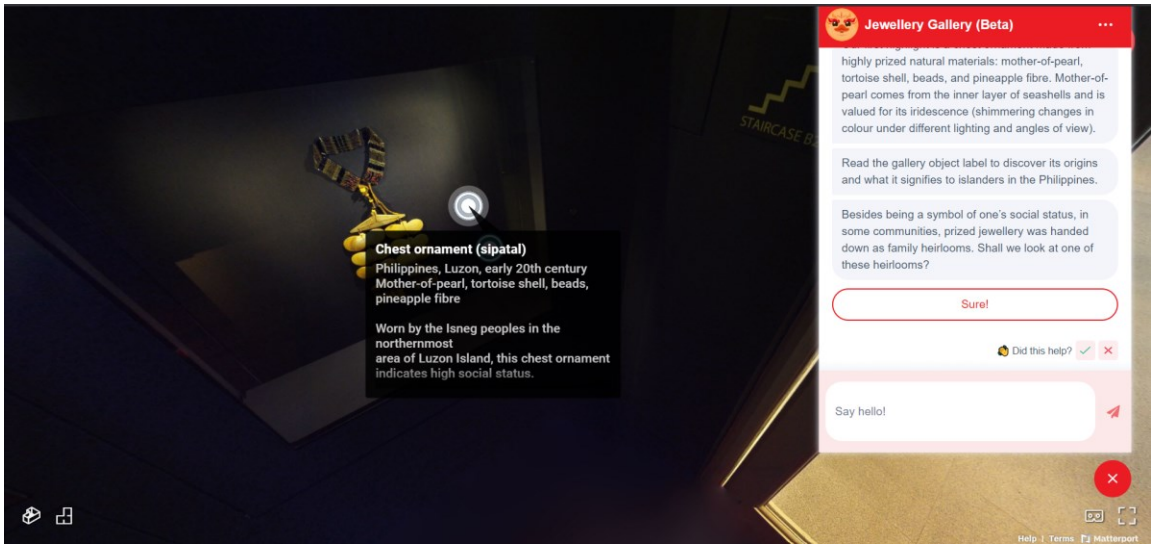

Fig. 59. *Screenshot of the online guided tour integrated with Allie. The chatbot programme will automatically bring the user to the next artefact and explain their significance.*

In addition to the virtual tours and chatbot, the ACM also explored using the web-based application developed by iMMERSiVELY. Titled *ACM Treasures in AR,* this group of artefacts was selected to represent the best of Asian "cross-cultural masterworks" that honoured "the region's rich artistic heritage and achievements"[364]. The web AR experience was accessible through the artefacts' webpage and allowed users to zoom and rotate the virtual 3D model replica of the artefacts on smart devices.

These examples demonstrate that while Ting preferred to allocate resources to physical exhibitions and acquisitions, the pandemic situation could have convinced the ACM to pivot toward more digital offerings from the museum to stay connected and relevant with the public during this period.

[364] "ACM Treasures in AR". Asian Civilisations Museum. https://www.nhb.gov.sg/acm/whats-on/tours/acm-treasures-in-ar (accessed 23 July 2021)

Fig. 60. *Visitors using the VR equipment in the ASM VR Gallery.*

Conversely, unlike the ACM, which had increased its digital and online offerings, the ASM instead opened a new physical, digital art space – the VR Gallery (fig. 60) as part of its 10th-anniversary programme[365] in July 2021. It should be noted that the ASM did create a series of YouTube tour videos of their exhibitions to engage their audience during Singapore's 'Circuit Breaker' period (April to June 2020), when museums were forced to close. The first set of VR artworks is titled *Hyperrealities*, featuring works from artists Olafur Eliasson, Marina Abramović, and Anish Kapoor. In this experience, the visitor dons the HTC Vive Cosmos headset while seated in a rotatable chair and navigates the experience using the provided controllers.

Even though the ASM exhibitions and programming typically lean towards digital technology, having an on-site AR/VR experience through the *Into the Wild* and the *Rewild Our Planet* exhibitions, as well as the launch of the VR Gallery during a pandemic, seemed to suggest that the on-site physical experience remains a core part of their exhibition experience.

[365] Maybeline. "#TheWeekendList: 9-11 July 2021". Weekender. https://weekender.com.sg/w/do/9-11-july-2021/ (accessed 23 July 2021)

While the ACM also values physical space and artefacts, it also provides online-only digital offerings as a substitute for the physical museum experience. This attitude is evident through the online virtual tours and the AR experience, *ACM Treasures in AR*, which do not require the user to be physically present in the museum.

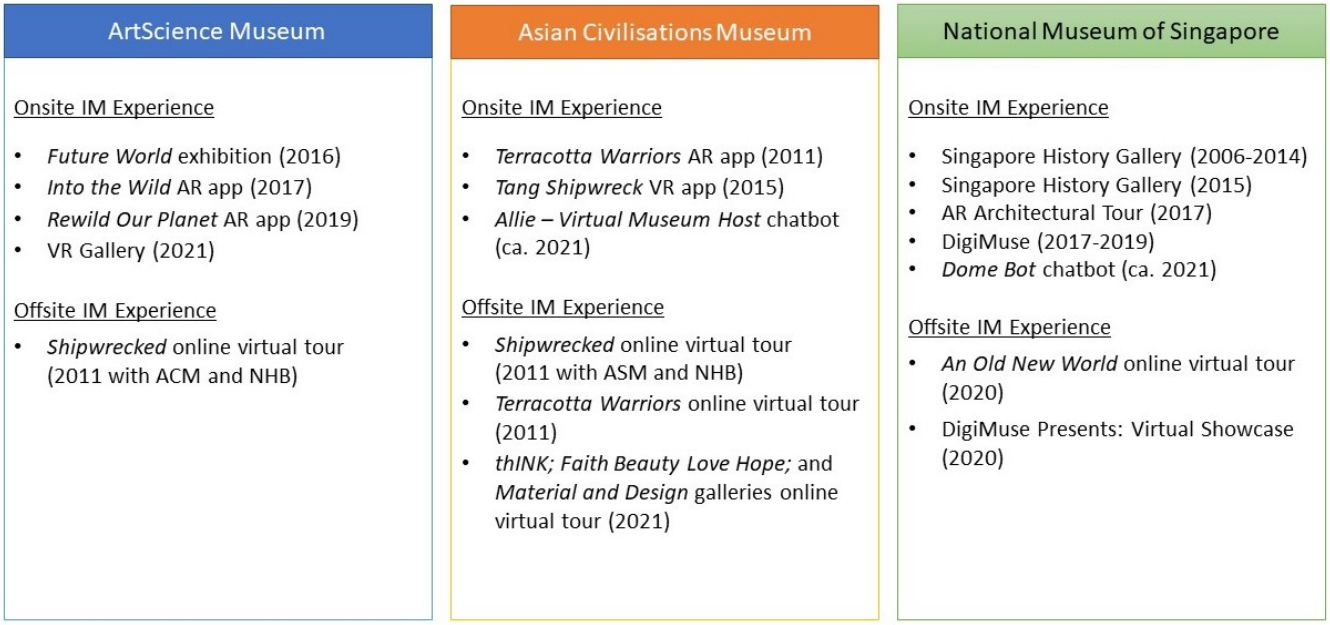

Fig. 61. *Comparing the onsite and offsite IM experiences in the three museums.*

The IHC, as a new and purpose built museum, suggested that digitized contents are the future of Singapore's museology. While both the ASM and the ACM believe in using digital and IM technologies, albeit using different strategies, the ASM focuses heavily on the physical space. At the same time, ACM moved towards online space during the pandemic. The NMS is similar to the ACM in using online experiences with *An Old New World: Digital Edition* virtual tour and DigiMuse virtual showcase in 2020 to highlight novel ways of incorporating digital offerings to further engage with their audiences. The NMS, as a social history museum, differs from the ACM, with their artefacts being used to support a historical narrative rather than looking into the artefacts' history.

CHAPTER 7: BEST PRACTICES OF USING IMMERSIVE MEDIA IN THE MUSEUM

This penultimate chapter looks at how we can utilise the information gathered so far to enable exhibition planners, particularly the NMS, to make informed decisions when they wish to include IM in their exhibitions and programming. It first summarises the ways to frame the best practices before delving into prioritising story and audience experience before choosing the most suitable IM technology for the task. It then examines some challenges of implementing the IM in a museum context before closing off with the short- and long-term aspects of using those IM technologies.

7.1 Framework for Best Practices

According to media researcher Maggie B. Stogner, the emergence of new technologies is reshaping the concept of a museum and the visitors' experience[366]. She noted that the paradigm shift was mainly due to the museums becoming more user-centric.

Fig. 62. *Diagram summarising how new technology is reshaping museums, based on Stogner's explanation. Highlighted in red are areas most related to IM.*

The diagram was created as a result of the author's research, summarises how new technologies are changing how museums are experienced (fig. 62). The research

[366] Stogner, Maggie Burnette. "The Media-Enhanced Museum Experience: Debating the Use of Media Technology in Cultural Exhibitions." Curator: The Museum Journal 52, no. 4 (2009): 385–97.

outcome notes that there are two distinct forms of the museum experience. First is the onsite media-enhanced experience, followed by the offsite media-driven experience, allowing visitors to act as their own "curators, docents, and artists"[367]. This behaviour is consistent with what the NMS did in 2006, and 2015 revamps concerning their digital strategy.

Of particular interest to this thesis is the visitor wanting to be entertained and wanting to create something. The NMS has demonstrated that they can produce multi-sensory exhibition experiences using historical narrative in their exhibition, employing tools such as props, lighting, sound, and specific IM technology such as panoramic projection.

Fig. 63. teamLab's Sketch Town *allows visitors to draw their artwork on a piece of paper that will appear on the projection wall when scanned.*

In the case of creating, the SHG used to contain the interactive map kiosk (during the pre-pandemic period) that was linked with the *Singapore Memory Project* database. The visitors can view the memories they wrote during the exhibition on a web browser. The ASM and the ACM also incorporated the creation aspects in their exhibitions. For example, in the ASM, the *Future World* exhibition allowed for user-generated content in the *Sketch Town* installation (fig. 63) and *Create! Hopscotch for Geniuses* installation[368]. The ACM, on the other hand, focused on the offsite continuation of their exhibition, with the *Faith Beauty Love Hope - Into 2021* exhibition webpage featuring a "social wall" where visitors can select their favourite artefact and explain why. Their response would then appear on the wall for everyone else on the Internet to see[369].

[367] Ibid.
[368] "Future World". teamLab.
[369] "Faith". ACM.

