Scaffolding Real and Unreal: Strategies for the Development of Virtual Tour Guides

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Abstract
Mobile and wearable devices have become common communication media for various applications. Especially, in museums and galleries, audio and multimedia guides remain the most common solutions in which visitors can concentrate on appreciating the exhibits while gaining a deeper understanding of collections. Since the spread of Covid-19 reduced the accessibility of physical venues and limited human interaction, the need for purpose-built audio and multimedia guides has grown. However, the multimedia guides were unable to fulfil the visitors' needs. Some organisations have begun to explore alternative solutions such as Augmented Reality by reassessing current digital strategies for the coming post-pandemic era. This paper aims to clarify the current trends in the development of on-site museum technology and identify the gaps that can be closed using the aspects of Education, Interaction, Personalization, and Visualization, which have been declared previously as the four key strategies to enhance the visiting experience. Our main goal is to define which aspect is the most important factor for the development of a Virtual Tour Guide to maintain a museum's resilience. In this paper, we conducted a survey that provides a comprehensive analysis on the development of on-site electronic devices in the top 103 most visited museums in 23 countries. Three stages of data collection are deployed to assemble information. The results show that 83% of museums surveyed are available to engage with on-site visitors through audio or multimedia guides or apps. Our findings indicate that Interaction is the most important strategy, followed by Education, Personalisation and Visualisation.

Keywords: Augmented Reality, Museum Virtual Tour Guides, Personalization, Interaction, Education, Visualisation

Introduction

With the rapid increase in the user population, mobile and wearable computing devices such as tablets, widescreen smartphones, and smartwatches are increasingly being used as common communication media for various applications (Krishnamurthi, Gopinathan, et al., 2021; Ometov et al., 2021). In museums and art galleries, audio and multimedia guides are the two most common solutions for visitors' experience of the curated material (R. Y.-C. Li & Liew, 2015). Some of these solutions include Augmented Reality (AR) which can aid learning due to the combination of its relevance to the learner's physical world and the customizability of the simulation to offer a virtual world (Damala et al., 2007, 2008; Y. Li, 2015). In this respect, AR realistically transforms visitors' reality and affects their appreciation of exhibits while establishing a deeper understanding of collections at the same time. This transformation is represented by a temporary scaffold between what is real and unreal, in other words. AR technology controls the accessibility, transparency and visibility of this scaffold as learning progresses.

There are many visitors who may benefit from the use of AR technology as a communication medium. Huang (2021) states that Forbidden City received more than 19 million visitors in 2019. The National Anthropology Museum also attracted more than 26 million visitors per year before the pandemic according to Gallaga, Trujillo, and Andrli (Gallaga et al., 2022). Furthermore, the Prado museum reported that the number of their visitor has gradually increased from 2.1 million in 2006 to 2.8 million in 2018. Therefore, to comprehensively understand the circumstance of the development of museum portable devices, this survey as a pilot project is conducted based on the list of "Top 100 Art Museum Attendance 2018" (Skeggs et al., 2019) plus the above cultural monuments to identify the strategies for the development of a Virtual Tour Guide as an augmented embodied conversational agent. The aim of this project is the development of an Embodied Conversational Agent (ECA), which can be used as a Virtual Tour Guide (VTG), integrating several techniques in Artificial Intelligence (AI), AR and Affective Computing, to provide guidance through museum collections when a human guide is not available.

Currently, AR frameworks discuss learning from mainly three perspectives: physical, cognitive, and contextual. On the physical dimension, they argue that physical manipulation affords natural interactions and encourages the creation of embodied representations to support learning. On the cognitive dimension, they discuss how spatiotemporal alignment of information through AR systems can aid learners' symbolic understanding by scaffolding the progression of learning and resulting in an improved understanding of abstract concepts. On the contextual dimension, they argue that AR creates possibilities for interactive learning, ultimately facilitating personal association and personally meaningful experiences (Bujak et al., 2013).

AR systems are successful because they display information relevant to the user at the appropriate time and location (Bujak et al., 2013). Most AR systems leverage this spatiotemporal contiguity by overlaying virtual information relevant to physical objects and spaces (R. Azuma et al., 2001; R. T. Azuma, 1997). Thus, AR technology can bridge the gap between physical manipulatives and their symbolic representation by morphing the physical object into its representation. The main advantages of AR technology are spatial and temporal alignment, engagement through personalisation, situated cognition, instructional scaffolding, mapping between abstract and physical manipulatives, and motivation through emotional connection.

