Handbook of Research on Technological Developments for Cultural Heritage and eTourism Applications

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Chapter 2
Interactive Technologies in Museums:
How Digital Installations and Media Are Enhancing the Visitors' Experience

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ABSTRACT

With the constant development of digital means of entertainment – that are easily made available to people and, in most cases, can be used anywhere – nowadays, a visit to a museum have to surround publics with unexpected and interactive experiences, in order to capture their attention and make them want to go to these places, in addition to continue to communicate their collections and promote society education. In this regard, it was discussed in this chapter the actual panorama of interactive technologies used in museums exhibitions worldwide, and there are discussed how these institutions are designing digital installations and utilizing virtual media to enhance the visitors' experience, promoting positive relations between them and their publics. The main conclusion and reflection of the chapter is based on how this new era of technology is allowing increasing physical, cognitive and sensory accessibility, and transforms this kind of experience for disabled publics.

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INTRODUCTION

Because one lives in an era where people spend the most part of their time in front of screens and connected to the internet, museum professionals have to think about how to make collections and exhibitions still relevant nowadays, and how to compete with all the available entertainment ways and technological developments, in order to capture the visitor's attention and encourage their visit to these spaces.

Once this chapter focuses on exploiting digital ways of interactivity in museums, it is crucial, first of all, to understand their role in contemporary: "A Museum is 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" (Desvallées & Mairesse, 2010, p. 57). Based on this professional definition, widely recognized and disseminated by ICOM – International Council of Museums – since 2007, it is clear that museums must provide to society the access to education, offering moments of study and leisure, in order to cooperate for its development, committing itself to safeguard and communicate their collections to the public (Desvallées & Mairesse, 2010).

As institutions are increasingly interested in providing outstanding informal learning experiences, there has been an effort to meet the visitor's aspirations, through the adaptation of innovative technology to communicate and encourage the visit to these spaces (Chelini, 2012). As pointed out by Sree Sreenivasan – the Metropolitan Museum of Art's chief digital officer, until June of 2016 – on an interview to Gilbert (2016), museums no longer need to compete with each other, because they are losing their visitors to the omnipresent technologies, games and social media consumed by the modern society; instead, those institutions have to find out ways to embrace the fact that smartphones, tablets, smartwatches and other digital devices are everywhere, and take advantage of the fact that people use them no matter when or where: "People ask me what our biggest competition is (…) It's not the Guggenheim; it's not the Museum of Natural History. It's Netflix. It's Candy Crush" (p. 32) and most recently, Pokémon Go (McCluskey, 2016). Taking these facts into account, it is self-explained why museums are committed, more than ever, in providing new scenarios of interaction and contact with their exhibitions.

On the other hand, it is important to make clear that the use of digital resources would not even be an option to communicate and to interact with the exhibitions if their use offers no contribution to what is being presented: in some cases, technological solutions are seen as essential for facilitating the reproduction of stories and intangible processes, like sound recordings, music, videos and other non-physical heritage; in other instances, they contribute to expand information about what cannot be exposed, like no longer existing artefacts and places, giving access to reconstructions and digital replicas (Chanda, 2013).

About the exhibition of physical samples, the use of digital resources proves to be beneficial because it enables visitors to have a better understanding of objects and ideas – since it allows offering complementary information in a more attractive way for visitors, without overloading the exhibitions environment with excess of information – and allows to increase accessibility and enable opportunities for disabled persons (Freeman et al., 2016; Israel, 2011).

However, professionals should be aware that technology must be used as a medium and not as an end, according to Israel (2011), McMullan (2015) and Olesen (2016), where, ideally, the museum themes should be harmoniously combined with digital content to communicate effectively the exhibitions and, at the same time, provide an incredible experience to visitors while using them: "given the increased emphasis on user experience, it is no longer sufficient to ensure that a system is merely usable" (O'Brien & Toms, 2008, p. 939).

Taking these considerations into account, this chapter aims to make a contribution to better understand the actual panorama of interactive technologies that museums are embracing to communicate their exhibitions, and to explore how the use of these digital installations and media are enhancing the experience of visiting these spaces, transforming the relations between them and their publics. Thus, they are discussed the virtual museum and online collections, the role of interactive kiosks and multi-touch surfaces to amplify exhibitions, interactive projections for immersive experiences, mobile applications and five types of emerging technologies. For each one, they will be addressed at least four projects currently implemented in museums all around the world and, at the end of the chapter, it is made a reflection about the use of technology to increase accessibility in museums and discussed examples of installations designed for enhancing the experience of disabled publics.