Stogner also suggested a framework that best manages visitors' "perceptions, expectations, desires, and demands". It ensures the best use of new media and technology to "enhance and educate", creating proper authentic cultural context and adding entertainment without reducing the cultural and educational experience.

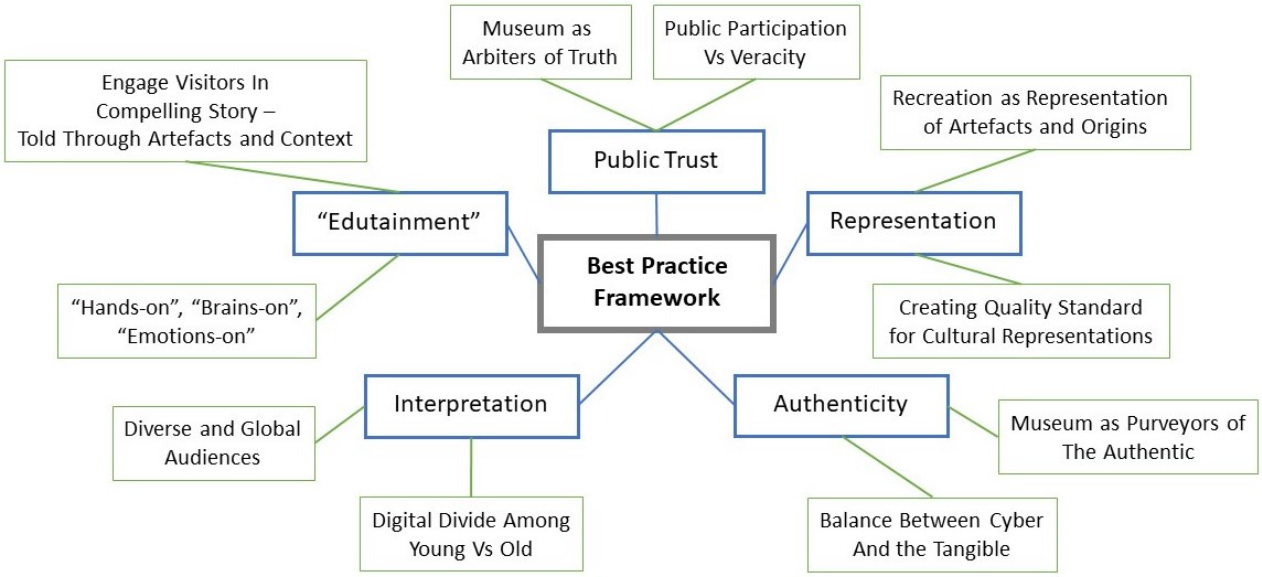

Fig. 64. *Diagram summarising the best practice framework, based on Stogner's explanation.*

The diagram, also created by the author as one of the thesis research outcomes, shows five different aspects museums should note when using new media and technologies. They are presented as inter-connected guiding questions the museum must ask themselves before committing to using them. They are broadly split into Public Trust; Representation; Authenticity; Interpretation; and Education verse Entertainment ("Edutainment").

In summary, the museums are seen as the authority in facts, truth, and everything they say and present is authentic. The digital offerings by the museum must also be of the same high-quality standard as their offline exhibitions and programming as they represent their respective artefact or intangible culture. Moreover, one should not overwhelm the others with a delicate balance between the use of the digital and physical.

Museums should also take note of the digital divide, as not everyone is digitally-literate. Similar concerns also extend to non-local audiences with different ways of interpreting digital information. While digital technology can be exploited to attract visitors to the museum, care should be taken to design and properly integrate them with more traditional

methods, using their varied and overlapping capabilities to meet the demands of different museum visitors[370]. Lastly, the two levels of learning engagement are noted by Stogner – physical activity ("hands-on") as the first step in learning, with multisensory media enriching the learning experience ("brains-on"). It is also suggested to add an additional layer - to appeal to the audience's emotions through a "sensory-stimulating, immersive environment" to create a personal connection with the artefact as the new frontier of learning ("emotions-on").

Studies have shown that technology should be "easy to use" and "provide an interactive experience"[371] regarding the impact of interactive technology on learning in museums. Integrating multi-sensory information are also better for learning than simply relying on a single sense (such as depending on just reading alone), provided that this information does not contradict each other[372]. Chris Lee, Chief Marketing Officer of the National Gallery Singapore, has a motto of the "3 S" when using digital technology – 'Keep it Simple'; 'Keep it Short'; and 'Don't Supersize the Technology'[373].

Many of these are exemplified by museums featured in this thesis. The NMS begins with an exhibition narrative with the artefacts as the focal point, adding multisensory media to aid engagement and learning. As public institutions, the NMS and the ACM cater to people from all levels of society. This position can be leveraged as a common ground for civic discourse and shared experiences[374]; thus, the digital offerings must similarly be designed with the general public in mind. *An Excavation Through Time* achieved this by simplifying the control scheme and making it intuitive with physical actions such that children and older adults would not find it too difficult to operate[375].

7.2 Focus on the Story and Audiences First, Technology Later

As mentioned earlier, digital technology is a museology tool, one of many that should not overshadow the core experience for museum visitors. The focus should be on the exhibition narrative and the audience experience first.

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[370] Recupero, Annamaria, Alessandra Talamo, Stefano Triberti, and Camilla Modesti. "Bridging Museum Mission to Visitors' Experience: Activity, Meanings, Interactions, Technology." Frontiers in Psychology 10, no. September (2019): 1–10.
[371] Pallud, Jessie. "Impact of Interactive Technologies on Stimulating Learning Experiences in a Museum." Information and Management 54, no. 4 (2017): 465–78.
[372] Levent, Nina, and Alvaro Pascual-Leone. The Multisensory Museum: Cross-Disciplinary Perspectives on Touch, Sound, Smell, Memory, and Space. Plymouth: Rowman & Littlefield, 2014.
[373] Viddsee. "Yours Virtually Ep 1: Arts And Culture In The Digital Age". YouTube Video. 5:50. https://www.youtube.com/watch?v=X2Q8l7BGR0o&list=WL
[374] Center for the Future of Museums. "Museums & Society 2034: Trends And Potential Futures," 2008. https://www.aam-us.org/wp-content/uploads/2017/12/Museums-Society-2034-Trends-and-Potential-Futures.pdf.
[375] Lionel Chok (iMMERSiVELY Founder) in discussion with author, 22 September 2020.

Tan Boon Hui, then-NHB Assistant Chief Executive (Museums and Programmes), commented on the future of the NMS before 2015 revamp that more technologies will be used in the museum to facilitate the NMS storytelling approach[376]. He also emphasised that the actual physical artefacts are surprisingly becoming more critical despite the digitalisation efforts of the museum. This emphasis could be due to visitors wanting to see the "real thing" and experience something only the physical museum can. Regarding the need to create a personal connection, Tan noted that the museums are shifting from "telling how things happened, to how people make things happen". He adds the need to capture the richness of human life and experiences, making the story and artefacts more authentic, compelling, intimate, and resonating well with the visitors[377].

This example is exemplified in the NMS level 2 *Life in Singapore* galleries' concentration on the "people's stories and their experiences of key moments or periods in Singapore's history" as the NMS slowly becomes a social history museum and a people's museum.

When it comes to introducing digital technology, including IM, it must be done after much careful consideration. The institution should clearly understand what it is trying to achieve before implementing them. As explained by Dr Kelly McErlean on the topic of interactive storytelling, he noted that "storytelling 'skills' must be fused with a solid knowledge of the technology", with an example of understanding the limits of using VR and what it can be used for[378]. That means selecting the most suitable IM for the role required. Some questions to ask can include:

- Why choose this particular IM?
- How does this IM alter and enhance the exhibition and visitors' experience?
- What can this IM offer that other traditional media (e.g. static text or video) doesn't?
- Who are the specialists capable of implementing this IM?
- What resources are required to implement this IM?
- What are the potential benefits and challenges of implementing this IM?

In the next section, we will go over some general challenges of implementing IM and possible solutions in reducing them.

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[376] Chew, David. "The Future of Our Museums." MuseSG 8, no. 3 (2015): 22–27. https://www.roots.gov.sg/resources-landing/publications/education-and-community-outreach/muse-sg-vol-8-issue-2.
[377] Ibid.
[378] McErlean, Kelly. Interactive Narratives and Transmedia Storytelling. Interactive Narratives and Transmedia Storytelling. First. New York: Routledge, 2018.

7.3 Challenges of Implementing IM in the Museum

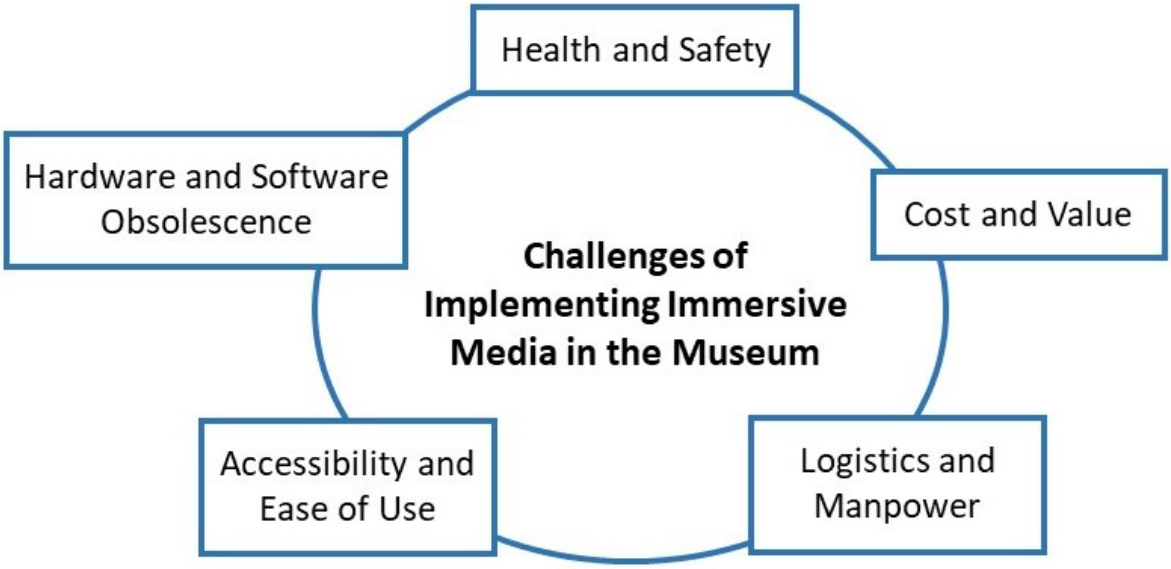

Fig. 65. *Diagram showing the challenges of implementing IM in a museum.*

In 2000, after the *VR: Dawn of a New Reality* exhibition in 1995, Lim Siam Kim, the then-CEO of the NHB, reflected that VR technology was still in its infancy and the educational value was "not high". He felt that VR served more as a "crowd-drawing gimmick" than being an integral part of the museum, concluding that "there may be cheaper, more enduring and perhaps equally effective ways of making a museum visit more engaging and experiential"[379].