The aspects of Education, Interaction, Personalization, and Visualization have been declared previously as the four key strategies to enhance the visiting experience during museum digitization (R. Y. Li & Liew, 2014). Our goal in this paper is to clarify the current trends in the development of on-site museum technology and identify the gaps that can be closed in near future. Among the four strategies, we will investigate which aspect is the most important factor for the development of a VTG.

In the remaining sections, we first explore the current state of the art in virtual tour guides, then in Section 3 we focus on data collection through surveys over 100 museums, in Section 4 we demonstrate the survey results, and after evaluating the results in Section 5, we draw conclusions and present our recommendations in Section 6.

Literature review on Virtual Tour Guides

Moving to the early nineties, with the constant improvement of technology, the museum device has changed from a simple audio provider to a multi-functional media presenter. The Tate Modern museum was one of the early examples. The Tate Modern Multimedia Tour Pilot (MMT) uses a PDA to offer a wide range of digital content by means of audio, video, and interactive application. It offered a 45-minute pre-set tour and was connected to local WIFI to detect visitors' physical location. In this way, they no longer need to enter a reference number to receive collection-related information. The goal was to observe the interaction between the visitors, devices, and the physical environment and further refine the design content (Proctor & Burton, 2004).

Some well-known techniques, such as VR, AR, QR Code, and html5 have soon been used widely to improve the capability of mobile applications as shown in Figure 1 (Ceipidor et al., 2013). However, according to Tallon (2013), most mobile-based museum apps are developed to be information providers without any back-end support. Pre-recorded audio and video tours remain the most common strategies to enhance museum visits. Typical examples are seen at the virtual museum of the Louvre on iPhone (LeVitus, 2010), the Love Lace exhibit in the Sydney Powerhouse Museum (Wainfeld, 2011), and the Leeum Mobile Guide on Samsung GALAXY NOTE II for the Samsung Museum of Art (Rhee & Choi, 2015).

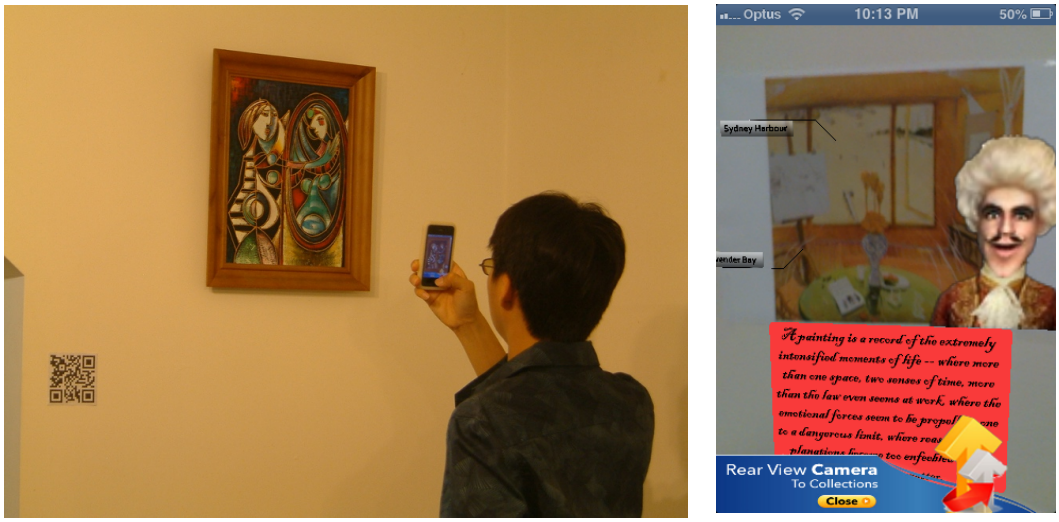

Figure 1. Virtual Tour Guide in a Museum

While most museum and gallery apps are acted as information providers, some focus on the visitor's interaction with limited personalisation. An example is the Solar Equation, a large-

scale public art installation developed as a part of the 2010 Light in Winter Festival in Melbourne Federation Square. According to Lynch (2011), visitors can use their mobile devices to interact with the installation by interfering with the animations on the reflective surfaces in real time. Another example is StreetMuseum, an outdoor AR mobile app launched by the Museum of London (Herman, 2019). Visitors can experience the city's past by interacting with historical images in more than 200 physical locations in the City of London. The motivation was to learn more about sights from the past by bringing the museum's photographic collections and artifacts to life. Similarly, the American Museum of Natural History presented a mobile AR tool for the exhibition - Beyond Planet Earth: The Future of Space Exploration. Visitors interact with 11 AR markers throughout the museum and mark their favourite collections before sharing their opinions and experiences with others via social networks to enhance the on-site visiting experience (Brustein, 2011).

