

Operations of Museum Digitization: Case Studies Comparing China and the U.S.

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China's museum industry has been booming since we entered the 21st century. The eastern country has made the prosperity of museum and culture industry one of the most important tasks in its 13th five-year plan. In the digital age, museum digitization is an inevitable step for the industry to achieve the goal. However, the overall degree of museum digitization in China still lags behind western countries. This article addresses the concerns of China's museum modernization in terms of digitization by comparing its museum industry to the United States' using six cases. Operations of museum digitization in China and the U.S. are compared in terms of technologies, web content and design, mobile apps, social media, and collaboration. Based on the comparison and discussion, suggestions to China's museum digitization, as well as to the America's, are given.

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I. INTRODUCTION

According to International Council of Museums (ICOM), a museum is defined as “a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment.” (ICOM, 2018). This definition is widely accepted in the museum industry.

It has been a while that people have attempted to use information technology and multimedia to extend the reach of physical museums and to enhance the visiting experience. As early as 1992, a multimedia software on CD-

ROM called exactly “The Virtual Museum” was released by Apple (Miller, et al., 1992). It presented an electronic museum in a prerendered 3D space, where users could “walk” from one room to another, “pick up” a virtual item to have a closer examination. The exhibits in the museum were educational, including subjects such as medicine, plant growth, environment, and space. One of the objectives of designing such a digital museum was to make it available to a large number of computer users requiring no special equipment. Another objective was “to prototype an electronic museum of the future” (Miller, et al., 1992). The creators of “The Virtual Museum” mentioned that they wanted to show museum-goers what the future online interactive museum experience would be like.

This virtual museum is a form of museum digitization, which means digitization of all aspects of a traditional museum (Li W., 2008), including generating digital surrogates of the physical cultural heritages and collections and storing born-digital materials (such as digital artworks created on computers); maintaining the whole digital collections; presenting and distributing these digital resources on various platforms with assistance of technologies – such as multimedia, virtual reality (VR), augmented reality (AR), artificial intelligence (AI), and data visualization; and crafting new creations and applications that involves usage of the digital resources. The result of museum digitization could be in two forms: digitized museum and digital museum. The former is a digital footprint of a physical museum and it complements, enriches, or expands the museum through customization, interactivity, novel and immersive user experience, and richness of content (Polycarpou, 2018). The latter, also known as a virtual museum, is a museum exhibition platform that utilizes computers information technology, on which cultural relics and historical collections can be preserved and displayed in digital format (Li & Liew, 2015). Digital museums only exist in cyberspace and do not have a physical form (Li W., 2008). The discussion in this paper covers both forms.

As early as 1967, a group of New-York-area museums founded an organization called Museum Computer Network (MCN) to build a shared museum “data-bank” (Misunas & Urban, 2009). In 1990, Library of Congress of the United States initiated “American Memory” project with purpose of making an online digital library archive (Library of Congress, n.d.), which marked the beginning of digital library era. First off-line virtual museum application was made in 1992, as aforementioned. Three years later, MCN’s website went online (Misunas & Urban, 2009). Meanwhile, some American and European museums, including Louvre, started to digitize their collections and

build their websites, for example, Metropolitan Museum of Art (the Met) and Museum of Modern Art (MoMA) launched their websites in 1996. The first website of museums in China wasn’t established much later. In August 1998, the Henan Museum website was established and available online (Li W., 2008). The content on the website was mostly static text and images instead of multimedia (Pan, 2014), which was quite common in that era. Soon after, Henan Museum and Shanghai Museum, among others, took the lead in converting collections of cultural relics to digital forms (Li W., 2008). As we stepped into 21st century, new technologies such as VR, mobile network, mobile apps, 3D-modeling and 3D-printing further empowered museum digitization efforts around the world. Many renowned museums take digitization very seriously. Since 2012, nearly a third of major US art museums have created “Digital Director” or “Chief Digital Officer” positions (Brian Droitcour, 2016).

This research addresses operations of museums in modern era from a unique perspective - how to improve the quality of customers’ visiting experience through digitization. Quality is one of the key elements driving every consumption decision and an essential consideration in Operations Management. Quality management stemmed from manufacturing industry where quality of the physical products was emphasized. Later, as service industries have been growing rapidly, people start to focus on quality of service. Nowadays, as competition in business world becomes increasingly fierce, business organizations commit to provide customers not just the product or the service with the best quality, but the whole consumption experience with the best quality.

Quality of the consumption experience depends on quality of the physical product, presale service – such as ease of finding the item to buy; ease of ordering; rapid, on-time, and accurate delivery; as well as accurate payment processing – and post-sale support – including

ease of exchange and return, warranties, technical support, and field service. Business organizations will easily lose customers if they fail to provide satisfying consumption experience. On the other hand, if organizations are able to consistently provide superior experience to customers, they will attract new customers and be patronized by existing customers repeatedly. In the same vein, museums must deliver high-quality visiting experience in order to attract new visitors and keep visitors coming back for the purpose of “education, study, and enjoyment”, and digitization is an essential approach to achieve this goal in modern era. However, research on the operations of museum digitization aiming to improve the quality of visiting experience for visitors is scarce. This study fills the gap.

Nowadays, numerous museums have started or been making progress on digitization, thus many visitors pay online instead of on-site visits to museums. For traditional museum-goers who make physical visits, the quality of visiting experience depends on the collection on exhibit, the presentation of the art pieces, the description of each art piece, and the guided tours, if adopted by visitors. As for online visiting, since the limitation of time and space have been overcome, the quality of visiting experience mainly depends on interaction between visitors and the museum, which largely happens through the interface of IT. For example, online navigation must be intuitive and user friendly, digital presentation of the collection must be aesthetic and enlightening, connections to relevant art pieces and information should be displayed, email and mobile notifications of new exhibits and activities should be delivered, social media should be used effectively to reach and engage audience. These aspects will be illustrated and discussed for each of the six museums in the case studies sections.

The rest of the article is organized as follows: Firstly, the reasons of museum digitization are explained. Next, three cases of

museum digitization in China and three in the United States are investigated. A section that discusses and compares the operations of museum digitization in China and the U.S. follows. Suggestions for future development and improvement to each country, especially to China, are deliberated in the subsequent section. Finally, a conclusion section completes the whole study.

II. THE REASONS OF MUSEUM DIGITIZATION

There are several reasons when it comes to museum digitization. One of them is to preserve the vulnerable cultural heritages. Besides war and social upheaval, natural or man-made disasters such as earthquake, flood, tornado, and fire could damage works of art. On September 2, 2018, 200-year old National Museum of Brazil, the largest natural-history and anthropology museum in Latin America, caught on fire. Only 10% of the 20 million items in its collection survived (Yong, 2018). The lost specimens are twice as many as those in the entire British Museum. Although digital images, 3D models, and documentation are not equivalent to the physical objects, at least some information of the items would have been preserved, had the Brazilian museum digitized its collections. Some delicate cultural heritage sites – such as Dunhuang Mogou Grottoes in China, murals in pharaohs’ tombs at the Valley of the Kings in Egypt, and The Treasure (El-Khazneh) at Petra, Jordan – will gradually be corroded because of humidity, sunlight, heat, and other unfavorable environmental conditions. And the damages are irreversible. The same situation applies to ancient archives on fragile media. Digitization could help preserve these cultural heritages by avoiding overuse or overtourism, or at least preserving the information carried by these cultural heritages.

Another reason is to overcome the floor space limitation. Floor spaces of many museums are too limited to display all

collections, whereas the virtual space online is unlimited. This means that although visitors may never have a chance to see some of the collection items on-site, they could access them digitally. For example, it is estimated that there are about three billion natural history specimens around the world, while the Smithsonian Institution's National Museum of Natural History alone holds 145 million specimens (Smithsonian, n.d.1). However, only a tiny portion of this treasure trove have been put on display and seen by visitors (Rogers, 2016). Another example is the National Palace Museum in Taipei, whose collection is composed of nearly 700,000 items (The National Palace Museum, 2018). The museum can put only 3,000 objects on display at one time and the exhibitions are rotated once every three months. Thus, it would take more than 58 years for the museum to display its entire collection.

Besides, online exhibition of digitized collections can be used to reach larger audience. According to Internet World Stats (2018), more than half of the world population have access to internet nowadays. Any internet user could be a potential visitor to an online museum. Furthermore, digital exhibitions could complement the on-site museum visiting experience with immersive and interactive activities and rich information. Combining easy access, rich details, and satisfying visiting experience together, museum digitization could encourage and stimulate content sharing, public engagement and enjoyment, research, education, and further creative activities.

The next two sections investigate three distinctive cases of museum digitization in China and the United States, respectively. URLs of the six museums are listed in Table 1.

TABLE 1. MUSEUM URLS.

Museum Digitization Cases in China	URL
Palace Museum	https://www.dpm.org.cn/Home.html
Digital Dunhuang	https://www.e-dunhuang.com
Baidu Encyclopedia Digital Museum	https://baike.baidu.com/museum
Museum Digitization Cases in the U.S.	URL
Smithsonian Institution	https://www.si.edu/
Metropolitan Museum of Art	https://www.metmuseum.org/
Google Arts & Culture	https://artsandculture.google.com/

III. CASE STUDIES OF MUSEUM DIGITIZATION IN CHINA

3.1. Palace Museum

The Palace Museum is, with no doubt, the most well-known palace and one of the most famous museums in China. It opened its door for the first time in 1925 at the rear quarters of the forbidden city, which was an imperial palace built 600 years ago, during 1406-1420 (The Palace Museum, n.d.; Neville-Hadley, 2016). According to the Guinness World Records, the

forbidden city is the largest palace in the world (Guinness World Records, n.d.). The art collections of the Palace Museum are built upon the imperial collections of the Ming and Qing dynasties and have extraordinary artistic, cultural, and historical values.

The Palace Museum has been a pioneer of museum digitization in China. It started its journey of digitization and established Department of IT, Imaging, and Digital Media in 1998 (Gao, Hou, & Zhao, 2018). In 2001, it became the first museum in China to make available an online database that provided

digital resources – including text descriptions and images – of thousands of antiques in its collection (Yuan, 2017). The Palace Museum has been exploring applications of media-related technologies such as VR since 2000 and has built an enormous collection of high-definition 3D models of the museum's architecture and artworks (Ensign & Zhuang, 2017). Curators, researchers, and designers have been working together to combine these valuable 2D and 3D data with interactive technologies to digitally present the Palace Museum to audience online and in person.

On July 18, 2001, the Palace Museum developed its official website (Zheng, 2017) which dedicates to representing a “digital Palace Museum”, hence the acronym “dpm” appears in its official URL. In 2015, the English version of the website was overhauled and the youth version was released (The Palace Museum, 2015). Both versions have adopted modern designs and are specifically customized to their target audiences. The youth version is a pleasant surprise. Its child-friendly design features cute elements with many Palace-Museum-style details. On the website, kids can find stories written in easy-to-understand language, drawing competitions, a mini encyclopedia, a mini theatre, and games. So far, there have been more than 31 million visits to the Palace Museum websites and the satisfaction rate was 95% in 2017 (Shan, 2018).

Both Chinese and English versions have been optimized for mobile platforms, while the mobile site for youth version is under construction.

On the websites, especially Chinese version, rich digital resources can be explored, such as details about historical palace buildings, collections of various artefacts, old archives, history of the Forbidden City, and culture-based online exhibitions. One show is particularly exciting: Masterpiece Painting Exhibition (<http://minghuaji.dpm.org.cn/>), which shows ultra-high-resolution photos of 118 famous Chinese paintings from nine dynasties with multimedia tours available for some of them. On the zoomed-in screen, every detail is visible for these treasures (as displayed in FIGURE 1), most of which are rarely on display for security, conservation, limited floor space, or other concerns. On the screen, research articles related to the painting can be found under a drop-down menu and are downloadable. These features make the exhibition invaluable to researchers, educators, and aficionados around the world. Another impressive and immersive showcase is a virtual tour with audio narrations, the Panoramic Palace Museum, at <http://webapp.vizen.cn/gugong-pc/index.html>. It is also viewable on smart phone by scanning a QR code (Quick Response code, or a two-dimensional barcode).



FIGURE 1. MASTERPIECE PAINTING EXHIBITION ON THE PALACE MUSEUM WEBSITE.

For the Millennials and Generation Z (born around year 2000), social media have unparalleled influences. The Palace Museum didn't miss the chance of reaching out to young people. In 2011 the Palace Museum registered its official account on Weibo, the most popular Chinese microblogging website. By now, it has over six million followers. Even the Weibo account of its online store – the Palace Museum on Taobao – has more than 940k fans. Three years later, on another omnipresent social media platform in China, WeChat, an official account “Mini Palace Museum” was established (Zheng, 2017). The official account on WeChat offers Palace-Museum-related stories, notifications about on-site exhibitions, and online showcases of collections. Moreover, it offers the mobile version of the Panoramic Palace Museum and VR-enabled digital exhibitions. It is worth mentioning that the Palace Museum owns official accounts on Facebook, Twitter, and Instagram as well. However, unfortunately, it hasn't collected as many followers as on Weibo and WeChat.