Indeed, VR and other related technologies still face numerous challenges in their implementation. The diagram (fig. 65), as created by the author as part of the research outcomes, highlights five different aspects that the museum would need to overcome.

[379] Kim. "National Heritage Board, Singapore."

Health and Safety

This section pertains mainly to IM that requires an HMD-based system such as VR or MR headset (e.g., Oculus Quest, Microsoft HoloLens). Some common issues for HMD are motion sickness, eye strain, seizures, physical fatigue, injury, and hygiene[380].

A common explanation for motion sickness would be sensory conflict when there is a mismatch in the cues received by the brain. An example could be a conflict in the visual and auditory cues that do not match up due to latency issues (e.g., lag). This issue can be reduced by using higher-end hardware as well as optimising the software files such that they will run more smoothly. Movement should be done via "teleportation" or from physical movements instead of using thumb stick controls, as there will be a conflict of the users seeing themselves moving, but their physical legs are stationary.

Prolonged use of the HMD headset may also cause eye strain, nausea, dizziness, and other adverse effects. While HMD headset has reduced in weight over the years, it is still a possible problem as most headsets are front-heavy, creating an unbalanced centre of mass that may strain the neck. The headset should also be a good fit for the user's head – if it is too loose, the headset may drop, and if it is too tight, it may be uncomfortable and cause a headache. It is therefore recommended to keep the session short, and the museum staff should be aware and ask the user if the user is comfortable before and during the session.

Care should also be taken when movements of the hands and arms or other body parts are required for interactions, as the user might accidentally injure themselves by falling or hitting something. Adequate space should be considered and situated apart from other objects, especially electrical wires, cables, computers, projectors, or museum displays[381].

Children, particularly young children, should avoid using VR or MR headsets as it may affect their developing eyesight and vision. Most headsets are also not designed with children in mind, where the headset's weight might cause upper-body injury. As of now, there is no industry-wide standard age limit for headsets, and different headset manufacturers have various age restrictions[382].

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[380] Jerald, Jason. The VR Book: Human-Centered Design for Virtual Reality. Edited by M. Tamer Özsu. First. Association for Computing Machinery and Morgan & Claypool Publishers, 2016.
[381] Ibid..
[382] "Should You Send Your Kids for Virtual Reality Gaming?" Mirage VR. Accessed 14 August 2022. https://miragevr.ca/should-you-send-your-kids-for-virtual-reality-gaming?#:~:text=The%20minimum%20age%20limitation%20for,warns%20its%20use%20for%20children.

Fig. 66. *Disposable face cover for VR headsets.*

The pandemic has highlighted the need for additional hygiene protocols. As many people will use the headsets and controllers, cleaning them after every use is essential. The museum can also provide each user with a disposable mask cover (fig. 66) and easy access to hand sanitiser as an added protection.

Cost and Value

As the cost of implementing IM (or any advanced digital technology) is still relatively high, the monetary cost should be weighed against the value it brings to the museum. The museum should ask itself why it would like to introduce this IM to the museum, how it can contribute to the exhibition narrative or museum experience, and if there is another cost-effective way of doing them.

While IM may draw crowds, it should not be done for the spectacle alone. A successful application of this is the Story of the Forest. It is linked to the *William Farquhar Collection of Natural History Drawings* and has increased visitorship to the Goh Seng Choo Gallery and contributed to learning about Singapore's natural history.

Consultation with the commissioned party on the cost, timeline, and deliverable is recommended, with the objectives of the project clearly outlined to create a common ground, dispel confusion, and make proper use of the allocated resources.

Logistics and Manpower

In terms of installation, different types of IM have distinct technical requirements. For example, in the *Museum Experiential Guide*, beacons to triangulate and map the physical space into virtual spaces need to be installed on the gallery's ceiling. AR markers such as a stand or floor stickers must be installed with adequate lighting as AR does not work well in a dim environment[383]. Instruction for installing the AR app should be simple and straightforward, and the barrier of entry can be lowered further with the use of a web AR application or loaning an AR-enabled device without needing to download any app.

Lionel Chok observed that digital installation hardware was usually required to run throughout operating hours[384]. Thus, it is vital that the hardware can handle prolonged usage, or multiple sets of the equipment should be made available.

For VR installation, manpower should be employed to assist the visitor. The station guide should ideally be able to handle crowds and people of all ages and explain the instructions clearly and easily. Floor markers should be placed to instruct visitors on where to move or stand.

On the development side, Jervais Choo mentioned a lack of local expertise in IM technology. Giant technology corporations such as Microsoft and Google do not have a VR/AR/MR branch in Singapore, making it slightly more challenging to commission projects that deal with IM[385]. This problem can be mitigated by leveraging existing local small and medium-sized enterprises (SME) that develop interactive multimedia projects and forming additional partnerships with more than one company per assignment[386]. Doing so also has the added benefit of providing a stage to showcase the abilities of Singapore’s IT industry in the museum.

[383] Ng, in discussion with author.
[384] Chok, in discussion with author.
[385] Jervais Choo (DigiMuse) in discussion with author, 14 Oct 2021.
[386] Ng, in discussion with author.

Accessibility and Ease-of-Use

Unless the IM technology or installation is specifically targeted at a certain societal segment or group of people, they should be designed for mass consumption while following the guideline of keeping things simple and easy to use.

DigiMagic's Michelle Ng noted that digital technology should not alienate but enable and enhance the museum-going experience, regardless of the person's physical or mental ability[387]. An example could be an image-recognition smartphone app that alerts visitors of the artefact they are pointing at and reads out the text description.

Regardless, it may be near impossible to create an experience that could cater to everyone in society. However, the effort should still be taken to ensure that a broad population can experience the media in at least one way or another. The Building and Construction Authority also has a Universal Design guideline that media practitioners can reference[388]. As coined by architect Ronald L. Mace, Universal Design refers to the design of a physical environment accessible to everyone, regardless of age, disability, or other factors[389].

Hardware / Software Obsolescence

With digital technology development becoming more rapid in recent years, it became easy for hardware and software to become obsolete very early. An example is the Oculus Go VR headset, which was discontinued just two years after its release. It was replaced by the more powerful and versatile Oculus Quest[390]. Similarly, hardware like the Samsung Gear 360 camera stopped receiving software support after 2 years. There is no official support for the newer Samsung smartphone, and the image stitching software is no longer downloadable.

Hardware and software will eventually become outdated and cannot be used in newer operating systems. It might not have official support after a certain period, such as when a

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[387] Ibid.
[388] "About Universal Design". Building and Construction Authority. https://www1.bca.gov.sg/regulatory-info/building-control/universal-design-and-friendly-buildings/about-universal-design (accessed 28 July 2021)
[389] Mace, Ronald L. "Universal Design in Housing." Assistive Technology 10, no. 1 (1998): 21–28. https://doi.org/10.1080/10400435.1998.10131957.
[390] "An Update On The Evolution Of The Oculus Platform". Oculus Blog. https://www.oculus.com/blog/an-update-on-the-evolution-of-the-oculus-platform-/ (accessed 4 August 2021)

specific file format is discontinued (e.g., HTML5 replacing Adobe Flash on YouTube from 2015 onwards).

This issue could be a problem for digital installation with specific requirements that cannot be repaired due to wear-and-tear. Editing or modifying the source files might become impossible. When using IM in permanent exhibitions, concerns should be raised about futureproofing and the maintenance of the technology.

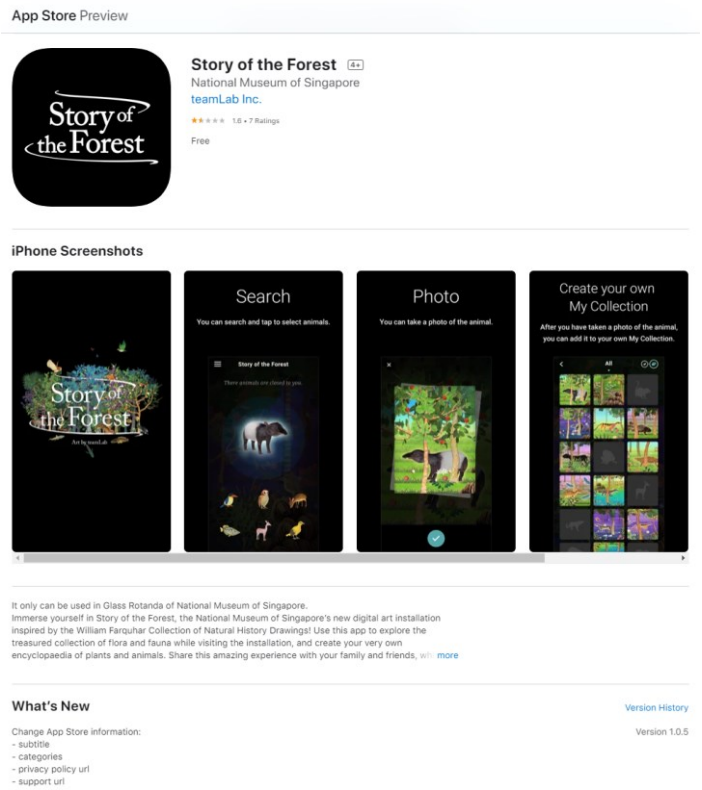

Fig. 67. The Apple app store page for Story of the Forest app, taken on 21 June 2021. The last update was in 2019. The Google Play store equivalent yield an error message showing the app is no longer available.

An example is the *Story of the Forest* interactive smartphone app (fig. 67), where it is likely too difficult to update and maintain the app for new phones and operating systems that were eventually discontinued. While the app is not a core part of the immersive experience, the *Story of the Forest* does lose one dimension of interaction. Even if software or hardware is defunct, it is a good habit to secure and archive them for posterity and future research.

7.4 Short-Term and Long-Term IM Experiences

After examining the exhibition strategies of the NMS, the ASM and the ACM when using IM, as well as the framework and challenges of implementing IM, this thesis concludes

that IM experiences can be split between short-term experiences and long-term/permanent experiences.