Although the technology is now ripe enough, the four key strategies (Education, Interaction, Personalization, and Visualization) to enhance the visiting experience during museum digitization and which aspects among these strategies are the most important ones remain unexplored in recent literature.

Data collection

The smaller institutes are now much more willing to adopt mobile technology than ever before. According to the Museums and Mobile survey, over 70% of art museums have provided mobile experiences to engage visitors, compared to 2012 which stated only around 50% of organizations reported the use of mobile technology (Tallon, 2013). However, from the visitor’s and investor’s viewpoint, the issue of whether the applications satisfy the user’s needs still generates a heated debate.

We conducted a survey that provides a comprehensive analysis on the development of on-site electronic devices in the top 100+3 most visited museums. Three stages of data collection are deployed to assemble information from May 2019 to mid-2020, including online search, personal contact, and personal visits. In this survey, the data are mainly collected from online resources except the cultural organizations located within Australia, Taiwan, Japan, and South Korea, which they are personally visited. The resources from the App Store (Apple), Google Play (Android market), official annual reports and websites, and online discussion forums are considered in the first stage of data collection. The organizations with no online information available were contacted by making phone calls or by emails and social media in the second stage. In the third stage, the chosen museums in the countries listed above are inspected personally before the overseas travel ban was applied in Australia.

Survey Results

After setting up the criteria and constraints, the first and second steps of data collection were done from May to October 2019. The third step of personal inspections was spread through the survey period until mid-2020. There are a total of 103 organizations located in over 23 countries. Most of them are in Europe (52%), the United States, and Canada (18%).

As demonstrated in Table 1, the results show that most museums are available to engage with on-site visitors through audio guides or multimedia guides/smartphone apps. 35 of them provide support for both engagements, 23 provide audio guides, and 28 provide either

multimedia guides or smartphone apps. Only 17 organizations do not offer any on-site handheld electronic devices.

Table 1. Types of engagement with visitors in Museums.

AG = Audioguide
CO = Cost
ED = Education
IN = Interaction
MS = Multimediaguide/Smartphone application
PE = Personalization
VI = Visualization
The italics are the museums which did not include in the original list of TOP 100 ART

NO	Name of Museums	AG	MS	CO	ED	IN	PE	VI
001	*Palace Museum- CN*	*Y*	-	*R*	-	*A*	*L*	-
002	Musée du Louvre- FR	Y	Y	R/P	K/r	A/O/d/p	L/f/i	-
003	The Metropolitan Museum of Art- US	Y	Y	R/F	r	A/O	L	-
004	British Museum- UK	Y	Y	R/I	K/Q/W	A/M/O/d/s /v	L/b/g/i	-
005	Tate Modern- UK	Y	Y	R/P	K/V/r	A/s	L/b	H
006	National Gallery- UK	Y	Y	R/P	V	A	L	-
007	Vatican Museums- VA	Y	-	R	-	A	L	-
008	National Palace Museum- TW	Y	Y	R/F	G/K/S/T	A/C/O/d/s	L/b/i/k	-
009	National Gallery of Art- US	Y	Y	R/F	K	A/O	L/i/k	-
010	Centre Pompidou- FR	-	Y	F	K/V	A/s	-	-
011	Musée D'Orsay- FR	Y	Y	R/P	G/K	A/M/O/s	L/e/f/i	-
012	Victoria & Albert Museum- UK	-	Y	F	K/r	A/O	-	-
013	National Museum of Korea- KR	Y	Y	R/F	S/r	A/O	L/i	-
014	The State Hermitage Museum- RU	Y	Y	P/I	D/K/V	A/O/s	L/b/i	-
015	*Museo del Prado- ES*	*Y*	*Y*	*R/P*	*K/U*	A/X/s	L/b/i	-
016	Museum of Modern Art- USA	Y	Y	F	K/r	A/O/h/s	L/b/i/k	H
017	The National Folk Museum of Korea- KR	Y	-	R	-	A	L	-
018	Museo Nacional Centro de Arte Reina Sofía- ES	Y	Y	R/F	K	A/E/s	L/i	-
019	CCBB (Rio de Janeiro)- BZ	-	-	-	-	-	-	-
020	National Portrait Gallery- UK	Y	Y	R/P	K/V	A/O	L/f	-
021	Shanghai Museum- CN	Y	-	R	-	A/O	-	-
022	National Museum of Scotland- UK	-	Y	F	K	O/s	i	-
023	Galleria degli Uffizi- IT	Y	Y	R/P	K/r	A/m	L/b/i	-
024	*National Museum of Anthropology- MX*	*Y*	-	*R*	-	*A*	L	-
025	The Moscow Kremlin- RU	-	-	-	-	-	-	-
026	National Galleries of Scotland- UK	-	Y	F	G/K/V	M/s	b	-
027	The J. Paul Getty Museum- US	-	Y	F	K/V/r	A/O	b	-
028	National Gallery of Victoria- AU	-	Y	F	K	O/s	-	-
029	Tate Britain- UK	-	Y	F	T/V	A/s	-	-
030	Le Grand Palais- FR	-	Y	F	V	-	L	-
031	Tokyo National Museum- JP	-	Y	F	K/r	s	L/b/i	-
032	State Tretyakov Gallery- RU	-	Y	R	-	A	-	-
033	Van Gogh Museum- NL	-	Y	F	-	A/p/s	L/k	-
034	Queensland Art Gallery/GoMA- AU	-	Y	F	V	O/s/q	-	-
035	FAMSF- US	Y	-	R	-	A	-	-
036	The Art Institute of Chicago- US	Y	Y	R/F	K	A/O/m	L/f/i	-
037	Saatchi Gallery- UK	-	-	-	-	-	-	-
038	Pergamonmuseum- DE	Y	-	R	-	A	L	-
039	Gyeongju National Museum- KR	Y	Y	R/F	S/r	A/O	L/i	-
040	Palazzo Ducale- IT	Y	Y	R/F	S	A/M/O/s	i	-
041	Musée du quai Branly- FR	Y	Y	R/F	K/V	A	L	-
042	Institut Valencià d'Art Modern- ES	-	Y	F	K/V/r	d/s/p	b/f/i	-
043	MMCA (Seoul)- KR	-	-	-	-	-	-	-
044	El Museo Thyssen-Bornemisza- ES	Y	Y	R/F	K	A/B/s	L/i	-
045	SAAM/Renwick- US	Y	-	F	-	A	-	-
046	Galleria dell'Accademia- IT	Y	Y	R/P	K/r	A/O/m	L/b/i	-