Since early 2000, mobile devices have increasingly gained popularity. To take advantage of the new platform, in May 2013, the Palace Museum published its first mobile app, which was exclusively for iPad and called Twelve Beauties. The app introduces Chinese court lady paintings in an artistic and elegant classical-Chinese style. As of 2018, nine high-quality apps have been developed, with two specifically for kids. Palace Museum Daily, another app, shows users one artefact a day, getting people exposed to the Palace Museum's rich collection built upon 5000-year Chinese culture and 600-year history of the imperial palace. The latest app that released in 2017, Palace Museum Community, is as ambitious as it sounds. It has been trying to build an interactive virtual world for museum-goers and culture-lovers. After registration, a user can build a house in traditional architecture in the virtual community. She can earn points by publishing stories, reading others' stories, or

completing tasks. Then the house can be upgraded by using the points. In this way, people could live a life digitally in a previous dynasty. The app also integrates assets in 11 categories such as Palace Museum news and notifications, digital collections, tour guides, video resources, educational and research information, cultural re-creations (such as apps and souvenirs), and games.

Besides the pure digital resources, the Palace Museum strives to combine “virtual” with reality. Established in December 2015, the Digital Gallery at the Gate of Correct Department (*Duan Men*) was the first fully digital exhibition space in China that integrates historical architecture, traditional culture, and state-of-the-art digital technologies (Ensign & Zhuang, 2017). “The Palace is a Museum” was the first, and is the permanent digital exhibition at the Digital Gallery. The exhibition was built upon decades of meticulous scholarly research and had utilized high-resolution images and high-quality data carefully captured from physical architecture and artworks. The exhibition has three sections: *From the Forbidden City to the Palace Museum*, *The Exquisite Selection of the Museum*, and *The Forbidden City: The Palace for the Son of Heaven*. The first section is a digital demonstration of the architecture of the forbidden city. The second section includes seven interactive installations such as Digital Painting, Digital Treasure (showing interactive 3D antiques), Digital Court: VR Hall of Three Rarities (*Sanxi Tang*), and Digital Wardrobes. For example, “Digital Wardrobes” presents some exquisite garments that are fragile in reality and may never allow physical touches by the visitors. People can try them on virtually and take pictures. The last section, *The Forbidden City: The Palace for the Son of Heaven*, is a VR movie theatre with a 44x13.5 feet screen. So far, six immersive VR short films have been produced (Szzs360, 2016). Through the films, audience can appreciate the history, construction, and aesthetic design of the palace

architecture. The Digital Gallery opens up a new gateway for a deeper understanding of the Palace Museum.

After more than one year of preparation, the second digital exhibition called “Discovering the Hall of Mental Cultivation (*Yangxin Dian*): A Digital Experience” was released in October 2017 (Ensign & Zhuang, 2017). It featured large-scale immersive projecting screen, VR headset, motion capture equipment, and touch screen. Using Artificial Intelligence (AI), VR, image and voice recognition technologies, the exhibition let visitors have a conversation with court ministers, cook imperial cuisine according to historical recipes, or even “wander” in the emperor’s residential hall. It is more interactive than the first and permanent exhibition (“The Palace is a Museum”) because it allows visitors to use a mini program on WeChat (as shown in FIGURE 2) to interact with the exhibits. For example, a tourist can “take” an antique off the digital Cabinet of Curiosities (*Duobao Ge*) and add it to the personal digital collection on her smart phone by scanning a QR code. Through the interactive displays, visitors build profound understanding of the Palace Museum’s history and culture in a fun and exciting way. This digital exhibition has received the Digital Interactive Installation Gold Award at AVICOM Festival of Audiovisual International Multimedia Patrimony 2018 (AVICOM, 2018), where AVICOM is the ICOM’s (International Council of Museums) International Committee for Audiovisual, New Technologies and Social Media.

Beyond projects like the Masterpiece Painting Exhibition (collaborated with Beijing University of Technology) and the Panoramic Palace Museum (partnered with a 3D-modeling company, VIZEN), there are others accomplished by alliances between the Palace Museum and other organizations. In 2016, the Palace Museum established a partnership with Tencent, an IT giant in China and one of the most valuable technology companies in the

world. They created an online cartoon story “Echo in the Palace Museum,” which is the first cartoon created by a museum in China (<https://www.dpm.org.cn/huishengs.html>) (Gao, Hou, & Zhao, 2018). At the end of the following year, the two organizations announced the establishment of a joint innovation lab. Tencent will contribute to the digitization and popularization of cultural heritage at the Palace Museum by providing such technologies as AI, big data, and cloud computing (Tang, 2017). The collaborations are not limited to domestic organizations. In 2017, the Palace Museum landed on Google Arts & Culture (The Palace Museum, 2017). So far there are descriptions and high-resolution photos of 125 items of the Palace Museum’s collection available on Google Arts & Culture, as shown in FIGURE 3.

The Palace Museum has over 1.8 million artifacts in its collection, but only 2% are on display (Shan, 2018). Sharing digital resources online allows visitors get to know more items in its collection than otherwise. It spurs people’s interests in the Palace Museum as well as in Chinese history, culture, and art in general. The online digital resources can also facilitate education, research, and other creative activities, such as crafting new artworks and cultural products.

As a summary, the strengths of the Palace Museum in digitization include its vast digital collections, rich digital contents and exhibits, well thought-out and designed website and apps, active reach out to younger generations, and collaborations inside and outside of the museum, while its weakness is that the mobile site for youth version is not yet available.

3.2. Digital Dunhuang

The Dunhuang Mogao Caves, also known as the Thousand Buddha Grottoes, is located about 16 miles southeast of the town of Dunhuang in northwestern China. There are 735 extant caves (while 492 contain artworks),

about 484,000 square feet of frescoes, and 2,415 surviving brightly painted clay sculptures, among which the largest is over 100 feet tall (Dunhuang Academy, 2014). The construction of the Mogao Caves spanned from the fourth through the fourteenth century (Wang Y., 2018). Mogao Caves contain the world's largest collection and some of the finest examples of Buddhist art spanning over 1,000 years.

Although located in the distant Gobi Desert, many visitors are attracted to the Mogao Caves to see the great art treasures, which raises a big concern to the conservation of the caves and the artworks within. The site can support an

optimal capacity of 3,000 visitors per day, but more than twice that many visitors flock to the caves during peak times (Wang Y., 2018). The Mogao Caves are vulnerable to overtourism. Humidity and carbon dioxide brought by a great many visitors accumulate to cause flaking and discoloration of the delicate frescoes as well as damage to the sculptures. In addition, natural threats to the art works include the sandy environment, sandstorm, wind, and rainwater. Conservation of the caves is an ongoing challenge.



FIGURE 2. THE MINI PROGRAM OF DIGITAL GALLERY AT THE GATE OF CORRECT DEPARTMENT ON WECHAT.

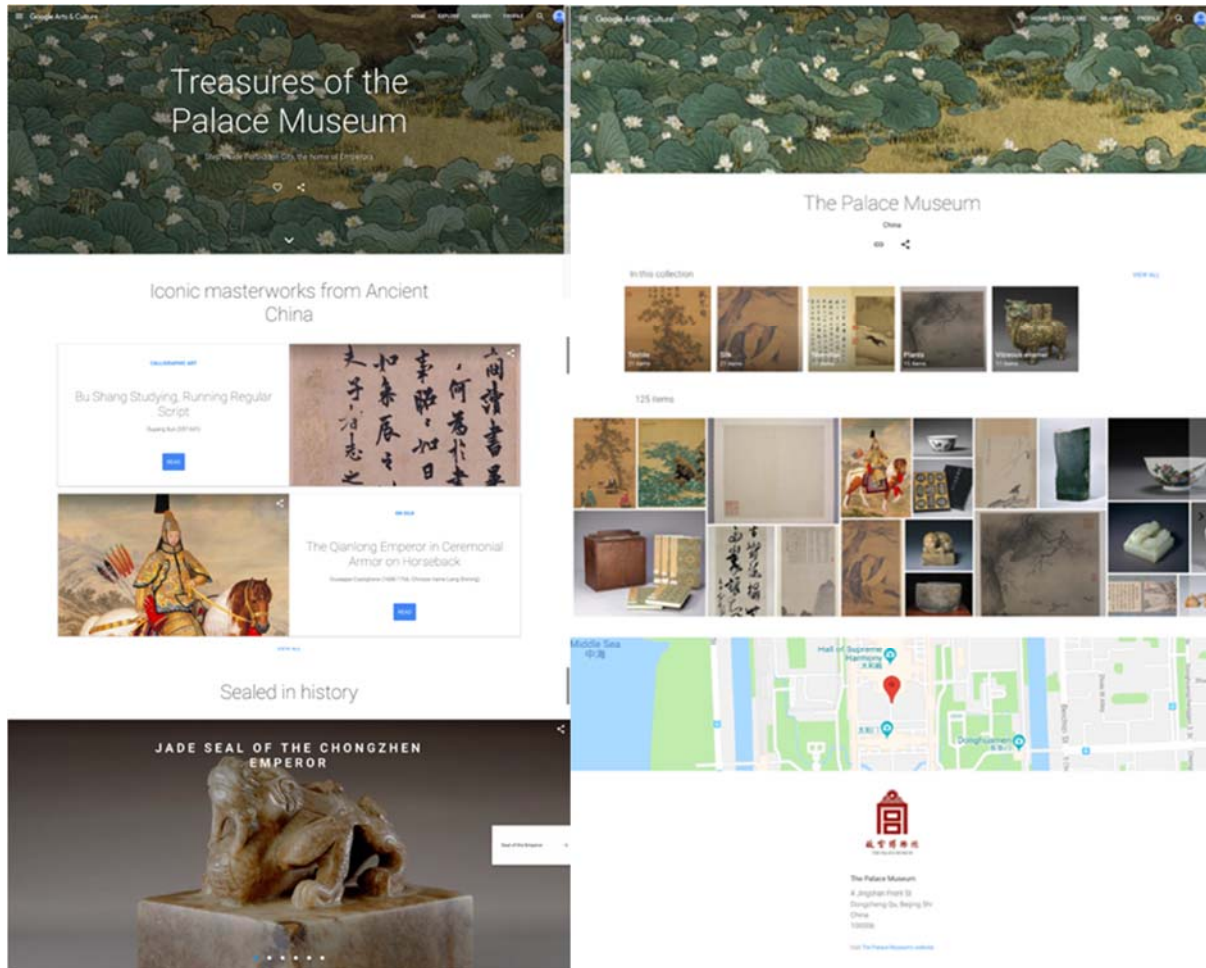


FIGURE 3. THE STORY PAGE OF THE PALACE MUSEUM AND COLLECTION PAGE OF THE PALACE MUSEUM ON GOOGLE ARTS & CULTURE.

Preservationists are desperately trying to digitize all relics before they are gone forever. The Dunhuang Academy launched the Digital Dunhuang Project in 1999 to protect the historic site and relics, preserve cultural heritage, and promote cultural inheritance and exchange. This project is “pursuing overall digitization, including collection, processing and storage of the Dunhuang Grottoes and related cultural relics by using advanced science and technology,” as stated on the official website of Digital Dunhuang. According to the Dunhuang Academy, the project intends to integrate different types of data including photographs, videos, 3D data, and other literature material into a digital repository of cultural relics, and

then share it globally through internet. The project has made significant progress since 2011 when Microsoft Research Asia donated a video camera – Apsara – with a resolution of 1.3 billion pixels, to the Academy to digitally archive the caves.

The niches holding the sculptures are not on flat surfaces and have complex depth variations, thus it is not possible to use a traditional camera to capture all elements in focus. Apsara, however, is capable of capturing numerous pictures of the same object using different focuses, and then by using the “focus-stacking” process, software compiles the images so that everything in the final picture is in focus (CCITimes, n.d.). Hence, high-quality

photos of the niches and caves can be taken. Furthermore, due to the ultra-high definition and vividness of colors, although the picture is two-dimensional, it is so lively that it looks like three-dimensional. These high-quality 3D-looking photos provide exceptional immersive experience for remote visitors who digitally visit the Mogao Caves.

In 2012, the Arthur M. Sackler Gallery in Washington, D.C. offered a glance at the ongoing Digital Dunhuang project. By putting on 3D glasses, visitors were transported into a spectacular “virtual” Mogao grotto, the Cave 220, which is one of the representative caves of Tang dynasty (Liu, 2012). The 3D, interactive experience is filled with vivid colors, close-up details, moving images of the exquisite frescoes, full-view navigation, and sound effects. Visitors can enjoy an animation of fluttering scarves of Bodhisattvas in a virtual breeze and watch a fancy harp being magnified and rotating in 3D form while the sound of it plays from hidden speakers. To enhance visitors’ interactive experience, the Tang dancer paintings are brought to life with the help of the Applied Laboratory for Interactive Visualization and Embodiment (ALiVE) at the City University of Hong Kong. Two Chinese dancers were filmed over and over performing intricate steps, fluid movements, and elegant manipulation of long, sinuous ribbons (Liu, 2012). They appeared in the virtual tour as performers in Tang-dynasty costumes dancing out of the paintings, in front of the visitors. Since 2013, the same technologies have been used in a touring exhibition for universities in China (Art China, 2013). The visitors highly acclaimed VR roaming and replicated murals and sculptures printed from ultra-high-definition (UHD) digital images captured by Dunhuang Academy. There was even a replicated cave at the exhibition. Even those who had visited Dunhuang on-site believed they saw more details on the replicas.