Short-term experiences such as the NMS DigiMuse or supplemental media for a temporary exhibition (ACM *Terracotta Warriors* exhibition with AR app) are good examples. The main advantage of this would be the human resources and obsolescence aspect. As the programme or exhibition is temporary, there is no need to allocate substantial manpower resources to support the use of the IM, and unlikely to become defunct during the duration of the programme or exhibition. Temporary programming with DigiMuse and inside Gallery10 are also good outlets for experimentation, testing ideas, and studying if they could be an excellent fit for the museum[391].

Design thinking can be applied when it comes to long-term or permanent experiences. The project prototype uses existing technology to solve a problem, making it more sustainable than chasing after the newest technology[392].

Fig. 68. The installation at the NGS uses Kinect to read the body's movement to translate into navigation in the software.

An example can be seen when local tech artist, Eugene Soh, was commissioned by the National Gallery Singapore to work on a digital installation to show the 360-degree view of the Old Supreme Court building[393] (fig. 68). Instead of using a VR headset; the artist

[391] Viddsee. "Yours Virtually Ep 1".
[392] Ibid.
[393] Eugene Soh, Tan Shao Yun (Dude.sg) in discussion with author, 21 Sept 2020.

chose a projection navigatable using a Microsoft Kinect. His reason was the installation's “durable” shelf-life, the ease-of-use, and maintenance compared to a typical headset.

That does not mean HMD headsets cannot be used in a permanent gallery. The ASM provides a solution by having the entire gallery dedicated to using VR headsets. The VR experience in their VR Gallery is also timed and ticketed, making it akin to a movie or drama theatre. This way, there will always be a standby staff member to assist the visitors and provide upkeep to the headsets and the area after every session.

Online exhibitions and programming are also great examples of long-term experiences, as they could remain online for as long as the museum requires. However, they might face obsolescence as the Internet standard changes in the future.

Ultimately, it is up to the individual museums to decide what is best for them while considering the framework and challenges to deliver a sustainable, cost-effective, and immersive experience to further engage the visitors.

CHAPTER 8: LIMITATION, FUTURE RESEARCH & CONCLUSION

8.1 Limitation and Future Research

Although the thesis managed to answer the research questions on using IM and made an in-depth examination of how these technologies fit into the NMS exhibition strategy, one unfortunate downside of this thesis project's duration was the inability to conduct user study due to the ongoing pandemic. Although it is impossible to do a user study of the 2006 SHG, future research could look at how visitors respond to the NMS IM examples and the DigiMuse program regarding knowledge retention and enjoyment.

Besides that, this thesis is limited in scope as it primarily deals with IM technology. The NMS does not distinguish between IM, VR, AR, and IT, preferring to group them into the overarching umbrella of 'digital technology'. The thesis only examined two examples of the 2018 DigiMuse showcase, which is insufficient to make a conclusive remark on the DigiMuse programme, mainly since the themes and modes of presentations differ yearly.

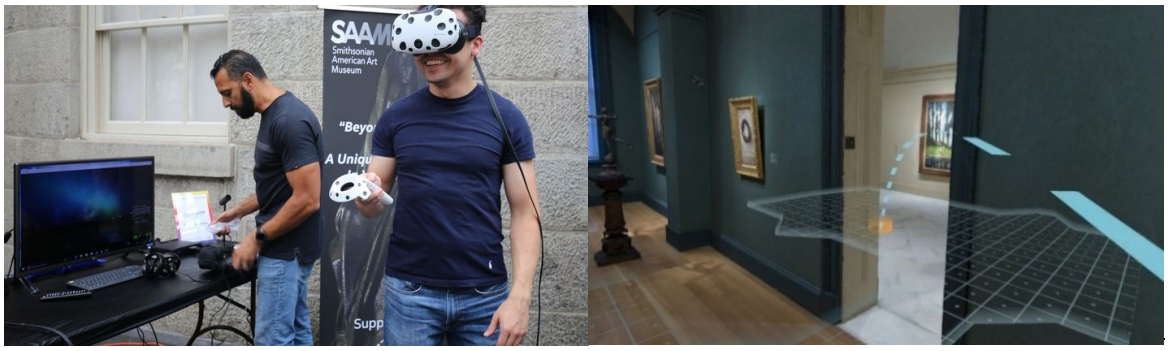

Fig. 69a and b. "Beyond The Walls" VR demonstration during Smithsonian American Art Museum Arcade *event.*

Nevertheless, the findings of this thesis opened many possible directions it could take as future research into the use of IM technology in museums. Examples include using and handling VR hardware in permanent galleries such as the SCS E3 exhibition and the ASM VR Gallery; and research into making meaningful online IM offerings (e.g., virtual tours) to supplement physical exhibitions. Another aspect of future research could expand to include the usage of VR and AR technology in overseas museums' programming and their effectiveness in audience engagement and knowledge retention (fig. 69).

8.2 Conclusion

In the end, the thesis introduced IM's role in Singapore museums, specifically the NMS. It showed that the NMS, being an artefact-centric museum, based its exhibition around a narrative or storyline, with the artefacts being the ‘protagonist’ to the story. Digital technology, including IM, played a supporting role in bringing out the story and further engaging the visitors that traditional media could not.

The DigiMuse programme was thus implemented as a way for the NMS to explore more digital technology and IM as the technology developed and was used in museums overseas. DigiMuse was not the first time the NMS explored using IM, as they held a blockbuster VR exhibition back in 1995 by working with a local company with links to the establishment of the NUS-ISS, a graduate research and education institution that grooms IT professionals in Singapore.

Lastly, the thesis also pointed out how new and emerging digital technology is changing the way museums are experienced, with visitors wanting to be entertained and creative output being the most relevant to IM technologies in the museum. Museums should also focus on stories, artefacts and audiences before considering which IM to include in their exhibition and programming. It also identified five areas of challenges when using IM in the museum: health and safety; cost and value; logistics and manpower; accessibility and ease of use; hardware and software obsolescence.

Hopefully, this thesis will contribute to the awareness of using IM and digital technology in local museums and how to implement them best.

BIBLIOGRAPHY / REFERENCES

Books, Journals, Conference Proceedings

Alsford, Stephen, and David Parry. “Interpretive Theatre. A Role in Museums?” Museum Management and Curatorship 10, no. 1 (1991): 8–23.

Aukstakalnis, Steve. Practical Augmented Reality: A Guide to the Technologies, Applications, and Human Factors for AR and VR. Crawfordsville, Indiana: Pearson Education, Inc., 2017.

Avenarius, Gundula; Deemas, Aisha; Kamel, Susan. Museology - Appropriate Language: Essays on Translation and Communication in the Museum. Berlin: Hochschule für Technik und Wirtschaft, 2018.

Bautista, Susana Smith, ed. Museums in the Digital Age: Changing Meanings of Place, Community, and Culture. Lanham: AltaMira Press, 2014.

Bedford, Leslie. “Storytelling: The Real Work of Museums.” Curator: The Museum Journal 44, no. 1 (2001): 30.

Brooks, Frederick P., Ouh Young Ming, James J. Batter, and P. Jerome Kilpatrick. “Project GROPE. Haptic Displays for Scientific Visualization.” Computer Graphics (ACM) 24, no. 4 (1990).

Burris, Jennifer, and Adrian Tan, eds. “Angelita Teo.” In Questioning Museum: Art Institutions in Singapore, 88. Singapore: School of Art, Design and Media, Nanyang Technological University, 2019.

Cameron, Fiona., and Sarah. Kenderdine, eds. Theorizing Digital Cultural Heritage: A Critical Discourse. Choice Reviews Online. Vol. 45. Media in Transition. Cambridge, Massachusetts: MIT Press, 2007.

Caudell, T.P., and D.W. Mizell. “Augmented Reality: An Application of Heads-up Display Technology to Manual Manufacturing Processes.” System Sciences, 1992. Proceedings of the Twenty-Fifth Hawaii International 2, no. February (1992).

Chew, David. “The Future of Our Museums.” MuseSG 8, no. 3 (2015). https://www.roots.gov.sg/resources-landing/publications/education-and-community-outreach/muse-sg-vol-8-issue-2.

Chua, Pricilla, ed. The Past in the Present: Histories in the Making. Singapore: National Heritage Board, 2009.

Chua, Priscilla. “Chapter 6 – Building an Economy: Getting Down to Work.” In (Re)Presenting Histories: Experiences & Perspective from the National Museum of Singapore, edited by Stephanie Yeo. Singapore: National Museum of Singapore, 2017.

Chua, Tat-Seng, and Tosiyasu L. Kunii, eds. “C G International ’90 - Computer Graphics Around the World.” In VG International ’90. Singapore: Springer-Verlag Tokyo, 1990.

Cipresso, Pietro, Irene Alice Chicchi Giglioli, Mariano Alcañiz Raya, and Giuseppe Riva. “The Past, Present, and Future of Virtual and Augmented Reality Research: A Network and Cluster Analysis of the Literature.” Frontiers in Psychology 9, no. NOV (2018).

E. Sutherland, Ivan. “The Ultimate Display.” Proceedings of the IFIP Congress 2 (1965): 506--508. http://citeseer.ist.psu.edu/viewdoc/versions?doi=10.1.1.136.3720.

Feiner, Steven, Blair MacIntyre, Tobias Höllerer, and Anthony Webster. “A Touring Machine: Prototyping 3D Mobile Augmented Reality Systems for Exploring the Urban Environment.” Personal and Ubiquitous Computing 1, no. 4 (1997).

Frost, Mark Ravinder. “The Making of the Singapore History Gallery: Some Personal Reflections.” In The Past in the Present: Histories in the Making, edited by Priscilla Chua, 61–77. Singapore: National Heritage Board, 2009.

Greengard, Samuel. Virtual Reality. Cambridge, Massachusetts: The MIT Press, 2019.

Guan, Kwa Chong. “Transforming the National Museum of Singapore.” In Rethinking Cultural Resource Management in Southeast Asia: Preservation, Development, and Neglect, edited by John N. Miksic, Geok Yian Goh, and Sue O’Connor, 202. London: Anthem Press, 2011.

Gurminder, Singh, Steven Keith Feiner, and Daniel Thalmann, eds. “Virtual Reality Software And Technology - Proceedings Of The VRST ’94 Conference.” In VRST ’94 Conference. Singapore: World Scientific, 1994.

Heng, Noi Loh; and Teh, Eng Eng. Making Museums Matter: A Post Symposium Publication. Singapore: National Heritage Board, 2008.