THE VIRTUAL MUSEUM: ONLINE COMMUNICATION, COLLABORATION AND SOCIAL MEDIA

According to Holdgaard (2011), there is no well-defined conceptualization for virtual museum: online museum, electronic museum, hyper museum, digital museum, cyber museum, web museum, among others, are the many possible names for the virtual museum. Regardless of the nomenclature, this is a database made digitally available over the internet, and can be distinguished in three main variants, with focus on content, communication and collaboration, that can also be fully connected with the museum's own museographic tools (Geser & Niccolucci, 2012; Holdgaard, 2011).

The museum's web site provides not only information support, but also contents generated by visitors through posted photos and videos, wikis and discussions, blogs, microblogs, collective subtitles, social bookmarking, tagging, integration and sharing of information via social media platforms, like Facebook, Twitter, Instagram, Pinterest, among others (Geser & Niccolucci, 2012; Johnson, Becker, Estrada & Freeman, 2015). Actually, there is a trend toward a preference, by users, of interactive, and not only passive, virtual relations (Carvalho & Raposo, 2014). The user, therefore, actively influences the construction of museum knowledge, structuring a new paradigm for the museum-visitor relationship. The museum's presence on the internet, in our days, may represent its very subsistence, since the lack of virtual communication may result in invisibility to many potential visitors.

Over the last two decades, the boom of web sites and social media associated to museums raised the question of whether those virtual spaces will, one day, take the place of the physical museum. It has been debated, actually, since the early days of photography. It is believed that the virtual museum will never eliminate the longing for physical matter that is present in all of us. On the contrary, from virtuality it can foretaste the knowledge of reality, and thus have a greater longing for a broader knowledge of it. Virtuality may, ultimately, work as a bridge toward reality or its amplification (Veiga, 2013).

The Louvre Museum is an example of that kind of bridge. It is possible, through the tools available at the museum's web site, to: download the maps of the museum; take an interactive, virtual tour through each one of the museum's floors; take a virtual tour through the museum's rooms, with 360° controllable images and 3D exploration; have access to mini-sites of specific works of art, as well as quick documentaries at the "eye-openers" section; have access to a huge database of works, with catalog information about them; schedule visits to researcher-only areas, such as technical reserves and fragile collections (Louvre, 2016). In recent queries, one found out that the Louvre's web site has broadened

the acquisition of knowledge about the archives and the institution, optimizing visitation time through previous planning and maximizing one's own experience with the real collections.

As an example of amplification of real-life experience, it can highlight the Google Art Project, which made available virtual tours to many art works in museums around the world, with the possibility of unusual approaches. That tool allows the detailed observation, even more than in a real-life visit, of the painting's surface, creating the possibility of technical and esthetical studies that would not be possible only with the direct observation of the work in the museum (Cultural Institute, 2013).

The project VanGo Yourself joins virtual exhibits, creation of contents, interactivity and the use of social media. The proposal consists in recreating, with friends, scenes portrayed in famous works of art. The visitor selects the work from various criteria, such as the number of persons portrayed or by choosing a specific museum. As soon as the photo is generated, the user uploads it to the web site, where the image is then twinned with the original and shared on social media (VanGo Yourself, 2016.).

The Art Detective portal is free-to-use online networks where anyone can help public art collections across the United Kingdom enhance painting information, uncovering attributions and solve mysteries through public discussions. Participants can post or answer questions related to various aspects of the work under analysis: artist, theme, date of execution, technique, support, description, among others. Since its debut in 2014, over 100 discussions have been initiated, bringing forth about 40 new findings (Art UK, 2016).

It has been realized that a solid and quality virtual museum isn't merely a repository of photographs of artefacts of the collection, but the ultimate challenge is to create virtual environments that are concerned with the narrative and relational aspects of the digital exhibition, that promotes collaboration between public and museum experts, social interaction and sharing, as well as foment knowledge dissemination. From this point, it will be analysed and discussed digital installations and technologies that are being used in-situ by museums, all over the world.