047	CCBB (Brasília)- BZ	-	-	-	-	-	-	-
048	Royal Academy of Arts- UK	Y	-	R	-	A	-	-
049	Art Gallery of New South Wales- AU	-	Y	F	K/V	A/M/s	b/e	-
050	Parco del Castello di Miramare- IT	Y	-	R	-	A	L	-
051	Guggenheim Museum- US	-	Y	F	K/V/r	A/O/s	L/b/e/i	-
052	LACMA- US	-	Y	F	K/V	a/m/s	f	-
053	Palazzo Reale- IT	-	Y	F	K/T/V	v	I	-
054	The Russian Museum- RU	Y	Y	R	K	A/O	L	-
055	The Belvedere- AT	Y	-	R	-	A	L	-
056	Museu Picasso- ES	Y	Y	R/F	K	A/O	L/i	-
057	The National Art Museum of China- CN	Y	-	R	-	A	-	-
058	The National Portrait Gallery- US	-	-	-	-	-	-	-
059	Mori Art Museum- JP	Y	Y	R/F	-	A/s	L/i	-
060	Kelvingrove Art Gallery and Museum- UK	-	Y	I	G/K/Q	A/O	f	-
061	Royal Ontario Museum- CA	Y	Y	R/F	G/K/V	A/O/X/q	i	-
062	Acropolis Museum- GR	-	-	-	-	-	-	-
063	Guggenheim Bilbao- ES	Y	Y	R/F	K/V/r	A/O/s	L/b/f/i	-
064	Riverside Museum- UK	-	Y	F	G/Q	-	-	-
065	Museum of Fine Arts- US	Y	-	R	V	A	L/f	-
066	The National Art Center, Tokyo- JP	-	-	-	-	-	-	-
067	CaixaForum Barcelona- ES	-	Y	F	V	-	-	-
068	CCBB (São Paulo)- BZ	-	-	-	-	-	-	-
069	Rijksmuseum- NL	Y	Y	R/F	V	A/O/m	L/b/f/i	-
070	The National Museum of Western Art- JP	-	Y	F	K/V	A	L/i	-
071	Palazzo Strozzi- IT	Y	Y	R/F	K	A	L/b/i	-
072	Parco di Capodimonte- IT	-	-	-	-	-	-	-
073	ACMI- AU	-	-	-	-	-	-	-
074	Castel Sant'Angelo- IT	Y	-	R	-	A	L	-
075	CaixaForum Madrid- ES	-	Y	F	V	-	-	-
076	Freer and Sackler Galleries- US	-	-	-	-	-	-	-
077	Ashmolean Museum- UK	Y	Y	R/P	-	A/O	L/i	-
078	Museum of Contemporary Art- AU	-	Y	F	K	A/O/s	b	o
079	Philadelphia Museum of Art- US	Y	-	F	-	A	-	-
080	Museo Soumaya- MX	-	Y	F	K	O	-	-
081	The Israel Museum- IL	Y	Y	R/F	K/V	A/O/s	L/b/f	-
082	Museu Nacional d'Art de Catalunya- ES	Y	-	F	-	A	L	-
083	Musée de l'Orangerie- FR	Y	Y	R/P	K/V	A	L	-
084	Art Gallery of Ontario- CA	-	Y	F	K/V/r	A/O/s	L/b/i	H
085	Melbourne Museum- AU	-	Y	F	K	s/c	b	-
086	Birmingham Museum & Art Gallery- UK	-	-	-	-	-	-	-
087	National Gallery of Australia- AU	Y	-	F	-	A	-	-
088	Hirshhorn Museum- US	-	-	-	-	-	-	-
089	Tel Aviv Museum of Art- IL	Y	-	R	-	A	L	-
090	Palazzo Pitti- IT	-	Y	P	K	M	i	-
091	The Museum of Fine Arts (Houston)- US	Y	-	R	-	A	L	-
092	MACBA- ES	-	Y	F	K	O/a/s	i	-
093	Kunsthistorisches Museum- AT	Y	Y	R/F	K	A/s	L/i	-
094	Neues Museum- DE	Y	-	R	-	A	L	-
095	Ullens Center for Contemporary Art- CN	-	-	-	-	-	-	-
096	Museo centrale del Risorgimento- IT	-	-	-	-	-	-	-
097	Reggia di Venaria Reale- IT	Y	-	R	-	A	L	-
098	Complesso del Vittoriano- IT	Y	Y	R/F	K/V	A/a/q	L/b	-
099	National Portrait Gallery- AU	Y	-	F	-	A	-	-
100	Istanbul Modern- TR	Y	Y	R/F	K/V/r	A/O/s/t/q	L/i	-
101	National Gallery of Ireland- IE	Y	Y	F	K	A	L/k	-
102	Musée des Arts Décoratifs- FR	Y	-	R	-	A	L	-
103	Gwangju National Museum- KR	-	-	-	-	-	-	-