When become available, more advanced technologies are utilized to improve the

digitization process. Three-dimensional scanning and reconstruction, as well as panoramic roaming technologies are used, in addition to high-definition (HD) photography and computer image processing. Lidar (light detection and ranging) laser scanning is employed to measure exact distances, while 360-degree panoramic images are produced by using fisheye lenses (Carter, 2017). The 3D mapping data generated by Lidar and fisheye lenses are perfect for VR reproduction.

Digital Dunhuang has been officially online since May 1, 2016, presenting to the world 30 classic caves with 3D panoramic roaming (Fu, 2018). In September 2017, the English version of the website was released (Fu, 2018), so these unique Buddhist arts can be accessed and enjoyed by a larger audience worldwide. It was so popular that there were 3.47 million visits in 2017 (Xinhuanet, 2018). FIGURE 4 shows one of these caves in panoramic view on e-dunhuang.com. The digital exhibitions on the website are part of the efforts to preserve the actual caves. In the real caves, there are no lightbulbs because they are damaging to light-sensitive murals, and once the humidity and temperature in a cave reach critical levels, the cave is closed to public access (Liu, 2012). Virtual tours, on the other hand, have no such worries and are much more visitor-friendly. Moreover, in a virtual tour, visitors can zoom in to check details on the wall or click on a marker to open a picture of mural (as shown in FIGURE 5), or even enjoy a VR experience with assistance of VR devices. Users can also easily switch back and forth between frescoes from different dynasties to identify and explore the differences. These digital presentations provide visitors an alternative virtual experience of being in the caves, which is immersive, interactive, and exciting, so visitors won’t feel the need to physically visit every accessible cave or remain inside the caves for long. Visitors can “stay” at the digital caves as long as they want to explore more and look closely, without worrying that buildup of the

exhaled carbon dioxide would disturb the temperature and moisture balance of the caves. As a result, stricter time limits and lower numbers of visitors allowed in the real caves can

be set to better protect these caves (Khan Academy, n.d.), thus reducing the impacts of tourist presence on the caves.

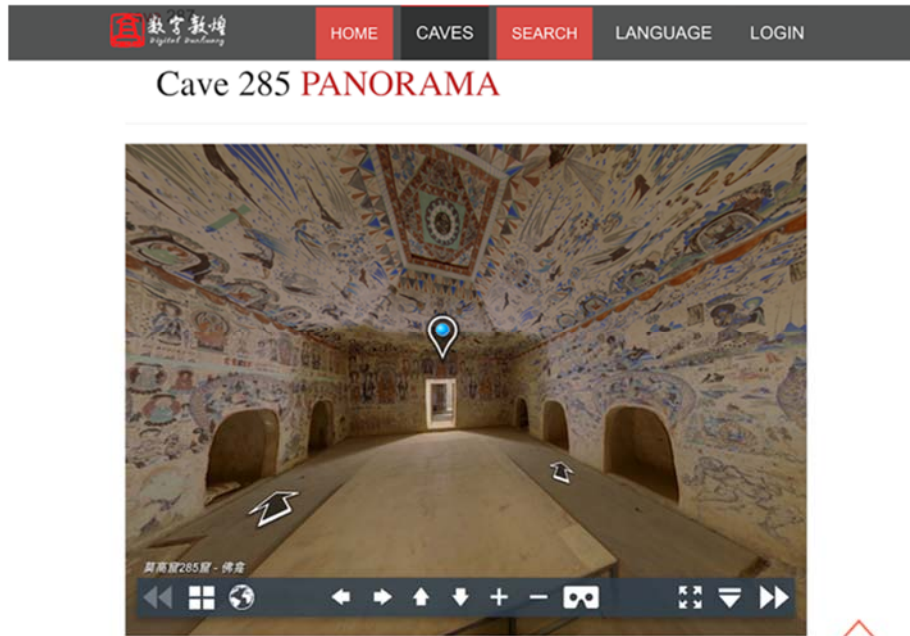


FIGURE 4. VIRTUAL TOUR OF CAVE 285 ON DIGITAL DUNHUNG WEBSITE.

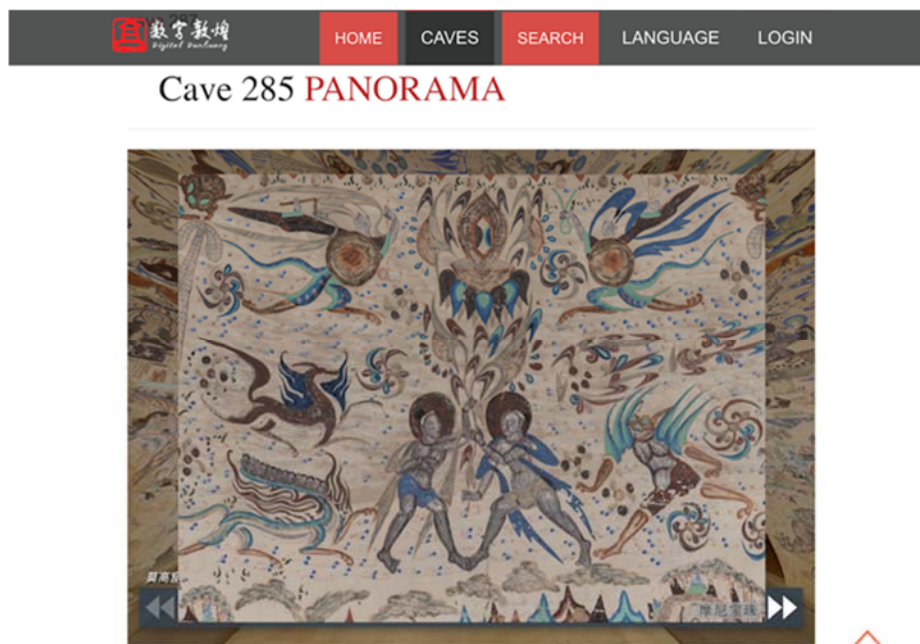


FIGURE 5. A MURAL IN THE VIRTUAL TOUR OF CAVE 285 ON DIGITAL DUNHUANG WEBSITE.

The navigation on its website is simple. With a few options listed on the top and some classic caves and murals populating the homepage, visitors can find what they want easily. Furthermore, users can search the site based on keywords or, even simpler, they can just enter a number in search box to find the corresponding cave, since all caves are named after numbers. The online exhibit of a cave is quite informative and includes basic information and introduction of the cave, a panoramic view, and content navigation showing different portions of the main chamber and corridor. In addition, the website has been optimized for mobile devices so people can “visit” these caves and enjoy the murals on their smartphones and tablets. However, unfortunately, the VR function is not available on the mobile site. Overall the web design is

clean and concise, but it is not artistic and doesn’t reflect the distinctive style of Dunhuang’s Buddhist artworks. Furthermore, by the end of 2017, more than 180 caves had been digitized, but still only the same 30 caves are viewable online by November 2018. No new digital exhibitions have been made accessible to the public since 2016, possibly due to copyright concerns. Also, there are no online material specifically made for kids. And no educational or research resources can be found on the Digital Dunhuang websites. Dunhuang Academy’s own website (<http://dh.dha.ac.cn>, as shown in FIGURE 6), on the other hand, focuses mainly on research and provides enormous academic resources and scholarly articles. In addition, there are some tourism information and multimedia content (such as panoramic roaming tours) on the website.



FIGURE 6. DUNHUANG ACADEMY WEBSITE.

Beyond websites, digital resources are also used at the Digital Exhibition Center at Dunhuang. On-site tourists watch a short film introducing Mogao Caves and view statues and murals in interactive multimedia presentations before they enter the actual caves. This helps reduce the length of time visitors stay in the

caves, while enriching their visiting experience (Wang Y., 2018).

In addition, Dunhuang Academy uses social media to reach audience and complement their online and physical visiting experience. They created an official account on WeChat that provides overview of the Mogao Caves, 360-

degree virtual tours and audio narration of caves, and introduction of caves in text. The official account also offers maps, guides to tours, as well as some cultural creative products, for example, monthly calendar with appealing pictures of frescoes. Since the official account on WeChat delivers a rich set of features, it resembles an app. Furthermore, Dunhuang Academy has an official account on Weibo and they use it to promote Mogao Caves and related culture and artworks to the public. Currently, they have over 220,000 followers on Weibo.

To make these achievements in digitization, Dunhuang Academy has collaborated with various organizations. Besides aforementioned Microsoft and City University of Hong Kong, it worked with Tencent to create a mini program on WeChat to provide an interactive tour map for on-site visitors. Additionally, Dunhuang Academy collaborated with Harvard University on a project – Interpreting Dunhuang Caves on Digital Media – in 2018 (Fu, 2018). Also, along with 22 institutions in 12 countries, Dunhuang Academy joined the International Dunhuang Project (IDP), which was founded by British Library in 1994 (IDP, n.d.). IDP is an international collaboration with focus on research and conservation through digitization. Its website (<http://idp.bl.uk/>) supports seven languages and provides more than 143,000 catalog entries and 522,000 digital images.

Overall, the strengths of the Digital Dunhuang include the ultra-high-definition images of the unique murals and simple website design. Weaknesses are: contents online are not updated in a timely manner – in fact, they have not been updated for a few years; most contents are plain description of what's on the murals; better content needs to be generated for education and enjoyment purposes.

3.3. Baidu Encyclopedia Digital Museum Project

Baidu, a Chinese technology giant, also one of the largest technology companies in the world, launched Baidu Encyclopedia Digital Museum (BEDM) on January 4, 2012, with six museums including National Museum of China (Donews, 2012). On May 18 of the same year, the system was upgraded to version 2.0 and included eight more museums including Shanghai Museum (ifeng, 2012). By 2013, more than 40 museums had joined the BEDM, which also launched the first 360-degree virtual tour of museum in China – Panoramic Yungang Grottoes Museum – on July 25 (NetEase, 2013). According to the BEDM website, in May 2014, version 3.0 was announced and became the largest online museum platform in China, presenting museums with various technologies such as AR, 3D exhibits of cultural relics, QR code scanning, and high-definition panoramic virtual tours. As of November 2018, there have been more than 90 million visits to the BEDM website. Furthermore, 245 museums in China have joined BEDM and have their collections digitized in various ways, while 1,632 museums can be found in Baidu Baike – Baidu's collaborative online encyclopedia (China's counterpart of Wikipedia) – mostly in short entries with some description and a few pictures though.

In addition to building up the digital collections for museums in China, BEDM started to explore the world recently. In cooperation with the China-based Gaudí Asia-Pacific Research Institute and the Gaudí World Congress, BEDM launched the first online museum in the world dedicated to renowned Spanish architect Antoni Gaudí in December 2017 (CGTN, 2018). This is BEDM's first overseas digital museum, showcasing digitized works and designs of this genius architect, including the famous Sagrada Família (Huang, 2017). In 2018, BEDM has attempted to further its collaboration with Spain to build a digital exhibition of “the Camino de Santiago” (i.e. the Way of Saint James), one of the most important and well-known Christian pilgrim routes since

the Middle Ages. The digital project will cover numerous cultural heritage sites – more than 250 towns and over 800 churches, castles, and museums – with audio narrations, VR simulation, and 3D exhibitions (CGTN, 2018). The project was planned to be finished and brought to public later (Wang K., 2018).

July 2018, Château de Fontainebleau became the second foreign museum collaborating with BEDM. The online exhibition is presented in Chinese and French (a visitor has to choose one on the frontpage). The digital platform employs VR, ultra-high-definition virtual tour, aerial photographing, and celebrity narrators to create an interactive,

immersive experience (Li Y., 2018). The result is truly breathtaking. The decorations and treasures exhibited in the virtual palace are very detailed and vivid. The navigation is smooth and effortless. Nothing could be better than this, except an in-person visit to the Château de Fontainebleau. A VR interface on smartphone is shown in FIGURE 7. Moreover, on September 14, 2018, BEDM signed a memorandum of understanding (MOU) with representatives of Mexico, Austria, and Germany to broaden the cultural collaboration with these countries and further expand BEDM's digital museum outreach (China.com.cn, 2016).



FIGURE 7. VR INTERFACE OF BEDM'S CHÂTEAU DE FONTAINEBLEAU ON IPHONE.

A special move is that BEDM and NAMU label, in August 2018, jointly developed Original Voice Museum presenting folk music from western China such as Gansu, Tibet, Xinjiang, and Inner Mongolia (Sohu, 2018). Although there are only ten folk music audio clips available in the Original Voice Museum by now, it is a unique attempt in the world of digital museum and the beginning of a valuable contribution to preserving intangible cultural heritage in China. One downside, however, is

that it is designed for mobile platforms and doesn't show up properly on computers (<http://baike.baidu.com/museum/benyuanshengyin>).

BEDM's website is more optimized for mobile platforms than for desktop computers. The desktop website's layout and design look good but the featured stories won't change from day to day. The map of China on the site zooms in and shows the selected province or highlighted city and a brief message about a key

museum in the area pops up when mouse pointer moves over the museum marker. A search box and a list of related museums are next to the map. It looks sleek and nice, as shown in FIGURE 8. However, users can only search based on museum names. The search cannot be done based on items, categories, or themes. Furthermore, the AR exhibit shown on

desktop website doesn't work very well and is awkward – one has to print out an image and aim it to a computer's video camera to initiate AR. Generally, AR works better on mobile devices since users can aim them at a target more easily. Unfortunately, the AR exhibit is not available on BEDM's mobile website.