FROM INTERACTIVE KIOSKS TO MULTI-TOUCH SURFACES: AMPLIFYING THE EXHIBITION

A kiosk is defined, according to the Oxford Dictionary, as a fixed terminal that uses a computational system to provide information, incorporating one or more interactive display screens. The content configuration can be done according to the purpose that it intends to serve in the institution in which it is inserted, and the navigation trough the content is usually done by touching the screen (with just one finger) and, in most cases, it can be used only by one person at a time (Kidd, Ntalla & Lyons, 2011).

Taking into account the presence of these terminals in several museums, Hall (2013) conducted a study where it is concluded that, in most cases, these terminals were not designed in a way to allow visitors to have an interesting interaction: since the large volume of information that can be accessed in a kiosk (such as text, images, video and some games) is not suitable for group use and doesn't allow a good experience of interaction, the social activity during the visit is limited; and this constitutes a problem, as "we often visit museums with others – whether friends, family, peers or colleagues – and even when we visit a museum alone we are sensitive to the behavior of others" (Heath & Vom Lehn, 2010, p. 266). This fact is also corroborated by Kidd et al. (2011), pointing out that the greatest criticism about the use of interactive kiosks to communicate museum exhibitions is exactly the limitation of the social experience during the visit.

Opposite to the case of interactive kiosks, multi-touch screens provide a greater openness to social sharing, because these interfaces facilitate the access to information to a larger number of people, simultaneously: multi-touch interfaces are input devices that identify two or more simultaneous touches providing opportunities to several users to interact with an application at the same time (EDUCAUSE, 2008). Beyond this, due the dimensions of the area to touch – corresponding, normally, to a big screen – and the interface design characteristics, the harmonious integration of these surfaces into the space narrative of the exhibitions constitutes, by itself, an immediate invitation to visitors to interact with this interfaces (Kidd et al., 2011).

One of the most mediatic multi-touch projects is located in Gallery One at Cleveland Museum of Art, a space near the entrance of the museum, where more than 4100 objects from the most important museum's in the world are displayed, on the *40-foot Collection Wall* installation. This surface, arranged as an enormous interactive wall, can be used by several visitors, simultaneously, to navigate through the collection. When an image is touched, the screen enlarges it and gives extra details about the object and where it is located, allowing visitors to personalize and share their own tours – according to its favourite's ones – in order to discover some pieces that are in exhibition inside other galleries of the Museum (Bernstein, 2013; Cleveland Museum of Art, 2013).

After a huge renovation, at the end of 2014, the Cooper Hewitt Smithsonian Design Museum reopened with new digital installations to enhance the public's experience. Several multi-touch high definition tables were used as a medium to communicate, interactively, the Museum themes, in which visitors can explore pieces of the collection – *Collection Browser* area, learn about the history and architectural details of the building – *Mansion History*, and understand the relationship between donors and objects in the collection – *People Browser* area (Chan & Cope, 2015; Cooper Hewitt, 2016). According to Cooper Hewitt (2016), it is possible to note that allowing the socialization during the visit was a core aspect of the Museum intentions, since the tables have various dimensions and the largest ones are described as to allow up to six visitors to interact with them, at the same time.

At the Los Angeles Museum of the Holocaust, visitors can interact with *The Memory Pool*, a multi-touch interface where information emerge on the surface of a table, as objects floating in a pool full of water, showing photographs of people in their daily lives before the Holocaust, like socializing with friends, playing sports, going to school, celebrating weddings, etc. When an image is touched, the information regarding to these moment is load and visitors could get to know more about that moment. On the other hand, if there is no interaction with some of the pictures, the images fade away, representing the loss of these memories (Potion, 2010).

As a last example of this section, the *Science Storms* exhibition, opened in 2010 at the Chicago Museum of Science and Industry, visitors can explore scientific principles behind natural phenomena, like tornados, tsunamis, lightning, and others (Lord & Piacente, 2014). In one of that interfaces, a touch screen is used to create and control, in real time, an authentic experience about the influence of water on fire: during the interaction with this installation it is possible to manipulate a real flame, by varying the gas flow rate and adjusting the water that is being sprayed (Museum of Science and Industry, 2016). With this, public can experiment and learn more about scientific phenomena by controlling, by their own, some of the variables that affect what they are seeing.