A = Audio guide/ Podcasts
B = E-book based collection interaction
C = Cooperative ranking
D = 3D collections recreation video
E = Sound enhancement
F = Free
G = Interactive game/ collection hunter
H = History of collection visiting
I = In-App purchases
K = Collections information/ related knowledge
L = Multi-language application/ audio supported
M = Outdoor Map navigation
O = On-site floor maps
P = Online purchases
Q = Interactive quiz
R = Rental
S = Storytelling introduction
T = Timeline of collections
U = Ultra-high image observation
V = Video authors/ collections/ exhibits introduction
W = Wikipedia supported
X = x-ray/Periscope viewing
Y = Yes
- = No

a = Augmented reality supported
b = Collection bookmarking
c = Motion control interaction
d = 3D model interaction
e = Event alert
f = Fixed preset tours
g = Personal trajectory guide
h = Photo shooting
i = Multi-language interface
k = Audio guide for adult/ kids
m = Indoor Map navigation
o = Trip overview
p = Real-world panoramic
q = QR Code supported
r = Collection retrieval
s = Social interaction
t = Microsoft Tag supported
v = 2D virtual environment

Some interesting implementations were explored during this year-long survey. For example, the interactive platform of Musée du Louvre is operated by a Nintendo 3DS, The Royal Ontario Museum used ScopifyROM1 technology to allow visitors to view x-rays of Egyptian coffins from their own devices and load a decoder to translate the hieroglyphs on the outside. The National Gallery of Ireland adopts Vision Recognition technologies to replace the traditional audio guide. Although the authorities attempt to enhance the museum experience via mobile devices, 40% of services charge an extra fee from either on-site renting or online/In-app purchases; only one-third of organizations offer the experiences completely free of charge.

Evaluation

In terms of the four key strategies defined by Li & Liew (2014), a total of 32 functions have been identified: 10 for Education, 14 for Interaction, 7 for Personalization, and 1 for Visualization. Figure 2 indicates the trend that each application focuses on. Each line represents an application assessed by the four aspects. The value represents the number of functions available for each aspect. Most respondents focus more on visitor interaction, followed by Education, Personalisation and Visualisation in an order.