Hung, Yi Ping, Tsui Mei Huang, Kuang Ti Li, R. P.C. Janaka Rajapakse, Yang Sheng Chen, Ping Hsuan Han, Iou Shiuan Liu, Hao Cheng Wang, and Da Chung Yi. “Simulating the Activity of Archaeological Excavation in the Immersive Virtual Reality.” Proceedings of the 2018 3rd Digital Heritage International Congress, Digital Heritage 2018 - Held Jointly with the 2018 24th International Conference on Virtual Systems and Multimedia, VSMM 2018, no. August 2019 (2018).

Ismail, Iman. “Chapter 8 – Using Contemporary Art to Relook at History.” In (Re)Presenting Histories: Experiences & Perspective from the National Museum of Singapore, edited by Stephanie Yeo.

Jerald, Jason. The VR Book: Human-Centered Design for Virtual Reality. Edited by M. Tamer Özsu. First. Association for Computing Machinery and Morgan & Claypool Publishers, 2016.

Kim, Lim Siam. “The Experience of the National Heritage Board, Singapore.” In Reforming Museums for the 21st Century: Report on the Stockholm Asia-Europe Conference on Museums 2000, edited by Karl Magnusson. Singapore: National Museums of World Culture, 2000.

Krueger, Myron W. “‘VIDEOPLACE’: A Report from the ARTIFICIAL REALITY Laboratory.” Leonardo 18, no. 3 (1985): 145–51. https://www.jstor.org/stable/1578043.

Lenzi, Iola. 2004. “Singapore History Museum.” In Museums of Southeast Asia, edited by Marilyn Seow and Laura Jeanne Gobal.

Lenzi, Iola. National Museum of Singapore Guide. Singapore: Editions Didier Millet, 2007.

Levent, Nina, and Alvaro Pascual-Leone. The Multisensory Museum: Cross-Disciplinary Perspectives on Touch, Sound, Smell, Memory, and Space. Plymouth: Rowman & Littlefield, 2014.

Lewi, Hannah, Wally Smith, Dirk vom Lehn, and Steven Cooke. The Routledge International Handbook of New Digital Practices in Galleries, Libraries, Archives, Museums and Heritage Sites. 1st ed. London: Routledge, 2019.

Lim, Sharon, Shihui Ong, and Stephanie Yeo, eds. Dome in the City: The Story of the National Museum of Singapore. Singapore: National Museum of Singapore, 2016.

Lim, Sharon. "Chapter 6E – More than a Little Red Dot: Becoming a Global City." In (Re)Presenting Histories: Experiences & Perspective from the National Museum of Singapore.

Magnusson, Karl. Reforming Museums for the 21st Century: Report on the Stockholm Asia-Europe Conference on Museums 2000, Singapore: National Museums of World Culture, 2000.

Mazuryk, Tomasz, and Michael Gervautz. "Virtual Reality - History, Applications, Technology and Future." Vienna University of Technology, 1999.

McCarthy, Cecilia Pinto. How Virtual Reality Will Impact Society. San Diego: ReferencePoint Press, Inc, 2019.

McErlean, Kelly. Interactive Narratives and Transmedia Storytelling. Interactive Narratives and Transmedia Storytelling. First. New York: Routledge, 2018.

McGee, Carrie; and Rosenberg, Francesca. "Art Making as Multisensory Engagement: Case Studies from the Museum of Modern Art". The Multisensory Museum: Cross-Disciplinary Perspectives on Touch, Sound, Smell, Memory, and Space. Levent, Nina; Pascual-Leone, Alvaro, eds. 2014. Plymouth: Rowman & Littlefield.

Milgram, Paul, and Kishino Fumio. "A Taxonomy of Mixed Reality Visual Displays." IEICE Transactions on Information and Systems E77-D, no. 12 (1994).

Milgram, Paul, Haruo Takemura, Akira Utsumi, and Fumio Kishino. "Augmented Reality: A Class of Displays on the Reality-Virtuality Continuum." In Proceedings Volume 2351, Telemanipulator and Telepresence Technologies, edited by Hari Das, 282–92. Boston, 1994.

Mouw, Michael, and Daniel Spock. "Immersive Media: Creating Theatrical Storytelling Experiences." In The Digital Museum: A Think Guide, edited by Herminia Din and Phyllis Hecht, 45–56. Washington, DC: American Association of Museums, 2007.

Mydin, Iskander. "Chapter 1 – Towards a Museum Narrative". In (Re)Presenting Histories : Experiences & Perspectives from the National Museum of Singapore. Edited by Stepanie Yeo. Singapore : National Museum of Singapore, 2017.

Mydin, Iskander. "Chapter 2 – Singapura Before 1819." In (Re)Presenting Histories: Experiences & Perspective from the National Museum of Singapore.

Pallud, Jessie. "Impact of Interactive Technologies on Stimulating Learning Experiences in a Museum." Information and Management 54, no. 4 (2017): 465–78.

Paul, Christiane. Digital Art. Third. London: Thames & Hudson Ltd., 2015.

Peddie, Jon. Augmented Reality: Where We Will All Live. Springer International Publishing AG, 2017.

Peselmann, Veronica. "Enacting Public Perception in the Late 19 Th Century: The Kaiserpanorama." Figurationen 17, no. 2 (2016).

Phua, Jay, and Chung May Khuen. "Chapter 7 - An Immersive History: The Use of Technology in the Life in Singapore Galleries." In (Re)Presenting Histories: Experiences & Perspective from the National Museum of Singapore, edited by Stephanie Yeo. Singapore: National Museum of Singapore, 2017.

Recupero, Annamaria, Alessandra Talamo, Stefano Triberti, and Camilla Modesti. "Bridging Museum Mission to Visitors' Experience: Activity, Meanings, Interactions, Technology." Frontiers in Psychology 10, no. September (2019).

Scala, Paola La. "Museums Presenting Past through Digital Technologies: MAV (Museo Archeologico Virtuale) of Ercolano and Site-Museum of Pont Du Gard Case Studies." MWF2014: Museums and the Web Florence 2014, 2014. https://mwf2014.museumsandtheweb.com/paper/museums-presenting-past-through-digital-technologies-mav-museo-archeologico-virtuale-of-ercolano-and-site-museum-of-pont-du-gard-case-studies/.

Second Asian Conference on Computer Vision. Singapore: Nanyang Technological University, 1995.

Stogner, Maggie Burnette. "The Media-Enhanced Museum Experience: Debating the Use of Media Technology in Cultural Exhibitions." Curator: The Museum Journal 52, no. 4 (2009).

Sturman, David J, and David Zeltzer. "A Survey of Glove-Based Input." IEEE Computer Graphics and Applications 14 (1994).

Tallon, Loïc, and Kevin Walker. Digital Technologies and the Museum Experience. Altamira Press. Plymouth: AltaMira Press, 2008.

Temasek Polytechnic. Proceedings of the Virtual Reality Technology & Internet Applications Conference. Singapore: Temasek Polytechnic, 1998.

Teo, Angelita. "A Golden Opportunity: Revamping the National Museum of Singapore for the Golden Jubilee Year." Edited by Thangamma Karthigesu and Marcus Ng. Cultural Connections 1 (2016).

Teo, Angelita. "Digital Technology And The Museum Experience: A Case Study Of The National Museum Of Singapore." In The Digital in Cultural Spaces Conference Publication, edited by Thangamma Karthigesu, Chui Hua Tan, and Cheryl-Ann Low, Mei Gek, 60. Singapore: Culture Academy Singapore, 2017.

Thangamma, Karthigesu; Tan, Chui Hua; and Low, Mei Gek Cheryl-Ann. Digital in Cultural Space. Singapore: Culture Academy Singapore, 2016.

Thian, Cherry. “Augmented Reality—What Reality Can We Learn From It?” In Museums and the Web. San Diego, 2012. https://www.museumsandtheweb.com/mw2012/papers/augmented_reality_what_reality_can_we_learn_fr.

Ting, Kennie. “Museums in Singapore: A Short History.” MuseSG 8, no. 2 (2015).

Wade, Nicholas J. “Ocular Equivocation: The Rivalry between Wheatstone and Brewster.” Vision (Switzerland) 3, no. 2 (2019).

Ward, Jamie. “Multisensory Memories: How Richer Experiences facilitate Remembering”. The Multisensory Museum: Cross-Disciplinary Perspectives on Touch, Sound, Smell, Memory, and Space. 273-281.

Wong, Hong Suen, and Jason Toh. “Imagining Singapore: Musings of a 120-Years-Old Dame.” In The Past in the Present: Histories in the Making, edited by Priscilla Chua, 42–51. Singapore: National Heritage Board, 2009.

Zeltzer, David. “Autonomy, Interaction, and Presence.” Presence: Teleoperators and Virtual Environments 1, no. 1 (1992): 127–32. https://doi.org/10.1162/pres.1992.1.1.127.

Newspapers, Magazines and News Media Outlets

“Family entertainment a virtual reality”. The Straits Times. 23 Dec 1994, 3.

“Getting into the insect world via Cyberbug”. The Straits Times. 20 Feb 1995, 2.

“Poly launches virtual reality lecture system”. The Straits Times. 9 Feb 1995, 22.

“Schools may use virtual reality if costs drop”. The Straits Times. 23 Oct 1995, 1.

“The Virtual Curmudgeon.” The Economist. London, September 2010. https://www.economist.com/technology-quarterly/2010/09/04/the-virtual-curmudgeon?story_id=16909935.

“VIRTEX '94 Exhibition”. The Straits Times. 4 Sept 1994, 21.

Anna Somers, Cocks. “How Google Became a Major Producer of Cultural Content.” The Art Newspaper. Accessed June 15, 2021. https://www.theartnewspaper.com/feature/how-google-became-a-major-producer-of-cultural-content.

Choudhury, Saheli Roy. “VR to Make Couch Potato Tours of the World’s Landmarks a Click Away.” CNBC, 2016. https://www.cnbc.com/2016/12/07/hiverlab-creating-a-virtual-heritage-of-the-worlds-most-historic-sites.html.

Chow, Clara. “Is the museum too 'Disney'?” The Straits Times. 21 Dec 2006, 4.

Foo, Lilian. “Museum abuzz with virtual reality activity”. The Straits Times. 9 Nov 1995, 39.

Hans David Tampubolo. “Virtual Museum Brings Indonesia’s Heritage Closer to Home.” The Jakarta Post. May 16, 2014. https://www.thejakartapost.com/news/2014/05/16/virtual-museum-brings-indonesia-s-heritage-closer-home.html.

Ho, Olivia. “The National Museum of Singapore launches first dedicated digital space”. The Straits Times. 2 Feb 2017. https://www.straitstimes.com/lifestyle/arts/making-exhibits-come-alive

Ho-Chan, Desirene. “Multimedia aid to explore history at own pace”. The Straits Times. 19 Jun 2011, 32.