CREATING IMMERSIVE EXPERIENCES THROUGH INTERACTIVE PROJECTIONS

In addition to increasing the engagement of audiences, some projects are being developed to integrate scenarios of new incredible experiences of immersion in museums' spaces, transforming the paradigms of information visualization and interaction with exhibitions.

The installation *Pure Land: Inside the Mogao Grottoes at Dunhuang* is one of these cases, described by Julian Raby – director of the Arthur M. Sackler Gallery and Freerer Gallery of Art, Smithsonian Institution – as an exhibition experience of the future (Smithsonian Institution, 2012), in which visitors can actually feel like if they had been transported to another place: while people are standing inside a panoramic enclosure that shows one cave of Mogao Grottoes – an UNESCO World Heritage Site – they "engage in a surrogate true-to-life experience of being inside this cave temple and seeing its magnificent Buddhist wall paintings at one-to-one scale" (Kenderdine, 2013, p. 204). The installation, first shown to public at City University of Hong Kong, integrates high-resolution digital photography's and tridimensional architectural models of the archeological space, combining them into a 360-degree visualization projection system, allowing visitors to navigate through the virtual space and also to interact with 3D animated objects, revealing key details when people uses digital glasses to better inspect the cave's walls (Kenderdine, 2013).

The *Connected Worlds* exhibition at the New York Hall of Science is, according to Holmes (2015), the largest installation ever created that uses projections. It aims to help visitors understand the interconnectivity and balance of a natural ecosystem, in which the interaction with the digital environment is made by using gestures and body movements, constantly tracked by 12 Kinects and an infrared system. The biosphere environment combines six ecosystems that form an interconnected world, so the changes introduced into a virtual organism impacts the system as a whole, regardless of whether they were personal or collective. In addition, visitors can use physical objects to setup the path of a virtual waterfall, and understand the effects that this cause. In an interview to Holmes (2015), the creators of the project said that the children's immersion into the virtual world facilitates and aids their learning: children of a wide range of ages make really impressive interpretations and also associate it to concepts they had been discussing in class.

In addition to promoting the exploration of distant places and enhance education through the interaction with virtual scenarios, some museums are using projection technologies to present art exhibitions. It is the case of *Pipilotti Rist: Pixel Forest* at the New Museum, where the artist' work explores physical and psychological experiences of the living world, through the presentation of textures, forms, lights and sounds, in immersive environments (New Museum, 2016). Described as being radiant with colour, projections on the floor, walls and ceilings expand video images everywhere, and to improve the visitors' experience, the space was embedded with steps, pillows and beds (Smith, 2016).

Contrary to this exhibition, where visitors' interaction with the digital world doesn't provoke a direct effect in what is being presented, the *Immersion Room* at the Cooper Hewitt Smithsonian Design Museum was designed to do so. Allowing public to browse the most important collection of wallcoverings in North America on a multi-touch table (Chan & Cope, 2015), the high-resolution digitized wallpapers are projected at full-scale on the walls around, and some can even be experienced accompanied by comments of their designers. Besides this, visitors can sketch their own designers and see them projected on the walls, in real time (Cooper Hewitt, 2016).

The last project presented in this section belongs to Museum Victoria and was built as a solution to the same difficulty that most museums face: due the lack of space, only a fraction of their collections can be displayed to public. The *mARChive* interface consists in a 360-degree three-dimensional stereoscopic interactive visualization environment that allows the navigation through more than eighty thousand digital records of objects of the Museum, grouped in eighteen themes, projected all around the surrounding walls. Using a tablet to browse and select images, and 3D glasses to visualize them, the immersive cinematic experience is augmented by the possibility of examine the high resolution images, at one to one scale, with descriptions of the objects (Kenderdine & Hart, 2014). This project constitutes a new way of organizing and thinking about how pieces that aren't in exhibition can be digitally accessed, and how they can be communicated to the public in an interactive scenario.

As seen, interactive projections are being used by museums to transform spatial environment, allowing visitors to interact with them using their body gestures, imagination and making decisions, contributing to improve education while providing new experiences of immersion inside their spaces.