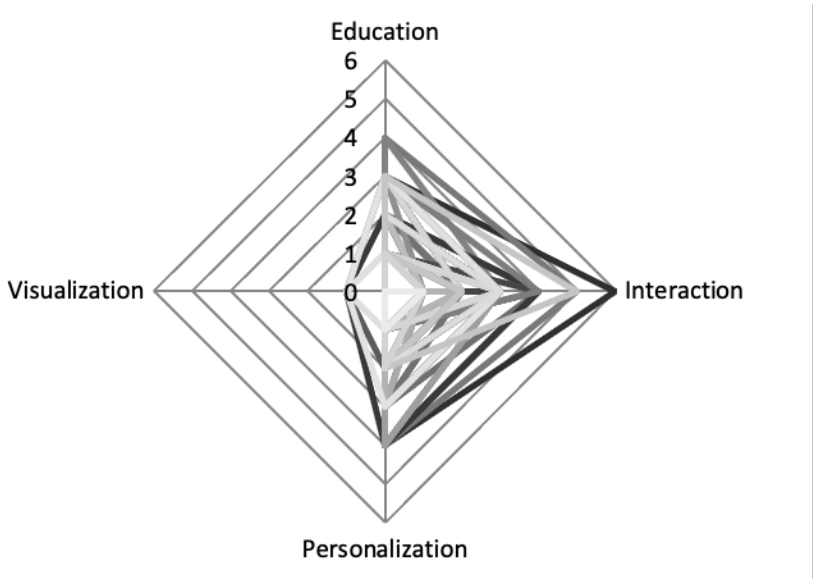

Figure 2. The trends of each aspect based on the available functions of each application.

According to the survey, British Museum provides up to 6 interactive functions in its app including audio guide, outdoor navigation, on-site floor maps, 3D model interaction, social interaction, and 2D virtual environment presentation is the most interactive application. On the other hand, the aspect of Visualization appears to be a major weakness in the development of museum handheld devices. Also, only 3 out of 103 organizations support after-visit feedback, such as a trip overview or a list of the visited collections. None of them provides recommendations during the visit. Interestingly, even for organizations that offer after-visit feedback, the feedback can only be received by email. This means that visitors cannot get feedback directly during the visit.

Interaction

Interaction is the most popular element conferred on mobile devices. Fourteen techniques are deployed to interact with visitors across different platforms. As shown in Figure 3, the traditional pre-recorded audio guide is still the preferred technique used by 70 out of 86 authorities. Social media, such as Facebook or Twitter gradually become the major communication platform compared to other tools, such as email or phone calls.

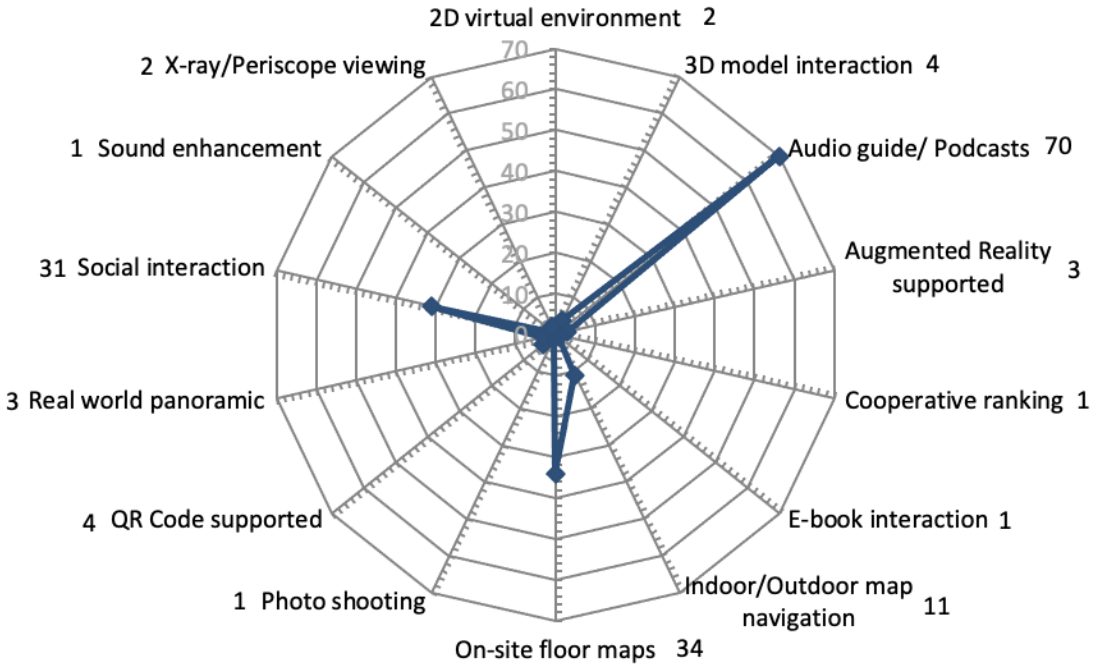

Figure 3. Distribution of adopted functions from the interaction aspect.