Hollister, Sean. “Here comes Pokemon Go's ARKit mode. Is your battery ready?” Cnet. 2017. https://www.cnet.com/news/pokemon-go-apple-arkit-iphone-ipad-pro/

Iyer, Lakshmy. “Curating a community museum for Indians in Singapore: Nalina Gopal”. Connected to India. https://www.connectedtoindia.com/curating-a-community-museum-for-indians-in-singapore-nalina-gopal-

Koh, Boon Pin. “Imagine that! Museum tampers with reality”. The Straits Times. 16 Oct 1995, 3.

Koh, Boon Pin. “Some hits, some misses at VR show”. The Straits Times. 25 Oct 1995, 3.

Koh, Tommy. “National Museum remains focused on Singapore history, replies Heritage Board.” The Straits Times. 6 July 2011, 25.

Lui, Rose Hasumi. “National Museum or fashion show?” The Straits Times. 12 Jun 2011, 28.

Marr, Bernard. “What Is Extended Reality Technology? A Simple Explanation for Anyone.” Forbes, 2019. https://www.forbes.com/sites/bernardmarr/2019/08/12/what-is-extended-reality-technology-a-simple-explanation-for-anyone/

Nayar Parvathi. “Seeing old things with new eyes”. The Business Times. 5 Jan 2007, 28.

November 2017. https://sg.news.yahoo.com/explore-prehistoric-sites-vr-december-national-museum-singapore-093831969.html

Oon, Clarissa. “Time for Museum to Dig Deeper.” The Straits Times. 5 Jul 2011, 2.

Rieland, Randy. “Augmented Reality Livens up Museums.” Smithsonian Magazine, 2012. https://www.smithsonianmag.com/innovation/augmented-reality-livens-up-museums-22323417/.

Robertson, Adi. “Google ARCore Gives Android Users Augmented Reality Without Tango”. The Verge. 2017. https://www.theverge.com/2017/8/29/16219696/google-arcore-augmented-reality-platform-announce-release-pixel-samsung

Robertson, Adi. “Google is discontinuing the Daydream View VR headset, and the Pixel 4 won’t support Daydream”. The Verge. 2019. https://www.theverge.com/2019/10/15/20915609/google-pixel-4-no-daydream-support-view-vr-headset-discontinued

Robertson, Adi. “Oculus CTO John Carmack says ‘we missed an opportunity’ as the Gear VR dies”. The Verge. 2019. https://www.theverge.com/2019/9/26/20885685/oculus-cto-john-carmack-samsung-gear-vr-headset-missed-opportunity

Said, Nabilah. “National Museum of Singapore Uses Augmented Reality to Tell Building’s History.” The Straits Times. 18 April 2017. https://www.straitstimes.com/lifestyle/arts/national-museum-of-singapore-uses-augmented-reality-to-tell-buildings-history.

Said, Nabilah. “Take a Selfie with a Whale at Museum.” The Straits Times, 14 April 2017. https://www.straitstimes.com/lifestyle/arts/take-a-selfie-with-a-whale-at-museum.

Tan, Kevin Y.L. “Museums Should Show Real Artefacts.” The Straits Times. 5 July 2011, 22.

Yeo, Heidi. “Virtual reality programs being prepared for home computers”. The Straits Times. 25 Aug 1994, 23.

YouThInk writers. “Promote exhibits directly to students”. The Straits Times. 16 July 2011.

Zacks Equity Research. “Microsoft Lures Investors with Azure Kinect & Partner Updates”. Yahoo! Finance. 2019. https://finance.yahoo.com/news/microsoft-lures-investors-azure-kinect-140402563.html

Zhao, Tingting. “Pimax launches 4K VR device in Beijing”. China Daily. 2016. http://www.chinadaily.com.cn/business/tech/2016-04/09/content_24398258.htm

Websites and Social Media

“About ArtScience Museum”. Marina Bay Sands. https://www.marinabaysands.com/museum/about.html (accessed 20 July 2021)

“About IHC”. Massive Infinity. https://www.massiveinfinity.com/indian-heritage-centre (accessed 24 Oct 2022)

“About NHB”. National Heritage Board. https://www.nhb.gov.sg/who-we-are/about-us (accessed 17 Jun 2020)

“About SAM”. Singapore Art Museum. https://www.singaporeartmuseum.sg/about#overview (accessed 5 July 2020)

“About Universal Design”. Building and Construction Authority. https://www1.bca.gov.sg/regulatory-info/building-control/universal-design-and-friendly-buildings/about-universal-design (accessed 28 July 2021)

“About Us.” Singapore Computer Society. 2021. https://www.scs.org.sg/about (accessed 5 July 2021)

“About Us”. National Museum of Singapore. https://www.nationalmuseum.sg/shared-content/exploremuseumtopmenu/about-us-top-menu/overview (accessed 24 Nov 2019)

“ACM Treasures in AR”. Asian Civilisations Museum. https://www.nhb.gov.sg/acm/whats-on/tours/acm-treasures-in-ar (accessed 23 July 2021)

“Allie - ACM's Virtual Museum Host”. Asian Civilisations Museum. https://www.nhb.gov.sg/acm/whats-on/tours/allie (accessed 23 July 2021)

“An Old New World: Digital Edition”. In National Museum of Singapore. 2020. https://www.nhb.gov.sg/nationalmuseum/our-exhibitions/exhibition-list/aonw-digital (accessed 5 July 2021)

“An Update On The Evolution Of The Oculus Platform”. Oculus Blog. https://www.oculus.com/blog/an-update-on-the-evolution-of-the-oculus-platform-/ (accessed 4 August 2021)

“Archaeological Excavation Site at Fort Canning Park.” Roots.sg. https://www.roots.gov.sg/places/places-landing/Places/surveyed-sites/Archaeological-Excavation-Site-at-Fort-Canning-Park (accessed 17 July 2021)

“Cyberworlds International Conferences”. Nanyang Technological University. N.d. https://www3.ntu.edu.sg/home/assourin/CW/cw-conferences.htm (accessed 6 July 2021)

“Designers create inspiring social AR experience ‘REWILD Our Planet’”. ARUP. https://www.arup.com/projects/rewild-our-planet (accessed 22 July 2021)

“DigiMuse Open Call for Digital Art and Innovative Concepts”. National Museum of Singapore. https://www.nhb.gov.sg/nationalmuseum/our-programmes/programmes-list/digimuse-open-call-2018?sc_lang=en (accessed 13 July 2021)

“DigiMuse: Circuit Breaker Edition.” National Museum of Singapore. https://www.nhb.gov.sg/what-we-do/our-work/community-engagement/public-programmes/digimuse (accessed 3 Jun 2020)

“Faith Beauty Love Hope - Into 2021”. Asian Civilisations Museum. https://www.nhb.gov.sg/acm/whats-on/exhibitions/faith-beauty-love-hope-2021 (accessed 23 July 2021)

“Future World: Where Art Meets Science”. teamLab. https://www.teamlab.art/e/artsciencemuseum/ (accessed 23 July 2021)

“Into the Wild: An Immersive Virtual Adventure”. Marina Bay Sands Singapore. https://www.marinabaysands.com/museum/exhibition-archive/into-the-wild.html (accessed 29 July 2021)

“Ministry of Communications and Information (MCI).” National Archives of Singapore. 2018. https://www.nas.gov.sg/archivesonline/government_records/agency-details/42 (accessed 5 July 2021)

“Ministry of Information and the Arts.” National Archives of Singapore. 2018. https://www.nas.gov.sg/archivesonline/government_records/agency-details/31 (accessed 5 July 2021)

“Museum Definition”. International Council of Museums. N.d. https://icom.museum/en/resources/standards-guidelines/museum-definition/ (accessed 5 July 2021)

“Museum Roundtable”. National Heritage Board. 2020. https://www.nhb.gov.sg/what-we-do/our-work/sector-development/museum-roundtable (accessed 17 Jun 2020)

"National Museum of Singapore Galleries." FARM. https://www.farm.sg/projects/details/national_museum_galleries (accessed 16 July 2022)

"National Museum Of Singapore International VR Content Showcase". Hiverlab. https://www.hiverlab.com/national-museum-of-singapore-international-vr-content-showcase (accessed 18 July 2021)

"National Museum of Singapore Mobile App Redesign". Meet Raph. http://meetraph.com/project/national-museum-of-singapore-app-redesign (accessed 17 July 2021)

"National Museum of Singapore". In apkpure, Andriod app archival website. https://apkpure.com/id/national-museum-of-singapore/com.specialistapps.national_museum (accessed 16 July 2022)

"Our Mission & Vision". National Heritage Board. https://www.nhb.gov.sg/who-we-are/about-us/mission-and-vision (accessed 17 Jun 2020)

"Our Story." National University of Singapore. N.d. https://www.iss.nus.edu.sg/about-us/our-story (accessed 5 July 2021)

"Picturing the Pandemic: A Visual Record of COVID-19 in Singapore". National Museum of Singapore. https://www.nhb.gov.sg/nationalmuseum/our-exhibitions/exhibition-list/picturing-the-pandemic (accessed 15 July 2021)

"Redesigning The Companion". In SlideShare. 2012. https://www.slideshare.net/kamiyahkimmy/redesigning-the-companion (accessed 16 July 2022)

"Rewild Our Planet". WWF. https://rewild.wwf.sg/ (accessed 22 July 2021)

"School Programmes". National Museum of Singapore. Last updated 30 June 2021. https://www.nhb.gov.sg/nationalmuseum/our-programmes/programmes-list/school-programmes (accessed 3 August 2021)

"Sejarah Singapura". M'Go Films. https://www.margofilms.com/exhibit/index.php?projects/SEJARAH (accessed 12 July 2022)

"Shipwrecked: Tang Treaures And Monsoon Winds". Haroko Studio. https://www.harokostudio.com/project/shipwrecked-tang-treasures-and-monsoon-winds/ (accessed 2- July 2021)

"Should You Send Your Kids for Virtual Reality Gaming?" Mirage VR. Accessed 14 August 2022. https://miragevr.ca/should-you-send-your-kids-for-virtual-reality-

"Singapore History Gallery" GSM Project. https://gsmproject.com/en/projects/case-study/singapore-history-gallery/ (accessed 12 July 2022)

"Southeast Asia, by Abraham Ortelius. 1584". Sanderus: Antique Maps and Books. https://sanderusmaps.com/our-catalogue/antique-maps/asia/southeast-asia/old-antique-map-of-southeast-asia-by-abraham-ortelius-27046 (accessed 11 July 2021)