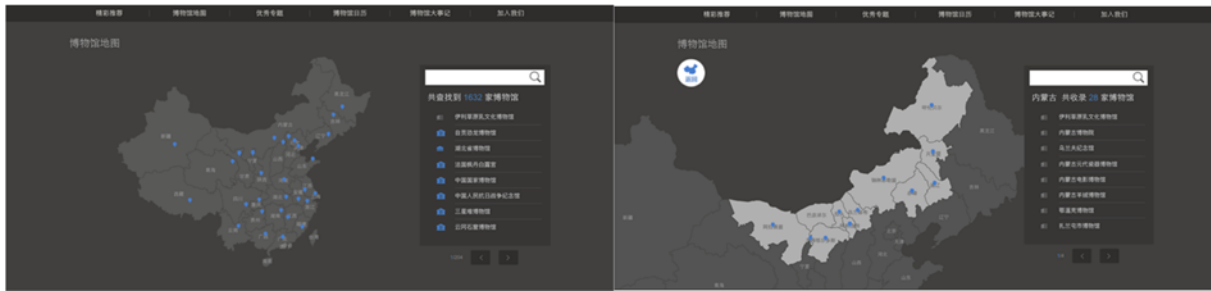


FIGURE 8. MAP AND SEARCH ON BEDM'S WEBSITE.

On desktop website's homepage and other webpages, users can scan a QR code to bring up the mobile site on a smartphone or tablet. The mobile website of BEDM, comparing to its desktop site, is better designed and teemed with more functions and features. It borrows the infinite scrolling design from Pinterest, Instagram, Weibo, and WeChat Moments alike. Visitors can scroll down endlessly as the website loads more museums. On the mobile site, users can search based on items as well as museum names, but nothing beyond that. As for virtual tours of museums, they look great on portable devices (as demonstrated in FIGURE 9).

On both desktop and mobile sites, digital exhibition of a museum is organized with a combination of a few elements including 3D objects, pictures (quite often not in high definition), audio narrations, and 360-degree virtual tours. Under a short description of the museum, there are two links leading to the corresponding Baidu Baike entry and the official website of the museum, respectively.

Surprisingly, Baidu Encyclopedia Digital Museum hasn't utilized social media to connect with visitors. Its presence can't be

found on WeChat, Weibo, or other popular social networks in China. Baidu Inc., however, does make announcements on social media, even Twitter and Facebook, when some new digital exhibitions are available on BEDM. But there is basically nothing beyond that.

So, essentially, Baidu Encyclopedia Digital Museum is an assortment of museums presented in digital format only, with no physical presence. Each display is about an individual museum. There is hardly any story or exhibition across institutes, for example, a presentation of dinosaurs based on timeline from different museums or a story about Chinese calligraphy integrating calligraphic collections across galleries and museums.

To sum up, the strengths of the Baidu Encyclopedia Digital Museum (BEDM) are large collections of Chinese museums and some advanced media technologies including VR and Virtual Tours. Some individual exhibits are quite visually attractive. The major weakness is that BEDM simply displays everything on the website instead of putting the vast collections and advanced technologies into meaningful use, such as creating across-museum stories and exhibits.

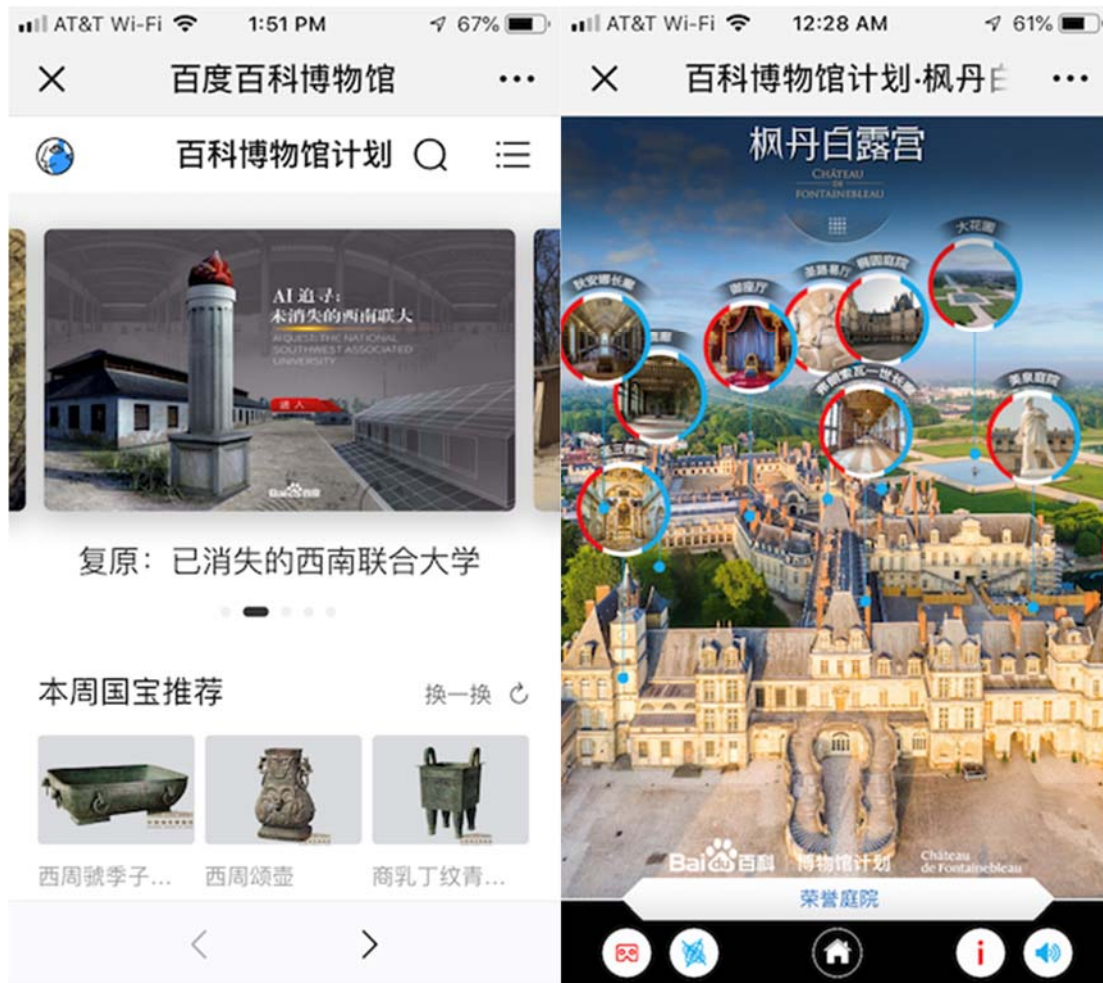


FIGURE 9. MOBILE WEBSITE OF BEDM.

IV. CASE STUDIES OF MUSEUM DIGITIZATION IN THE UNITED STATES

4.1. Smithsonian Institution

The Smithsonian Institution (SI) was initially founded and funded by the British scientist James Smithson in 1846 "for the increase and diffusion of knowledge." It reveals that the major mission of SI is on research and education, which is clearly reflected by the top-level domain of ".edu" in its web address. Today, it is the world's largest museum, education, and research complex (Smithsonian, n.d.2). Besides the National Zoo, the SI holds 19 museums, galleries, and gardens (such as the

renowned National Air and Space Museum, National Museum of Natural History, and Cooper-Hewitt Design Museum), as well as nine research centers covering areas of sciences, arts, and environment. Researchers around the world benefit from the vast collections of the SI in conducting their research to further human knowledge. By 2017, there are 155.1 million objects and specimens in the collection (Smithsonian, n.d.3), which makes the Smithsonian Institution truly the "Nation's Attic," as people say. However, unfortunately, majority of these treasures get stashed away in the "attic" while only 1-2 percent can be seen on display in the museums at any given time (Grebenstein, 2016). Digitizing the collections

substantially improve the accessibility and make them available anytime, anywhere for education, research, and enjoyment.

One of the SI's strengths is the uniqueness and independence of its multiple museums and research centers. This strength, however, also poses a challenge to its digitization process: the collection of more than 155 million items are stored in 41 facilities (McQuaid & Rahaim, 2017) and some objects of a single topic exist in multiple museums – for instance, photos of American Indians can be found in the National Museum of American Indian, the National Anthropological Archives, and Smithsonian Libraries (Kalfatovic, Kapsalis, Spiess, Van Camp, & Edson, 2008). Furthermore, although Smithsonian Institution's website serves as a portal –

providing a page of basic information for each museum such as dining, floor plan, and digital resources like collection sampler, exhibitions, and events – each museum manages its own website (though many are hosted at si.edu) and one site could look drastically different from another. FIGURE 10 shows the different designs on websites of the National Air and Space Museum (NASM) and the National Museum of Natural History (NMNH). It is clear that the former has a more modern design (larger-size visuals and spanning across the whole screen with HD resolution of 1920x1080 or higher) and the latter still sticks to an old-fashioned style (to suit the lower screen resolution of 1024x768 that was mainly used ten to twenty years ago).

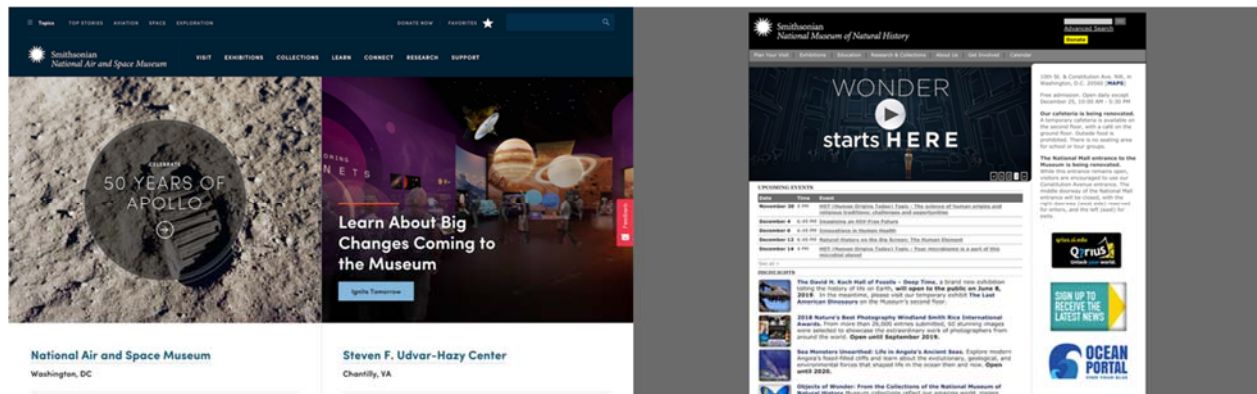


FIGURE 10. HOMEPAGE OF THE NATIONAL AIR AND SPACE MUSEUM (ON THE LEFT) AND HOMEPAGE OF THE NATIONAL MUSEUM OF NATURAL HISTORY.

Due to the aforementioned challenge, in August 2006, the Smithsonian created a Digitization Steering Committee to initiate a cross-museum discussion on digitization at the Smithsonian (Kalfatovic, Kapsalis, Spiess, Van Camp, & Edson, 2008). As a result, in fall 2009, a pan-Institutional Digitization Strategic Plan of “*Creating a Digital Smithsonian*” was developed. The purpose is to “broaden access, preserve collections, support education, and enrich context” (Smithsonian Institution, 2010). One of the strategic goals is to build a centralized Digitization Program that works

with all 19 Smithsonian museums and nine research centers to implement the strategic plan and integrate digitization into the core functions of the Smithsonian (Smithsonian Institution, 2010). Thus, as a division of the Smithsonian’s Office of the Chief Information Officer (OCIO), Digitization Program Office (DPO) was established with a mission “to increase the quantity, quality, and impact of digitized Smithsonian collections” (Smithsonian, n.d.4).

One exciting technology employed by Smithsonian’s DPO is 3D modeling, which provides more immersive experience and much

richer information of the subject. As early as 2012, SI scanned and created an exceptionally detailed 3D model of a Thomas Jefferson statue in Virginia, and then used 3D printing technology to build the "largest 3D-printed museum-quality historical replica" on the Earth, for the installation of one of its own exhibits in Washington D.C. (Termidan, 2012). Now visitors can interact with 3D models online using the Smithsonian X 3D Explorer (Beta version for now), which allows users to rotate, zoom, pan, and even measure the 3D models. Additionally, users can change opacity, lighting (strength, color, etc.), and shading (wireframe, or x-ray), or split the screen and show two 3D models side by side. The advanced feature will be vastly useful for researchers, educators, artists, and aficionados alike. Some 3D models are accompanied by guided tours and are hugely popular, such as the woolly mammoth skeleton and the Apollo 11 command module, as shown in FIGURE 11. There are also some Chinese cultural relics such as Square Lidded Ritual

Wine Container (Fangyi or 方彝) with Taotie, Serpents, and Birds. The 3D model even allows users to read the interior inscriptions of the Fangyi, as demonstrated in FIGURE 12. At the SI, 3D modeling technology has been increasingly used for cultural relic conservation, scientific research, and public education purposes. For example, the gunboat Philadelphia, built in 1776, has been regularly 3D-scanned so that early signs of deterioration on the wooden structure could be detected and remedies could be implemented. Two life masks of Abraham Lincoln, casted on the former president's face in 1860 and 1865, have been 3D-scanned. The resulted 3D models can be explored online, or, even better, downloaded and printed with a 3D printer, which have been done by many U.S. schools (Lohr, 2014). One drawback for the SI's online 3D collection, however, is that there are only 99 models available for public to use (<https://3d.si.edu/browser>).