Education

The most popular method to enhance education through technology is by providing extra information, which is adopted by 47 authorities. This is followed by the video-based introduction and collection retrieval applied by 28 organizations. It is worth noting that some organizations use dynamic presentations to trigger visitors' interest instead of literal transcription of collection information. For example, the National Museum of Korea and Gyeongju National Museum present their collection information through a series of storytelling videos; the literal transcriptions of antiques are replaced by 3D recreation clips in the State Hermitage Museum, and the Van Gogh Museum applies real-world panoramic with an audio guide to explain Vincent's painting.

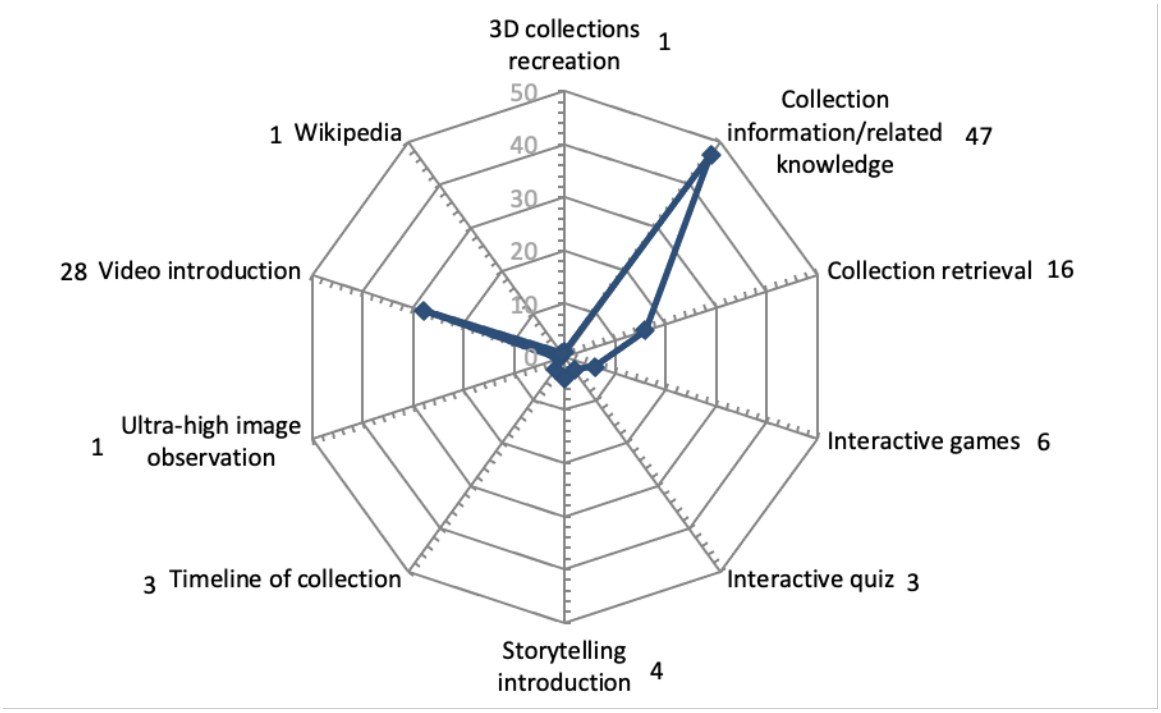

Figure 4. Distribution of adopted functions from the education aspect.

Personalisation

Personalization is regarded as the third most popular application just above Visualization. As seen in figure 5, most organisations applied multi-language support to enhance the personalised experience. However, around 60% of museums still use the traditional audio guide as an information provider despite significant advances in mobile technologies over the past decades. The machine-guided tour, such as personal trajectory guides and pre-set fixed tours can also be seen in some of the museums. However, without collecting user behaviour, these systems can only perform preloaded tours with a limited number of themes.