"Story of the Forest". teamLab. N.d. https://www.teamlab.art/w/story-of-the-forest/ (accessed 18 July 2021)

"thINK: Chinese Calligraphy, Connoisseurship, and Collecting". Asian Civilisations Museum. https://www.nhb.gov.sg/acm/whats-on/exhibitions/think (accessed 23 July 2021)

"Virtual Tour of Materials and Design". Asian Civilisations Museum. https://www.nhb.gov.sg/acm/whats-on/tours/virtual-tour-of-materials-and-design (accessed 23 July 2021)

"Yours Virtually". Cultural Academy. Feb 2021. https://www.mccy.gov.sg/cultureacademy/resources/digital-training/Yours-Virtually

Abdullahi, Khullani M. "The Reality-Virtuality Continuum: Understanding Augmented and Virtual Reality for Marketing." Medium, 2016. https://khullani.medium.com/the-reality-virtuality-continuum-db166a704c01. (accessed 5 July 2021)

ACM (Asian Civilisations Museum). 2015. "ACM Staff Cherry Thian elaborates…" Facebook. 15 November 2015. https://www.facebook.com/asiancivilisationsmuseum/photos/acm-staff-cherry-thian-elaborates-more-on-how-you-can-enjoy-the-tang-shipwreck-i/10153475036816749/

ACM (Asian Civilisations Museum). 2015. "We are launching our very own ACM VR app!" Facebook. 14 November 2015. https://www.facebook.com/asiancivilisationsmuseum/photos/we-are-launching-our-very-own-acm-vr-app-now-available-for-download-from-the-app/10153472317466749/

An Old New World: From the East Indies to the Founding of Singapore, 1600s–1819". In National Museum of Singapore. 2020. https://www.nhb.gov.sg/nationalmuseum/our-exhibitions/exhibition-list/an-old-new-world (accessed 5 July 2021)

Barnard, Dom. "History of VR - Timeline of Events and Tech Development." Virtualspeech, 2019. https://virtualspeech.com/blog/history-of-vr.

BCC Research Editorial. "The History and Evolution of Virtual Reality Technology." BCC Research, 2018. https://blog.bccresearch.com/the-history-and-evolution-of-virtual-reality-technology.

Chandhok, Nikhil. "Camera Effects Platform is now Spark AR". Facebook for Developers. 2018. https://developers.facebook.com/blog/post/2018/10/05/camera-effects-platform-is-now-spark-ar/

Cooper, Daniel. "Nintendo puts 3DS in the Louvre, France remains generally indifferent." Engadget. 2012. https://www.engadget.com/2012-04-12-3ds-louvre.html (accessed 22 Jun 2020)

Devi, Reena; Gopal, Nalina. "Indian Heritage Centre". Roots.sg. https://www.roots.gov.sg/stories-landing/stories/indian-heritage-centre-our-community-treasure/story (accessed 13 July 2022)

Everett, Dino. "Morton Heilig: Inventor of VR." USC Hugh M. Hefner Moving Image Archive, n.d. https://www.uschefnerarchive.com/morton-heilig-inventor-vr/.

Ford, Lily. “Virtual Reality, 19th Century Style: The History of the Panorama and Balloon View.” The Open University, 2017. https://www.open.edu/openlearn/history-the-arts/visual-art/virtual-reality-19th-century-style-the-history-the-panorama-and-balloon-view.

Grimes, Gary J. Digital Data Entry Glove Interface Device. US4414537A. United States: United States Patent, issued 1983. https://patents.google.com/patent/US4414537A/en.

Ibacache, Jessica. “Researchers Abuzz over HIVE and Immersive Visualisation.” Curtin University, 2013. https://news.curtin.edu.au/stories/researchers-abuzz-over-hive-and-immersive-visualisation/.

Ismail, Fairuz Iman. The Story of the Forest. Roots.sg. Jun 2017. https://www.roots.gov.sg/stories-landing/stories/the-story-of-the-forest/story (accessed 11 July 2021)

Kirkpatrick, Ficus. “Introducing Camera Effects Platform”. Facebook for Developers. 2017. https://developers.facebook.com/blog/post/2017/04/18/Introducing-Camera-Effects-Platform/

Lenzi, Iola. National Museum of Singapore Guide. Singapore: Editions Didier Millet, 2007, 17.

Levin, Goland. “ALIVE Project (MIT), ca. 1992”. Vimeo video. Posted 2011. https://vimeo.com/18824784

Loke, Kok Fai. “Parliament passes Info-communications Media Development Authority Bill.” ChannelNewsAsia, via Internet Archive Wayback Machine. 2016. https://web.archive.org/web/20160826220615/http://www.channelnewsasia.com/news/singapore/parliament-passes-info/3048966.html (accessed 5 July 2021)

Lowood, Henry E. “Virtual Reality.” Britannica, 2020. https://www.britannica.com/technology/virtual-reality.

Mace, Ronald L. “Universal Design in Housing.” Assistive Technology 10, no. 1 (1998): 21–28. https://doi.org/10.1080/10400435.1998.10131957.

Mai, WenYi. “Story of the Forest: An Interactive Exhibition Of William Farquhar’s Drawings At The National Museum Of Singapore”. Hype and Stuff. 2019.. https://hypeandstuff.com/story-forest-exhibition-singapore/ (accessed 12 July 2021)

Maybeline. “#TheWeekendList: 9-11 July 2021”. Weekender. https://weekender.com.sg/w/do/9-11-july-2021/ (accessed 23 July 2021)

National Library Board. “Renaissance City Report is Issued: 9th March 2000”. In History SG. 2015. https://eresources.nlb.gov.sg/history/events/d0504b41-06f4-4f4b-80d2-f7d84aa2086d (accessed 17 Jun 2020)

NationalMuseumSg. “DigiMuse Presents: Museum Experiential Guide”. YouTube Video. 1:01, 1 Aug 2018. https://www.youtube.com/watch?v=HRveJ-TkVnU

Preservation of Sites and Monuments, National Heritage Board. “National Museum of Singapore.” In Singapore Infopedia. Singapore Infopedia, 2015. https://eresources.nlb.gov.sg/infopedia/articles/SIP_2015-08-31_132917.html.

Seow, Janice. “Retelling the Story of a Nation”. InDesignLive. https://www.indesignlive.sg/projects/retelling-the-story-of-a-nation (accessed 12 July 2022)

Shaw, Jeffery. “Extended Virtual Environment”. In Jeffrey Shaw Compendium. https://www.jeffreyshawcompendium.com/platform/eve/

Shaw, Jeffery. “Virtual Museum”. In Jeffrey Shaw Compendium. https://www.jeffreyshawcompendium.com/portfolio/virtual-museum/ (accessed 20 June 2020)

Sokol, David. “National Museum of Singapore Collection”. In Architectural Record. (accessed 14 July 2022)

Tan, Lay Yuen. “National Heritage Board”. Singapore Infopedia. https://eresources.nlb.gov.sg/infopedia/articles/SIP_94_2005-01-27.html (accessed 17 Jun2 2020)

Viddsee. “Yours Virtually Ep 1: Arts And Culture In The Digital Age”. YouTube Video. 5:50. https://www.youtube.com/watch?v=X2Q8l7BGR0o&list=WL

Viddsee. “Yours Virtually Ep 4: Re-Imagining Exhibition: An Immersive Experience”. YouTube Video. 5:17. https://www.youtube.com/watch?v=Ge42YMWWxgQ

Virtual Reality Society. “History of Virtual Reality,” 2019. https://www.vrs.org.uk/virtual-reality/history.html.

Zakaria, Faizah bte. “ArtScience Museum”. Singapore Infopedia. Last updated 2017. https://eresources.nlb.gov.sg/infopedia/articles/SIP_1816_2011-07-01.html (accessed 21 July)

Zimmerman, Thomas G. OPTICAL FLEX SENSOR. US4542291A. United States: United States Patent, issued 1985. https://patents.google.com/patent/US4542291A/en.

ZKM Hertz-Lab. “"EVE Dome", the Extended Virtual Environment explained”. In Google Arts and Culture. https://artsandculture.google.com/asset/eve-dome-the-extended-virtual-environment-explained-jeffrey-shaw/uAHHRUZ3uHRiqA?hl=en

Government Records, Reports, and Others

ACM (Asian Civilisations Museum). “Experience Our Asian Civilisations Anew”. Media Release. 9 November 2015. https://www.nhb.gov.sg/acm/-/media/acm/document/about-us/media/press-releases/media-release-experience-our-asian-civilisations-anew.pdf

Center for the Future of Museums. “Museums & Society 2034: Trends And Potential Futures,” 2008. https://www.aam-us.org/wp-content/uploads/2017/12/Museums-Society-2034-Trends-and-Potential-Futures.pdf.

National Heritage Board. “Indian Heritage Centre Media Factsheet”, 2015. https://www.nas.gov.sg/archivesonline/data/pdfdoc/20150516001/ihc_and_galleries_factsheet_-_final.pdf
National Heritage Board. “National Heritage Board Annual Report 2005/2006: Living Heritage.” Singapore, 2006.
National Heritage Board. “National Heritage Board Annual Report 2006/2007: Muse in Vogue.” Singapore, 2007.
National Heritage Board. “Our SG Heritage Plan.” Singapore: National Heritage Board, 2018.
Tan, Heidi. Museum - Community Partnerships: The Role of ASEAN Museums in the 21st Century, Singapore: National Heritage Board, 2010.

Oral Interviews

Eugene Soh, Tan Shao Yun (Dude.sg) in discussion with author, Eugene’s office, 21 Sept 2020.
Jervais Choo, Iskander Mydin (NMS) in discussion with author, video conference, 14 Oct 2020.
Koh Keng We (NTU SOH) in discussion with author, video conference, 9 Mar 2021.
Li Junting Benjamin (NTU WKW) in discussion with author, video conference, 1 Oct 2020.
Lionel Chok (iMMERSiVELY) in discussion with author, video conference, 22 Sept 2020.
Michelle Ng (DigiMagic Communications) in discussion with author, video conference, 13 Oct 2020.

Interview data collection reviewed by NTU Institutional Review Board (IRB),
NTU-IRB Reference No, IRB-2020-07-003.

Interviewees’ Profiles

Prof Benjamin is a researcher at NTU Wee Kim Wee School of Communication (NTU WKW) and Information who specialises in VR, especially with regard to health and safety of using these technologies.

Prof Koh is a researcher in NTU School of Humanities (NTU SOH) and the deputy director of the Chinese Heritage Centre. The information to be extracted from him revolve around using IM in the museum to help students learn about Singapore’s history and heritage.