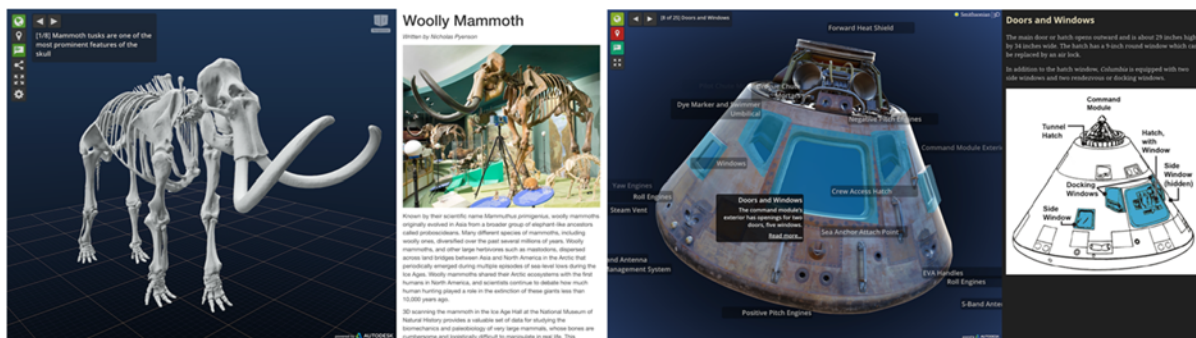


FIGURE 11. 3D MODELS IN THE SMITHSONIAN X 3D EXPLORER ON THE SMITHSONIAN 3D PROGRAM WEBSITE.

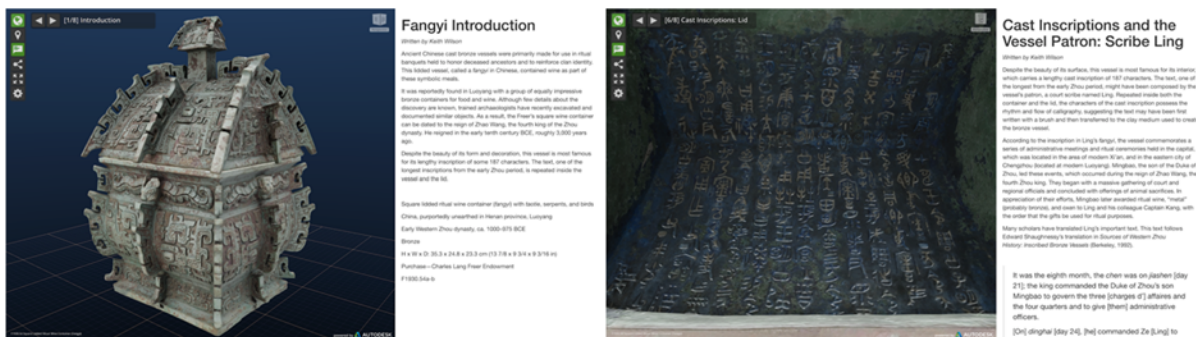


FIGURE 12. 3D MODEL OF FANGYI ON THE SMITHSONIAN 3D PROGRAM WEBSITE.

Due to the large quantity of items in the Smithsonian's collections, the Mass Digitization program initiated by the DPO strives to digitize the collections as quickly and cost-efficiently as possible without compromising the quality. In 2014, the program invented a conveyer-belt imaging system with a custom-designed 80-megapixel digital camera. The system involves multiple automations to remove inefficiencies (Kutner, 2015). Before such technology was available, digitizing what the new system could accomplish in days would have taken years. And this "rapid capture" system reduces the digitization cost from \$10 to less than \$1 per item (Kutner, 2015). In a pilot project in 2014, the project team digitized 45,000 bumblebee specimens in 40 days, at a rate of 700 to 1,300 bees per day (Kutner, 2014). Later on, Mass Digitization program took just 18 months to complete digitization of over 180,000 objects for the SI's Cooper Hewitt Design Museum. By now, almost the entire collection of Cooper Hewitt is available online. Freer and Sackler Galleries of the SI, instead, spent 15 years (2000-2015) to digitize its collection of 45,000 items with traditional approaches (McQuaid & Rahaim, 2017). Mass digitization of entire collections opens up new ways of doing research while sporadic digitization can't. For example, data visualization, network analysis, statistical analysis, and machine learning could perform better on the entire digitized collections since such collections can be treated as complete data sets (McQuaid & Rahaim, 2017). These innovative ways of "seeing" collections will generate new insights and make Smithsonian's digitized collections more meaningful,

inspirational, and significant. DPO had digitized one million museum objects by June 2016 (Barrat, 2016), and two million before the end of 2017 (Smithsonian DPO, 2017). Comparing to 2D photographing, 3D capture and processing are much more complicated and take much longer time, which leads to a high-cost and low-output 3D digitization process. The DPO is trying to find a more scalable and automated 3D processing solution to improve the efficiency of 3D digitization at the SI (DPO 3D, 2017).

The Smithsonian also actively collaborates with other institutes and companies on its digitization effort. For example, Google's Expedition mobile app uses AR to present 3D models of art collections from Freer and Sackler Galleries. These AR presentations can be used in classroom to enrich students' learning experience. FIGURE 13 shows a 3D-modeled antique on top of a table.

Now, among 155 million objects and specimens in the SI's collections, in addition to countless archives and millions of library volumes, 29 million have been described by digital records and around 4 million have been represented by digital images (Smithsonian, n.d.3). Among them, 14 million digital records and all images can be searched online by public at <http://collections.si.edu/search/index.htm> and some intriguing collections and stories created based upon these digital materials can be explored and searched at <https://www.si.edu/explore>. Both are shown in FIGURE 14. Moreover, visitors can also search or discover online exhibitions at <https://www.si.edu/exhibitions/online>.



FIGURE 13. AR EXHIBIT OF FREER AND SACKLER COLLECTION IN GOOGLE'S EXPEDITION APP.

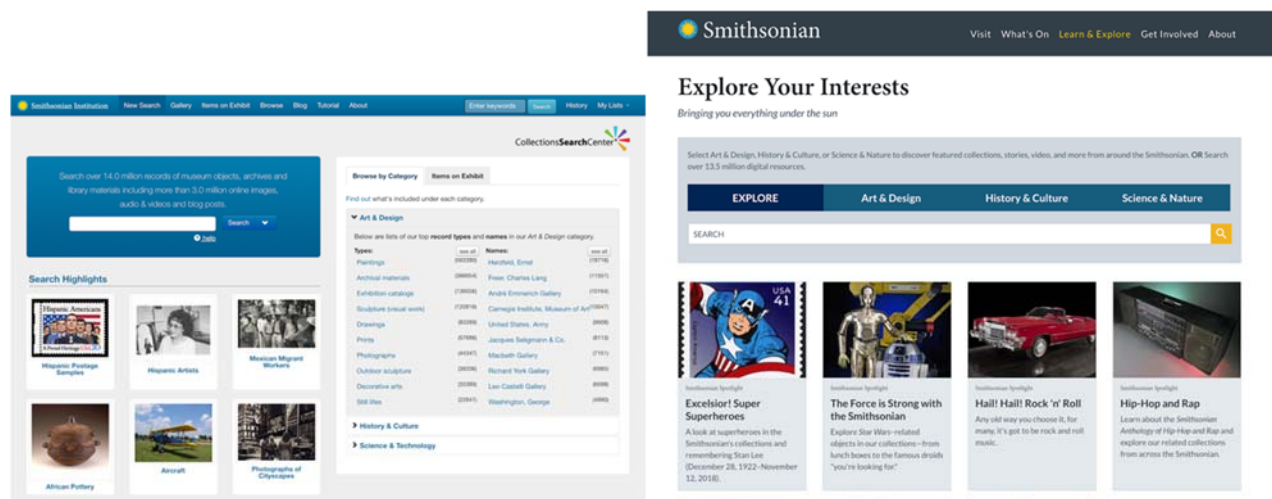


FIGURE 14. THE SI COLLECTION SEARCH CENTER AND THE “EXPLORE YOUR INTERESTS” WEBPAGE.

In the year of 2018, 28.8 million visitors have seen the collections in person, while 160 million online visitors have accessed SI's digital resources across its numerous websites (Smithsonian, 2018). In Smithsonian's next five-year strategic plan (2017-2022), one of the ambitious goals is to "reach one billion people a year with a digital-first strategy" through exploring new museum-related technologies, taking advantages of mobile platforms, partnering with major digital leaders, and providing better accesses for researchers and educators (Smithsonian, 2017).

From 2013 to 2016, the Smithsonian Center for Learning and Digital Access (SCLDA) conducted intensive research on the potential educational impact of SI's rich digital assets and on how to empower learners to explore their interests. As the result, a new Web-based platform called Smithsonian Learning Lab (<https://learninglab.si.edu/>) was created in June 2016 to satisfy students' and educators' needs to discover and creatively utilize the SI's digitized collections to learn and collaborate (Milligan, Wadman, & Ausland, 2017). The SCLDA will keep measuring and researching on user activities, and developing recommendations for the Smithsonian Learning Lab to consistently improve future visitors' learning experience. There are also a dedicated platform for educators (<https://www.si.edu/educators>) and a Science Education Center (<https://ssec.si.edu/>), as well as a fun site for kids (<https://www.si.edu/kids>). In 2018, 11 million people have been served by SI's education programs, face-to-face or online (Smithsonian, 2018).

Overall, the Smithsonian Institution's web design may not be as fancy as that of some other museums (for example, the Met), but it provides vast searchable and downloadable digital resources for general public to enjoy, for students and educators to learn, and for scholars to study.

In a word, SI's strengths are huge amount of digital collections, especially the

natural history specimens; the efficient and cost-saving mass digitization process; the excellent searchable online access to the collections; and the resources oriented toward kids. The weakness is that the online interface is sometimes confusing, due to the complexity introduced by its multiple museums and the vast collections held individually.

4.2. Metropolitan Museum of Art

Located in the New York City, the Metropolitan Museum of Art, also known as "The Met", is one of the world's largest and finest art museums (The Met, n.d.3). The Met was founded in 1870 to bring art and art education to the people of the U.S., and it opened in 1872. With a permanent collection containing over two million works, the Met welcomed more than seven million visitors in 2016 and became the third most visited art museum in the world (Hunter, 2017). Its permanent collection is divided into 17 curatorial departments covering a wide variety of cultural heritages and art forms.

In order to meet the ever-growing demands of external users and internal staff, the Met established the Digital Media Department in November 2009 (Tallon, 2017). It leads the "creation, production, presentation, and dissemination of multimedia content to support the viewing and understanding of the Met collection and exhibitions, both within the galleries and online" (The Met, n.d.1). The Digital Department consists of three teams, each accountable for distinct functions: Collections Information team manages the collections information system, digital assets, and rights and permissions for digital content; Content team produces multimedia content, manages content on the website, and provides editorial services for digital content online and on-site; Product Development team is responsible for design, development, and management of all public digital platforms (Tallon, 2017).

According to the Chief Digital Officer (CDO) of the Met, Loic Tallon, as digitization becomes more and more critical for cultural institutions to build relevance and participation in society, responsibility for digital transformation should be cultivated and distributed across the organization, rather than being limited within a single department (Tallon, 2017). Digitization is not only the responsibility of the Digital Department, but a shared one of the whole institution. As a matter of fact, numerous departments have actively engaged in digital-related activities, for example, digitizing and cataloging fragments of art works by Department of Greek and Roman Art, 3D scanning and photogrammetry by Imaging Department, and livestreaming the public events by Education Department (Tallon, 2017).

Besides the effort put on digital transformation within the organization, the Met has been devoting to enhancing visitors' physical experience of exploring the museum by complementing it with digital experience. The museum not only allows visitors to use mobile phones while browsing the art pieces but also encourages the phone usage. The Met revamped its website to make it more user-friendly on mobile phones. At first, some people were concerned that exhibiting collections online would cause a decrease in museum attendance since people can enjoy the art online instead of paying a physical visit to the gallery. However, it has been proved just the opposite: More museum attendance has been observed. A glance of an artwork on screen may spark interests and make people eager to see and experience the nuances of the real artwork in person (Lohr, 2014). Furthermore, by displaying its artworks on multiple platforms aesthetically and with the help of social media, the museum obtains more exposure and extends its reach to more people. In 2014, the Met's Instagram account was selected as the Webby Award Winner in the Social: Arts and Culture category (The Webby Awards, 2014). Webby Award is the leading international award

honoring excellence on the internet and considered as the internet's highest honor (Heffernan, 2008).

The Met launched its app developed by the museum's Digital Media Department in September 2014 (Campbell, 2014). The app provides an easy way for the Met community to stay current with what's going on at the museum on a daily basis, regardless of audience locations. It provides information such as events, current exhibitions, collection highlights, family-friendly activities, and even Met's Twitter feed to help people schedule their on-site visits.