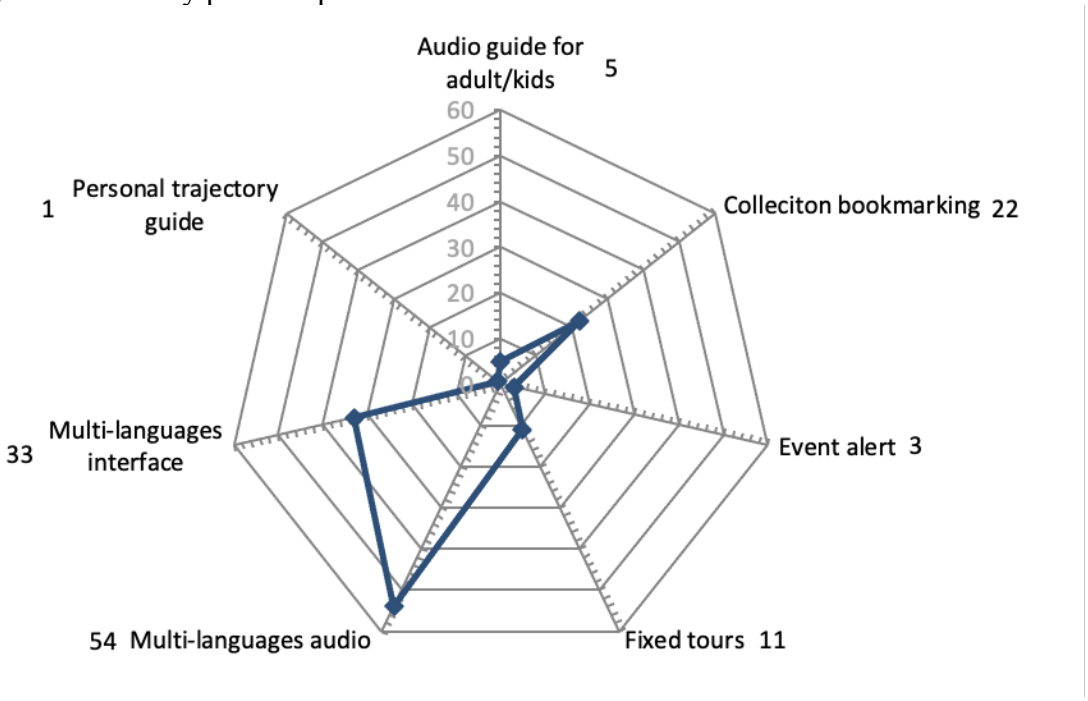

Figure 5. Distribution of adopted functions from the personalisation aspect.

Visualisation

In terms of Visualisation, only three museums, the Art Gallery of Ontario, the Museum of Modern Art in the USA, and the Museum of Contemporary Art in Australia allow visitors to review their visited collections by bookmarking collections on-site.

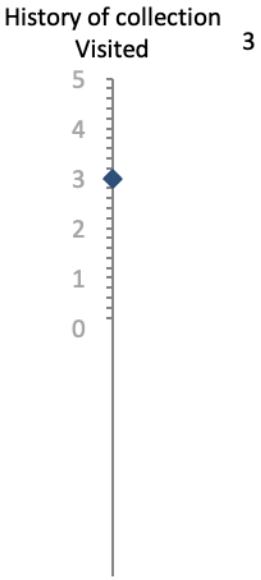

Figure 6. Distribution of adopted functions from the Visualisation aspect.

Conclusion

In this paper, our goal was to clarify the current trends in the development of on-site museum technology and identify the gaps that can be closed in the future using the aspects of Education, Interaction, Personalization, and Visualization, which have been declared previously as the four key strategies to enhance the museum visiting experience. We conducted a survey that provides a comprehensive analysis of the development of on-site electronic devices in the top 103 most visited museums in 23 countries. Three stages of data collection are deployed to assemble information from May 2019 to mid-2020, including online search, personal contact, and personal visits. The results show that 83% of museums surveyed are available to engage with visitors either through audio guides or multimedia guides/smartphone apps. However, only 35% of them support both. Our findings indicate that Interaction is the most important strategy implemented in the museums, followed by Education, Personalisation and Visualisation in order.

The main gaps in the development of VTG are the following: First, apart from the audio guide, the apps developed by most English-based museums do not support a multi-language interface. Second, all applications in this survey perform only one-way passive interaction. The visitor cannot receive personalised recommendations or feedback during their interaction with the devices. Third, none of the applications provides active personal on-site tours and visiting recommendations. Finally, Casual InfoVis, which focuses on promoting personalized experiences has not yet been considered widely to enhance museum visiting experiences.

Although many organizations strive to bring visitors back through their doors in the post-pandemic era, our results indicate that the on-site visit experience is still at the primaeval stage. With these results, we conclude six recommendations for future work below:

(1) The system should be developed based on open-source tools, applicable to different platforms, to reduce development costs and avoid additional charges to visitors.
(2) The development of mobile devices in museums needs to pay more attention to the cooperation of personalization and visualization.
(3) Personalization should focus on providing real-time recommendations about the collections during the visit.
(4) The concept of Casual InfoVis can be considered a strategy in the system development to collect visitor's behaviours proactively.
(5) Social media should be used as a cooperative platform to enhance on-site interaction.
(6) Collection information should be accessed through interactive technologies, such as AR or QR Code to arouse the interest of visitors to achieve educational goals.

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