Michelle Ng is the Associate Account Director at DigiMagic Communications, and the liaison contact for the company. Lionel Chok is the founder and Creative Technologist of iMMERSiVELY.

Eugene Soh is the founder and leader of Dude.sg, while Tan Shao Yun is one of the start-up’s technologies developers. For DigiMagic and iMMERSiVELY, their questions will mainly focus on the DigiMuse interactive applications they developed in 2018, while for Dude.sg, their questions will involve creating IM content for museums as they have experience in making IM content for National Gallery Singapore (NGS) previously.

Jervais Choo is the Programme Director of DigiMuse while Iskander Mydin is a Curatorial Fellow of the NMS. They focus on the history of DigiMuse and how IM is used to enhance the NMS in exhibition and programming.

This version is the 1st revision of the thesis (2nd edition), updated as at 2 November 2022. The original thesis version sent for the 1st examination was done in 13 August 2021.

Appendix

Figure Source

1 Image from: https://www.open.edu/openlearn/history-the-arts/visual-art/virtual-reality-19th-century-style-the-history-the-panorama-and-balloon-view
2a Image from: https://www.kcl.ac.uk/charles-wheatstone-the-father-of-3d-and-virtual-reality-technology-2
2b Image from: https://en.wikipedia.org/wiki/Stereoscope#/media/File:PSM_V21_D055_The_brewster_stereoscope_1849.jpg
3 Images from Roots.sg database.
4 Image from USC Hugh M. Hefner Moving Image Archive: https://web.opendrive.com/api/v1/download/file.json/Ml8xNTA4NjQyOTJf?inline=1
5a, b Image from USC Hugh M. Hefner Moving Image Archive: https://web.opendrive.com/api/v1/download/file.json/Ml8xNTA4NjQyNzVf?inline=1
6 Image from “Augmented Reality: Where We Will All Live”, which referenced from *Electronics magazine* (1961).
7 Image from *Project GROP*: https://dl.acm.org/doi/10.1145/97880.97899
8a, b Image from *A Head-Mounted Three-Dimensional Display*: https://dl.acm.org/doi/10.1145/1476589.1476686
9 Image from *Leonardo* (1985), Vol 18 No 3, pp. 145.

10 Image from “Augmented Reality: Where We Will All Live”, which referenced from *Electronic Visualization Laboratory*.
11a, b Image from *Proceedings of the 1986 workshop on Interactive 3D graphics*, 1987 January issue, pp. 82.
12 Image from *Virtual Reality - History, Applications, Technology and Future*, which referenced from *EUROGRAPHICS’95 State of The Art Reports.*
13 Image from Sony History: https://www.sony.com/en/SonyInfo/CorporateInfo/History/sonyhistory-m.html
14a-d Image from https://www.jeffreyshawcompendium.com
15 Image from *Augmented Reality: An Application of Heads-Up Display Technology to Manual Manufacturing Processes*.
16 Image from *Augmented Reality: A Touring Machine: Prototyping 3D Mobile Augmented Reality Systems for Exploring the Urban Environment*.
17a, b Image from Curtin University. https://humanities.curtin.edu.au/research/centres-institutes-groups/hive/visualisation-systems/
18 Image from *Google Arts and Culture.* https://artsandculture.google.com/asset/video-game-sony-playstation-2-eyetoy-usb-camera-logitech/6gEFT_V3wBIJYA?hl=en
19a, b Source: Louvre official English website. https://www.louvre.fr/en/visit/visitor-amenities
20a Image from https://www.smithsonianmag.com/innovation/augmented-reality-livens-up-museums-22323417/.
20b Screenshot from YouTube: https://www.youtube.com/watch?v=nkbwiQrdGMo&ab_channel=RoarkGourley
20c Screenshot from YouTube: https://www.youtube.com/watch?v=6QH5p8AFkdM&ab_channel=GettyMuseum
20d Screenshot from YouTube: https://www.youtube.com/watch?v=KkmceD0qpmc&ab_channel=MartinStanford
21 This image is in the public domain. From *Wikimedia Commons*. https://commons.wikimedia.org/wiki/File:Google-Cardboard.jpg
22a, b Chart taken from https://store.steampowered.com/hwsurvey/Steam-Hardware-Software-Survey-Welcome-to-Steam (accessed 16 July 2021)
23 Image from National Heritage Board. https://www.nhb.gov.sg/nationalmuseum/-/media/nms2017/image/homebanner/nmswebsitevsbanner/website-banner-visit-us.jpg
24a Image from the National Archives of Singapore: https://www.nas.gov.sg/archivesonline/photographs/record-details/e4a9dce3-1161-11e3-83d5-0050568939ad
24b Image from the National Archives of Singapore: https://www.nas.gov.sg/archivesonline/photographs/record-details/92941139-1162-11e3-83d5-0050568939ad
25a-d Image from National Museum of Singapore Guide (2007)
26a Image from Flickr: https://www.flickr.com/photos/buttshaker/2461634968
26b Image from: https://www.flickr.com/photos/25802865@N08/3377759698/
27a-d Image from Flickr: https://museatsg.wordpress.com/2012/05/16/national-museum-of-singapore-the-living-galleries/
28 Image from Flickr: https://www.flickr.com/photos/shaunwong/2437144471/
29 Screenshot from website: https://www.nhb.gov.sg/media/exhibition-online/aonw-new/index.html
30a From National Archives of Singapore: https://www.nas.gov.sg/archivesonline/photographs/record-details/15a7b713-1162-11e3-83d5-0050568939ad
30b From National Archives of Singapore: https://www.nas.gov.sg/archivesonline/photographs/record-details/5e8358d0-1162-11e3-83d5-0050568939ad
31a Image from Flickr: https://www.flickr.com/photos/wuzanru/6195718080/
31b Image from Flickr: www.flickr.com/photos/smidgewidget/7620987136/
31c Image from Flickr: https://www.flickr.com/photos/stardust96/5561209402/
32 Image from The Straits Times: https://www.straitstimes.com/lifestyle/arts/take-a-selfie-with-a-whale-at-museum
33 Image from National Heritage Board: https://www.nhb.gov.sg/nationalmuseum/research-and-publications/resources-and-publication-list/musing---nms-blog/digimuse
34 Screenshot from “ANNEXES A-2 IMMERSIVE MEDIA AND ADVANCED INTERFACES” in *Technology Roadmap*, published in Nov 2018.
35 Diagram created by author.
36a Image from: *Augmented reality: a class of displays on the reality-virtuality continuum*, published in Jan 1994.
36b Image from “Virtual Reality History, Applications, Technology and Future”, https://www.semanticscholar.org/paper/Virtual-Reality-History-%2C-Applications-%2C-Technology-Mazuryk/6cebef400df6c387852b6c76570f226a86965104
37 Diagram created by author.
38 Photo taken by author in 2020.
39 Image from Flickr: https://www.flickr.com/photos/_odie_/356750291/
40a Image from Flickr: https://www.flickr.com/photos/vjzoo/1311901819/in/photostream/
40b Photo taken by author in September 2019.
41a Image from Flickr: https://www.flickr.com/photos/vrocampo/3476537822/
41b Image from Flickr: https://www.flickr.com/photos/vrocampo/3475746441/
42 Photo taken by author in 2021.
43 Photo taken by author in 2018.
44a Photo taken by author in June 2021.
44b Photo taken by author in March 2020.
45 Photo taken by author in 2021.
46 Photo taken by author in 2018.
47 Image from Roots.sg: https://www.roots.gov.sg/stories-landing/stories/the-story-of-the-forest/story
48 Images from DigiMagic: https://www.digimagic.com.sg/our-work/national-museum-of-singapore-meg/

49 Image from National Heritage Board: https://www.nhb.gov.sg/nationalmuseum/research-and-publications/resources-and-publication-list/musing---nms-blog/digimuse
50 Image from: https://www.immersively.co/wp-content/uploads/2018/11/Digimuse-2018.pdf
51 Figures extracted from 'Simulating the activity of archaeological excavation in the immersive virtual reality'.
52a Image from Cypress Labs Pte Ltd Facebook: https://www.facebook.com/cypresslabs/photos/a.1714330142170010/2402017300067954/
52b-e Image from https://apkpure.com/id/national-museum-of-singapore/com.specialistapps.national_museum, and https://download.cnet.com/National-Museum-of-Singapore/3000-20414_4-78567168.html
53 Image from *Digital Technology And The Museum Experience: A Case Study Of The National Museum Of Singapore,* https://www.mccy.gov.sg/cultureacademy/researchandpublications/conferencepapers/The-Digital-In-Cultural-Spaces-Publication
54 Image from Haroko Studio: https://www.harokostudio.com/project/shipwrecked-tang-treasures-and-monsoon-winds/
55a, b Image from ACM conference proceedings: https://www.museumsandtheweb.com/mw2012/papers/augmented_reality_what_reality_can_we_learn_fr
56a Image from ACM Facebook: https://www.facebook.com/asiancivilisationsmuseum/photos/we-are-launching-our-very-own-acm-vr-app-now-available-for-download-from-the-app/10153472317466749/
56b Image from ACM Facebook: https://www.facebook.com/asiancivilisationsmuseum/photos/acm-staff-cherry-thian-elaborates-more-on-how-you-can-enjoy-the-tang-shipwreck-i/10153475036816749/
57a-c Image from: https://play.google.com/store/apps/details?id=com.ihc.indianheritagecenter&hl=en&gl=US
57d Image from: https://www.arup.com/projects/rewild-our-planet
58a, b Screenshot from ACM: https://www.nhb.gov.sg/acm/whats-on/exhibitions/faith-beauty-love-hope-2021
59 Screenshot from ACM: https://www.nhb.gov.sg/acm/whats-on/tours/virtual-tour-of-materials-and-design
60 Image from ASM Facebook: https://www.facebook.com/ArtScienceMuseum/photos/pcb.3965734190146861/3965732583480355/
61 Diagram created by the author.
62 Diagram created by the author.
63 Image from teamLab: https://www.teamlab.art/e/artsciencemuseum/
64 Diagram created by the author.
65 Diagram created by the author.
66 Image from Amazon: https://www.amazon.sg/INKECI-Universal-Disposable-Prevent-Infections/dp/B07CTPDVRM
67 Screenshot from Apple app store: https://apps.apple.com/sg/app/story-of-the-forest/id1177299424
68 Photo from author's collection.
69 Image from Smithsonian American Art Museum: https://www.smithsonianmag.com/blogs/smithsonian-american-art-museum/2018/12/11/testing-new-reality-museum-vr/