The Met goes an extra mile to benefit the public through digitization. At the beginning of 2017, the Met made all images of public-domain artworks in its collection available for anyone to use under Creative Commons Zero (CC0) license, which means no copyright reserved. Educators, students, researchers, hobbyists, designers, and artists now have more than 406,000 high-definition images of artworks to download, use, share, and re-create without restriction (The Met, n.d.2). This move to encourage and facilitate open access to the museum collection demonstrates the Met's commitment to increasing public access to the art collections in the digital age.

The Met also dedicates itself to making art available to everyone by education, especially through online digital presence. One prominent resource is the Heilbrunn Timeline of Art History. This interactive timeline depicts global art history and culture through artworks in Met's collection. It pairs over 1,000 essays and almost 8,000 works of art with close to 300 chronologies, and is constantly updated to provide new insights on the collection and the human art history. Users can select a specific time period (e.g. 1000 B.C. or 1600 A.D.) and a geographical region (e.g. Africa or East Asia) to have an overview of human artistic accomplishment at that particular time in that specific region, as shown in FIGURE 15. This tool provides users an immersive and

exploratory experience. The new edition of this timeline works seamlessly on computers and mobile devices, giving users a smooth browsing experience. The Heilbrunn Timeline of Art History has an average of 1.5 million visits per month during an academic year (The Met, 2016).

Numerous schools and institutions have adopted the timeline into their curriculum. For instance, Harvard has used the Timeline in one of its online courses called ChinaX (<https://projects.iq.harvard.edu/chinax/links/heilbrunn-timeline-art-history-china>).

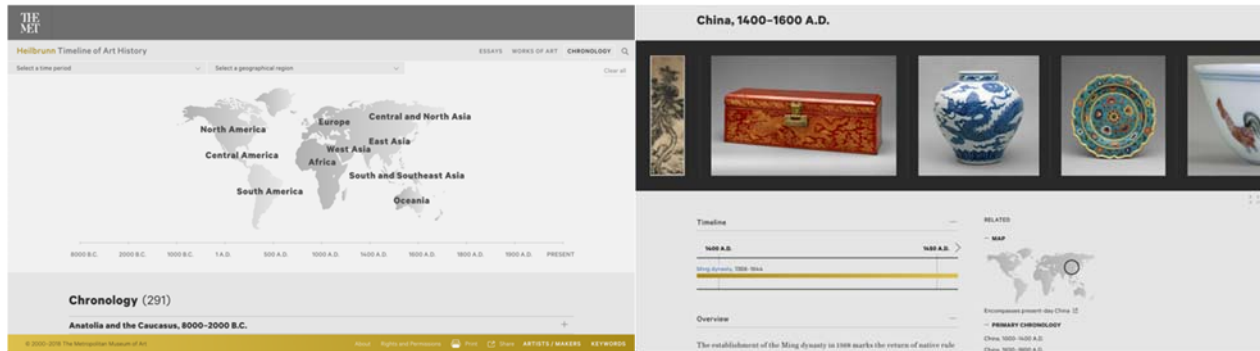


FIGURE 15. THE HEILBRUNN TIMELINE OF ART HISTORY ON THE MET'S WEBSITE.

The Met has also developed some educational tools for young audience, and one example is /Metcraft, which uses the gaming platform Minecraft. The tool is designed to let young museum-goers rejoice in exploring the museum and stimulate their interests in art. Connecting with Minecraft, one of the most popular games among children and adolescents, demonstrates Met's efforts in reaching out to young generations. Besides, the Met has

specific webpages designed for kids, #Metkids (<https://www.metmuseum.org/art/online-features/metkids/>), which bring joy to children through their interactions with the online content. FIGURE 16 shows an example. Moreover, the Met provides abundant resources and various programs for educators to cultivate students' learning and spirit of independent exploration of art.

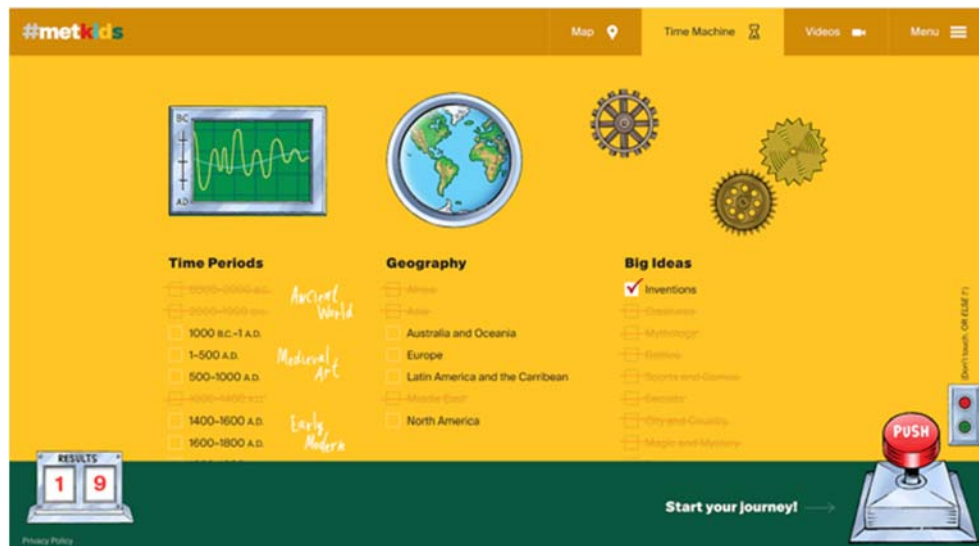


FIGURE 16. #METKIDS WEBPAGE.

The Met certainly hasn't missed the opportunity of outreaching to younger generations on social media. It has almost two million followers on Facebook, 2.6 million on Instagram, and over four million on Twitter. It even has an official account on Weibo, with much fewer followers though.

Remarkable progress on digitization has been made by the Met, but they still plan to further their digital-related efforts by considering the following: developing overall vision and strategic decision-making capabilities for digitization at the leadership level; cultivating a culture across the organization that facilitates digitization in the long-run; providing training and professional-development resources for staff to improve digital-related skill sets; and continuously improving user experience on the digital product, platform, and apps (Tallon, 2017).

In short, the strengths of the Met are: large amount of copyright-free downloadable digital resources; modern web design; well-thought-out contents (such as Heilbrunn Timeline of Art History); and kid-friendly online resources. Overall, the Met has set an example in museum digitization. In the future, the Met may consider initiating more collaborations with other institutions, domestic and overseas.

4.3. Google Arts & Culture

Originally named Google Art Project, Google Arts & Culture was initiated on February 1, 2011 with 1,000 artworks by over 400 artists from 17 partner museums in nine countries, including State Hermitage Museum, Uffizi Gallery, the Met, Museum of Modern Art (MoMA), Rijksmuseum, Van Gogh Museum,

and Palace of Versailles (Sood, 2011). After just five years, more than 1,000 museums and cultural institutions have already joined (Sood, 2016). And as of January 2018, there are multi-million artifacts and more than 6,000 exhibitions from over 1,500 museums in 70 countries (Luo, 2018). In essence, Google Arts & Culture is a digital museum of museums. The idea is to use technology to make arts more available to global audience, not only typical museum-goers but also people who have less or no access to the real artworks. However, it was not easy to convince museums to share their art assets. In order to alleviate the museum curators' concerns about copyright and commercialization, Google signed contracts of copyright protection and agreements of not using digitized artworks for commercial gain (Lohr, 2014).

Google has used "gigapixel" photo-capturing technology to take photos of the artworks and the average resolution is around seven gigapixels (Sood, 2011), which is about 140 to 350 times of the resolution provided by a high-end consumer digital camera (20-50 megapixels). These Art Cameras have been improved so that a painting can be photographed within an hour. These ultra-high-definition images show visitors jaw-dropping brushstroke-level details, often more details than what they can capture from looking at the real artworks in museums, since usually visitors can't get very close to these treasures on-site due to security and preservation reasons. Visitors on the Google Arts & Culture website can only wish they have a jumbotron to view these images on. By now, there are 1,773 items can be viewed at gigapixel level, and all of them can be found at <https://artsandculture.google.com/project/gigapixels>. An example is shown in FIGURE 17.

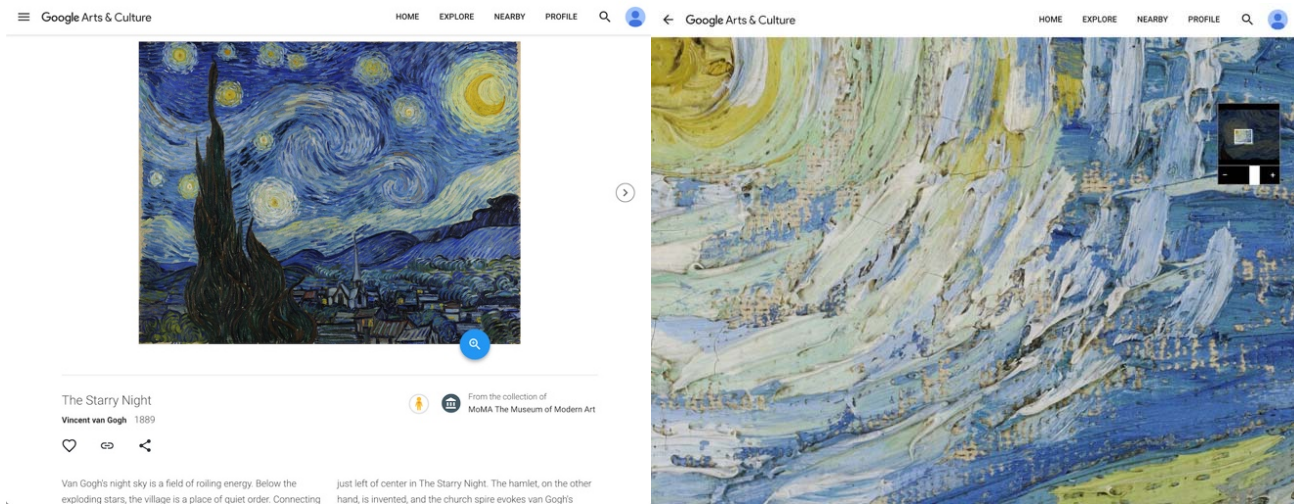


FIGURE 17. THE STARRY NIGHT AND ITS CLOSE-UP VIEW (83% OF FULL RESOLUTION).

Remember “Street-View” in Google Map? The same technology, modified and put on a trolley, has been used to create 360-degree virtual tours for museums around the world (Sood, 2011). The virtual tours provide online viewers life-like, smooth navigation of hundreds of rooms within those museums. Once a visitor is inside the virtual museum and in front of a masterpiece, she can seamlessly switch from virtual-tour mode to image-viewing mode by an easy click and examine the microscopic details provided by the “gigapixel” resolution, as shown in FIGURE 18 and FIGURE 17. Virtual tours of outdoor graffiti and cultural heritage sites such as Machu Picchu and Taj Mahal have also been included. To date, there are over 2,700 virtual tours available at: <https://artsandculture.google.com/project/street-views>. The platform even includes performing arts now. Visitors can submerge themselves in 360-degree virtual shows of world-class performances of music, opera, theatre, and dance: <https://artsandculture.google.com/project/performing-arts>.

Furthermore, on the Google Arts & Culture website, visitors can explore artworks by time, subject, color, artist, medium, historical event, place, or collection from museums and art institutions, among others. Occasionally, Google Arts & Culture includes links to Wikipedia. There are also stories and themes (articles with embedded images and virtual tours, e.g. “The Folk Art of Zhangzhou Puppets” and “The Essential Guide to Arts & Culture in Sydney”), exhibits (slideshows with images and videos, such as “From station to the renovated Musée d’Orsay”), and projects (assemblies of stories, themes, and exhibits based on the same subject, for instance, “The Charities of The Prince of Wales”). And, don’t forget what Google is best at, visitors can search this digital museum site using any keywords they like. Furthermore, under “Nearby” tab, one can find information about the exhibits, museums, and historical sites in adjacent areas based on Google Map technology, and explore the artworks depicting landmarks close by (for instance, if a visitor is in San Francisco, the website may show her a painting of Yosemite).

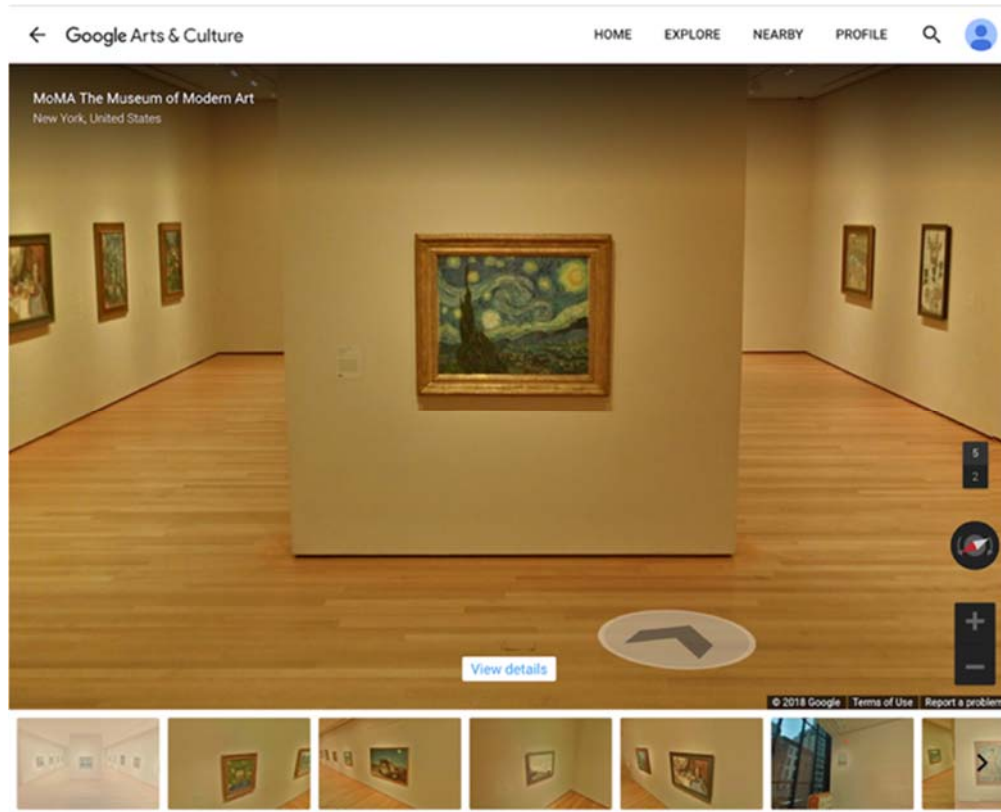


FIGURE 18. VIRTUAL TOUR OF MOMA (IN FRONT OF “STARRY NIGHT” BY VINCENT VAN GOGH) (CLICKING “VIEW DETAILS” TAKES VISITORS TO THE IMAGE-VIEWING PAGE SHOWN IN FIGURE 17).

For all these high-definition images, exhibits, projects, and museum collections, one can simply click on the “heart” symbol to put them into her personal collection, if logged in with a Google account. An individual can even customize them into her own galleries and share to her friends and family. If a visitor makes her personal galleries public, people can find and view them when they search relevant keywords.

Google has a powerful collection management system to make possible these functions of searching, filtering, and content publishing and hosting. It also provides image zoom viewer and story-telling tools for partner museums to create their own stories.

In December 2015, Google Arts & Culture app was released for mobile devices. Users can use it to conveniently access the same rich content as on the website. And there are interesting features exclusive to the mobile app.

For example, Art Selfie, as seen in Figure 19, has been available since mid-December 2017. It was a new and fun way for people to interact with art, and it suited the digital age very well: A user simply takes a selfie and the app – powered by facial recognition technology based on machine learning – will search, find, and present the most resembling portraits in its art collection database. Soon, Art Selfie exploded in popularity and went viral. By January 2018, there had been more than 20 million selfies and the matching art doppelgängers shared on Instagram, Twitter, and YouTube (Hauser, 2018). This single feature had made Google Arts & Culture app the most downloaded mobile app for several weeks. The fun feature, along with the app, received extensive news coverage. And it was not a short-lived phenomenon. By September, 78 million selfies had been taken in the Google Arts & Culture

app (Luo, 2018). Along the way, users have explored artworks and artists they may have never encountered before. Another interesting feature in the mobile app is virtual reality with assistance of various peripheral devices

including Google's low-cost VR solution – Google Cardboard, which provides a 360-degree, full-vision, immersive view of virtual exhibitions.

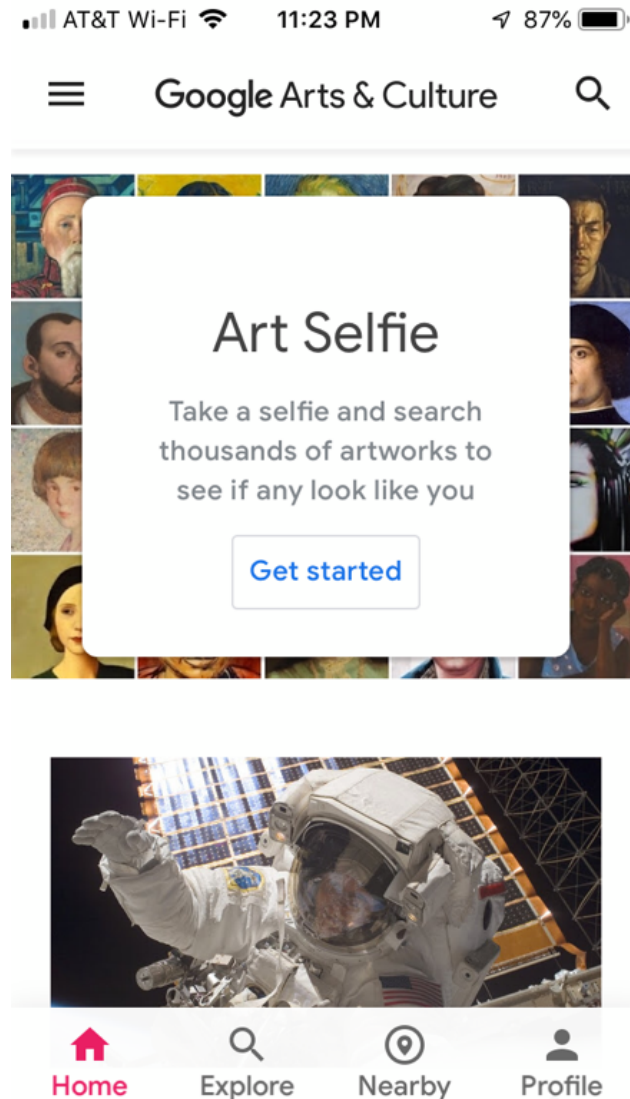


FIGURE 19. GOOGLE ARTS & CULTURE MOBILE APP.

All these contents and fun features on website and in app – such as art stories and themes, as well as Art Selfie, customization and sharing – seamlessly serve the educational purpose for this gigantic digital museum. The featured stories on the homepage of Google Arts & Culture are updated on a daily basis.

Furthermore, on the social media Google+, Google Arts & Culture has been holding real-time “ArtTalks” with diverse institutions from time to time and recordings of the sessions are provided on YouTube. However, Google+ is scheduled to be discontinued in August 2019 (Smith, 2018), so a new venue will have to be

introduced. In addition, Google Arts & Culture created an extension (i.e. a software plug-in) for Chrome web browser. After installation, a beautiful artwork will be fully displayed when a new tab is opened in Chrome browser, as demonstrated in FIGURE 20. The artwork is refreshed every day, or users can adjust the

setting to see a different image for every new tab. At the lower-left corner of the artwork, one can click on the title, author, or museum to explore more on Google Arts & Culture. It is indeed a creative idea to reach, amuse, and educate the public.

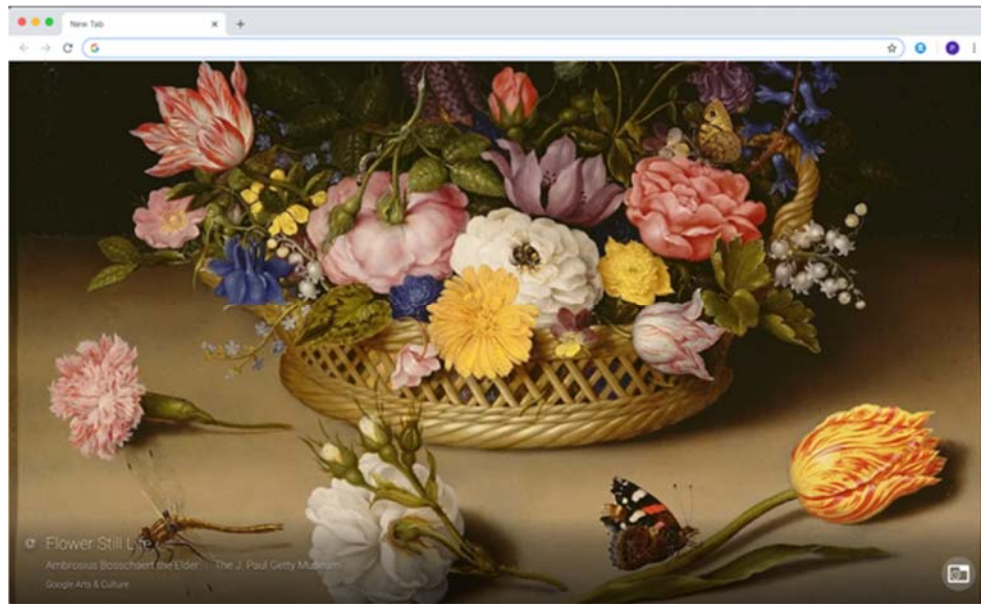


FIGURE 20. A NEW TAB IN CHROME BROWSER (WITH GOOGLE ARTS & CULTURE EXTENSION INSTALLED AND ENABLED).

The lab of the Google Cultural Institute (the creator of Google Arts & Culture) is the place where new technologies are developed and where creative ideas, arts, and technologies join together. The well-known low-cost VR device, Google Cardboard, was born here. Google also acquired and further developed Tilt Brush, an VR application that allows artists to draw and paint in 3D space. It is like that one jumps into 3Ds Max (a well-known 3D-modeling software) herself and paints in 3D space with different colors and types of brushes and even light. The possibility is endless. The outcome is a digital creation that viewers can walk around, or even step into and immerse within. Artists of traditional and digital media around the world are excited about it and

believe this technology will be potentially revolutionary in art creation (CNN, 2018).

Google never stops experimenting with newer technologies and creative ideas (<https://experiments.withgoogle.com/collection/arts-culture>). One amazing example is an experiment made by Google Cultural Institute and British Museum. It is called “the Museum of the World” and is an interactive data visualization based on British Museum’s collection. Viewers can discover the artefacts that are aligned to a timeline and make connections among them and listen to museum curators’ insights on the objects, as demonstrated in FIGURE 21 (<https://britishmuseum.withgoogle.com/>).

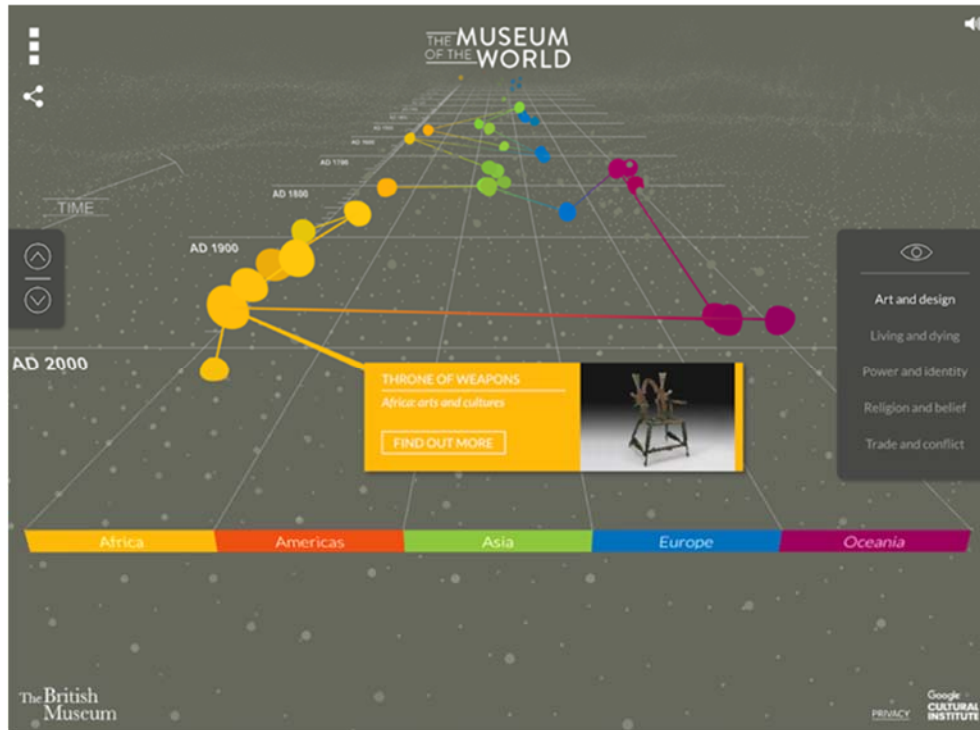


FIGURE 21. THE MUSEUM OF THE WORLD.

It seems Google Arts & Culture has been successful at accomplishing its original goal: make great art more accessible. Although digital visits can never replace the face-to-face encounter with the real artworks, technology – combined with modern tasteful design and creative story-telling – can get people interested in arts and culture, and hopefully, inspire them to visit the actual museums and culture heritage sites in person someday.

In brief, Google Arts & Culture has done well in bringing online large collections of various museums around the world; the applications of technologies are very creative, taking Art Selfie and the Chrome plugin for examples. Many intriguing stories are available online and articles on the website are updated on a daily basis. One thing Google Arts & Culture can do better is to add kid-friendly webpages and contents.

V. COMPARISON AND DISCUSSION

Besides these examples, there are many other prominent museums worth studying, such as Shanghai Museum and Henan Museum in China and Cleveland Museum of Art and San Francisco Museum of Modern Art (SF MoMA) in the United States, among others. Due to the limitation of space, the authors couldn't cover all museums that have done excellent jobs in digitization work. In the meantime, keep in mind that the museums covered in this study are among the best in regard to museum digitization in China and the U.S.

In this section, we will compare the operations of museum digitization at country level in terms of technology, website, mobile apps, social media, and collaboration, which jointly affect the quality of users' visiting experience. Comparisons along various dimensions are summarized in Table 2 and 3 below.

5.1. Technology

When it comes to museum digitization, an arsenal of technologies – from UHD photographing and 3D modeling to 360-degree virtual tour, VR, and digital content management system – is available for curators to choose from. Museums from each country have made their choices, by purchasing a ready-to-use package, self-developing, customization, or collaboration. Google actively develops new technologies in the lab of its Cultural Institute, such as Tilt Brush, and explore new ideas through experiments with other institutions. Smithsonian has built their own online 3D-model viewing system, which looks impressive. Overall, although the United States might be slightly more advanced in technology, there is not a big gap between the two countries due to the fact that digitization technologies are much more readily available and inexpensive than a decade ago. Hence, the key now is not the technology per se, but how to apply proper technologies to the content in order to tell intriguing stories (Kane, 2016) and to provide an immersive user experience with outstanding design (Li, Liew, & Su, 2012). Google Arts & Culture as well as the Palace Museum, for example, have done remarkable jobs. Next subsection will provide more details.

5.2. Website

Today World Wide Web is one of the major platforms on which information is distributed. With the support of new technologies such as HTML5 (fifth version of HTML) and WebGL (Web Graphics Library), rich media can be presented on websites – for example, audio/video, animation, 3D modeling, and VR – which enables museums to exhibit their content and collections online more effectively and provide audience with unprecedented experience.

When it comes to a museum website, there are several factors to consider. Firstly, as people say, content is still the king. A good museum website starts with a rich digital

collection and thrives with a good use of it. For example, a third of the Met's heavy online traffic goes to a single destination – the Heilbrunn Timeline of Art History – which shows that the content and expertise matter (Lohr, 2014). All six cases discussed in this study do have good numbers of digitized items online, while generally United States museums have richer content. Baidu Encyclopedia Digital Museum built a large online collection of museums, but hasn't put much effort in generating stories and themes across museums, like what Google Arts & Culture and the Met have done. Secondly, technologies are just tools. Merely showing them off doesn't guarantee a good museum website. They have to be used creatively and fittingly to bring the digital collection to life and deliver a satisfying visiting experience. Google Arts & Culture and the Palace Museum are great examples for the applications of technologies on their websites. Both websites have rich content, great stories, and immersive virtual tours enabled by digital technologies. Their web designs are modern and tasteful while echoing their collections. Both websites are easy to navigate and there are multiple ways to explore and search. On the contrary, although Baidu is a technology company specializing in online searching, the search function on its digital museum website is surprisingly limited. Additionally, the technology-enabled story-telling is lacking and the visiting experience is not as rich as that of Google Arts & Culture. Last but not least, in an era when everything goes mobile, it is wise to take advantage of the new platform. All the investigated museums' major websites have been optimized for mobile devices, which is beneficial to both mobile users and museums themselves – in that easy access brings a large number of mobile visits.

5.3. Mobile App

Since the end of 2016, mobile internet traffic has surpassed desktop web browsing

(Gibbs, 2016). Portable devices are often people's first choice when accessing internet, which is especially true for the younger generations. To get connected with them, museums need good mobile apps. Table 3 shows that US museums have done a better job than their counterparts in China. Two out of three studied museums in China (namely, Dunhuang and Baidu) haven't launched apps yet. The Palace Museum, on the other hand, has released nine well-designed apps for tablets and smartphones and most of them are acclaimed by general public and critics. Its most recent app, the Palace Museum Community, is ambitious and remarkable in that it tends to integrate multiple essential services aligned with the Palace Museum digitization strategy into one virtual community on your palm.

5.4. Social Media

Social media has been a low-cost high-efficiency marketing tool to reach a large audience and stay connected with them. It has been exploited by many companies in the business world and works well for museum industry too. Google Arts & Culture's Art Selfie went viral early this year and made Arts & Culture well-known by general public. According to Table 2, obviously, museums put more efforts into promoting to and connecting with communities in their home countries. However, Baidu Digital Museum didn't do much on the social media either in China or overseas and Digital Dunhuang is still not yet on par with the other four institutions. The U.S. museums have made more outreach efforts. They have large groups of followers in English-speaking world and have attempted to reach out to the East. The size of Google Arts & Culture's fan base is not very impressive possibly because it is still fairly young in the museum world and not as well-known as museums like Smithsonian and the Met.

5.5. Collaboration

Teamwork matters, not only among departments within a museum, but also between the museum and external organizations. Collaboration is important for all six museums investigated in this study. Smithsonian had to make a pan-institution effort across its 19 museums and nine research centers to make its digitization operate smoothly. Google Arts & Culture works with 1,500 museums in 70 countries to build its digital curation. The Palace Museum collaborates with Tencent to experiment on new ideas and technologies. Baidu Encyclopedia Digital Museum cooperates with institutions in Spain and France to extend its outreach overseas. Furthermore, the Palace Museum, Smithsonian, and the Met work with Google Arts & Culture to further spread their influence and increase online presence.

In sum, the quality of visiting experience provided by the U.S. museum digitization is superior to that by the Chinese counterpart. Although technologies are not much different between the two countries, the uses of technologies are dissimilar: generally, museums in the U.S. have better story-telling and content generation, as well as more creative applications of technologies. Web design of the U.S. museums is more modern and appealing, and websites are easier to navigate and search. As far as mobile apps are concerned, the U.S. has a slight edge over China while the Palace Museum has made great efforts on its app development. Both the East and the West need to establish stronger social media presence for overseas audience outreach. Extensive collaborations engaged in by museums of both countries benefit visitors by providing more innovative and high-quality digital exhibits, thus enriching their visiting experience. In short, operations of museum digitization play a critical role in impacting the quality of users' visiting experience and, therefore, should be planned and implemented strategically.

TABLE 2. NUMBER OF FOLLOWERS ON SOCIAL MEDIA.

Social Media	China			The United States		
	Palace Museum	Digital Dunhuang	Baidu Digital Museum Project	Smithsonian Institution	Metropolitan Museum of Art	Google Arts & Culture
Weibo	Multiple accounts: - 6.1 M (Palace Museum) - 945K (Palace Museum on Taobao)	Multiple accounts: - 225K (Mogao Grottoes) - 67K (Dunhuang Academy) - 9.8K (Dunhuang Academy Mogao Grottoes Visitor Center)	N/A	1K	41K	55K
WeChat	Yes, rich app functions	Yes, some app functions	No official account; Only a mini program displaying its mobile site	Yes, but only some articles/notifications	Yes, some app functions	N/A
Facebook	372	N/A	N/A	578K	1.9 M	130K
Twitter	675	N/A	N/A	2.7 M	4.3 M	131K
Instagram	N/A	N/A	N/A	750K	2.6 M	176K
YouTube	N/A	N/A	N/A	Multiple accounts: - 1.6 M (Smithsonian Channel) - 28K (Smithsonian)	95K	83K

TABLE 3. COMPARING SIX MUSEUMS ACROSS CHINA AND THE UNITED STATES.

Traits		China			The United States		
		Palace Museum	Digital Dunhuang	Baidu Digital Museum Project	Smithsonian Institution	Metropolitan Museum of Art	Google Arts & Culture
Web Content	Text	Rich	Some	Limited	Rich	Detailed	Rich
	Image	UHD/HD	UHD	HD and regular	Vast, downloadable	HD/UHD, downloadable	UHD/HD
	Video	Some	No	Few	Vast collection	Some	Rich
	Audio	Some	No	Narrations	Rich	Mainly narrations	Mainly narrations
	Stories/Exhibits	Plenty	Plenty	No	Plenty	Rich	Rich
	Other	Virtual tour	VR, virtual tour	VR, virtual tour	3D models	360-degree video	VR, street view
Technology		- VR - Multi search functions	- Multi search functions - Broken links	- Broken links - Some images in low-res	- 3D modeling - AR	- Multi search functions - 360-degree video	- Multi search functions - Tilt Brush - Data visualization
Design*		- Artistic - Unique imperial style	Clean	Good	Somewhat Old-fashioned	Modern and Informative	Modern and tasteful
UX**/Navigation		- Easy navigation*** - Multiple ways of search	Easy navigation	Limited search functions	Website is rather complicated; could be confusing at times	- Easy navigation - Information is displayed in an organized way	- Easy navigation - multiple ways of search
Features		Rich	Medium	Limited	Plenty	Plenty	Rich
Mobile App		- Nine apps - Tastefully designed	N/A	N/A	Multiple, but not fancy	Not good	Excellent, optimized
Social Media		- Excellent in China - Mere in West	- Mediocre in China - None in West	- Minimum in China - None in West	- Excellent in West - Mere in China	- Excellent in West - Good start in China	- Good in West - Beginning in China
Collaboration		Extensive	Some	- Mostly in China - Just started overseas	Extensive	Extensive	Worldwide
Education		High	Medium	Medium	Very high	High	High
Study/Research		High	Low (Hi on Dunhuang Academy website)	Low	Very high	High	Medium to low
Enjoyment		High	Medium-high	High	Medium	High	High

*: “artistic” means that the design reflects certain artful tastes; “clean” means the design is simple and toward minimalism; “Good” means the design is useful and without flaws; “Modern” means the design fits HD (1920x1080) or higher-resolution screens, uses large images, is sleek, and shows design efforts/tastes; “Old-fashioned” means the design fits older/lower-resolution screens, uses small images and lacks design efforts; “Tasteful” means the design shows great efforts and reflects excellent design tastes.

** : user experience.

*** : browsing through and searching on the website are intuitive, painless, and user friendly.

Education, study, and enjoyment are the three main purposes of museum defined by ICOM.

VI. SUGGESTION

6.1. Suggestions for Museums in China

Based on the case studies, the first suggestion to China's museum industry is to further digitize its collections. China has 5,000 years of history and countless art and cultural masterpieces, but only a small amount has been digitized. Converting the collections to digital forms (2D or 3D) can be time-consuming but is essential to any digitization strategy. Organizations in China can learn from Smithsonian's Mass Digitization program to speed up the process while preserving the high quality.

Second, the importance of story-telling can't be overemphasized, which has been recognized by many administrators in museum industry, such as the Met's former CDO, Mr. Sree Sreenivasan (Preston, 2013). Good stories are educational, enjoyable, and memorable. But making good stories is not easy. Museums in China need to dig deeper for the cultural, art, and historic values of the collections and conduct more research (Gao, Hou, & Zhao, 2018), like what Google Arts & Culture and the Met have done. Talent and expertise indubitably play a vital role in generating high-quality content, thus hiring, training, and retaining talented personnel become increasingly important. China's museum industry should put more efforts on workforce employment and development to improve the quality of digital content.

Next, user experience is more important than technology. Museums and cultural institutes in China should make sure the websites (both desktop and mobile version) are easy to navigate, look aesthetic, and provide multiple ways to explore and search the content online.

We have entered a mobile era, so it is necessary to have a mobile app. Designing a good app will give museums an extra means to connect with art lovers and to provide

visitors a new way to interact with on-site exhibitions. Social media is also becoming more and more important if museums want to reach out to younger generations, so it is helpful to build a good reputation on social networks. And if China's museums want to extend their influence overseas, they should consider establishing and strengthening their presence on Western social media such as Facebook, Twitter, Instagram, and YouTube.

Collaboration should be always welcomed, both inside the museum and outside, with a Chinese organization or an international one. But keep in mind, the collaboration or any operations of museum digitization should be aligned with strategic plan to avoid digression.

6.2. Suggestions for Museums in the United States

Generally, museums in the United States have done a better job on museum digitization than those in China, but it doesn't mean there is nothing they can learn from the latter. For example, Google Arts & Culture hasn't done anything specifically for kids. For educational purposes, a dedicated child version of the website could be really helpful, like what the Palace Museum has done. Starting early is a good move but technologies change fast. Museums that are still using outdated website architecture or digitization tools should consider upgrade to embrace more advanced technologies. In addition, if American museums want to open Chinese market and let the eastern country know more about their artworks and collections, they should consider putting more efforts in promoting to Chinese audience and building connections with users on Weibo and WeChat.

VII. CONCLUSION

Besides the preservation and archival purposes, digitization can help museums to reach larger audience, educating them and inspiring them to visit the museums and historical sites in person or explore more digital resources online. Digitization provides viewers a new “dimension” of museum visiting experience, grants artists new ways of creation, and offers scholars rich data and creative tools to do research. In a word, digitization can help museums to serve all three purposes defined by ICOM – education, study, and enjoyment – in the digital age. It has become an inseparable part of museums in the new age and is an inevitable approach to accommodate the younger generations of educators, researchers, and general public.

So far, although plenty of efforts have been devoted to museum digitization, there is still much left to be desired. As new technologies emerge and existing ones become more powerful and less expensive, there are numerous opportunities to explore and new ideas to try out. The East and the West can collaborate and learn from each other to make the operations of their museum digitization more fruitful and efficient and to consistently provide high-quality visiting experiences to users.

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