MOBILE APPLICATIONS: AUGMENTED EXHIBITIONS, MUSEUM TOURS, AND GAMING EXPERIENCES

Portable devices like smartphones, tablets and smartwatches became ubiquitous and, in addition to allowing connections to the Internet, also include built-in cameras and sensors that enable the interpretation of the real world, which can contribute, in some cases, to stimulate new interactions with collections and museum spaces (Freeman et al., 2016; Johnson, Adams & Witchey, 2011).

In fact, most part of visitors bring their own devices when visiting museums and, as result, these institutions are embracing and taking advantage of this reality by producing applications (apps), since "they can meet those visitors in their comfort zones to not only fulfil information needs, but also encourage enhanced exploration, interpretation and sharing … heighten visitor experiences by providing more comprehensive materials, including multiple critical interpretations, stories and contextual information" (Freeman et al., 2016, p. 16).

According to McMulla (2015), successful museum apps are those who create engagement with museum themes and invite public to move within the space, in a way that learning can be complemented with enjoyment, instead of requiring constant attention to what is happening on the digital world. As an example, the San Francisco Museum of Modern Art designed the *SFMOMA* app to encourage visitors to explore the museum with their eyes on the physical exhibition and art, instead of having to look and being concentrate on their phone screens, as they listen to unique descriptions while moving through the museum (SFMOMA, 2016). Based on a virtual map created by Apple for the museum, the app implementation goal was to use visitor's phone's location-aware technology to triangulate its position and combine immersive audio storytelling that adjusts its contents – like perspectives, reflections and responses to artworks, and point-to-point direction to locations in the building – accordingly to their walking (Chun, 2016; SFMOMA, 2016).

On the other hand, the *Second Canvas* app by Museo del Prado was created to let visitors explore with extra detail 14 masterpieces from the permanent collection, in images with giga-pixel resolution, which means a level of detail practically invisible to the naked eye. Additional information about the

layers of paintings can be exposed by using super-zoom, ultraviolet, infrared and x-ray vision functions, only experienced before by the curators and restorers of the museum, and the app allows to share cropped images of the pieces directly via Facebook and Twitter (Mad Pixel Factory, 2014; Williams, 2014). In an interview to Williams (2014), the deputy director of the Museo del Prado – Gabriele Finaldi – says this app aims to change the way people experience artworks, providing a deeper level of understanding while using smartphones and tablets to discover the paintings: with the app you can discover every centimetre of the work of art in your own time on your iPad, leading to a profounder understanding of how it was created and each element the artist included.).

Some museums, like the Royal Ontario Museum allow visitors to experience the past by using augmented reality. Through the *SopifyROM* app it is possible to add skins to dinosaur skeletons, give life to extinct animals, restore destroyed objects to their original form, decipher antique languages and see objects in its original setting (Czikk, 2013). The app also allows x-ray views of some pieces and to scan QR codes scattered throughout the museum, which give visitors extra information about the artefacts in exhibition, in the form of video, audio, text and interactive graphics (Oliveira, 2013).

In an effort of trying to reduce the distance between visitors and museum professionals, the Brooklyn Museum designed the *ASK* app, that allows onsite visitors to ask questions and have conversations with experts, in real time, and get responses about the works of art in the museum, with the facility of capturing images and sending photographs directly to them, which helps to give context to the question being asked (Browne, 2014). After measuring the impact of ASK, Shelley Bernstein – the Deputy Director of Digital Initiatives and Chief Experience Officer at the Barnes Foundation – concludes that the conversations via the app are a success for deeper engagement and understanding of the works, and the use rate and depth of interaction achieved was never so high on Brooklyn Museum previous projects, like comment kiosks, mobile tagging and QR Codes (Bernstein, 2015).

As the last project of this section it is mentioned the *Capture the Museum* app from the National Museum of Scotland, the first physical team game developed for a museum in which visitors, with their own smartphones, explore galleries of the museum to solve exhibit-related puzzles and scan into territories using their device's camera, in order to beat the other team. With duration of 30 minutes, the game can accommodate up to 50 players at the time and a map shows in real time which team is winning the challenges concerning to the different galleries of the museum. Gamification was the surprise element when designing the app, since visitors didn't expect to find nothing like this in such an august institution and, by introducing technology to encourage visitors to learn more about history, it was expected that the app could appeal to new audiences (National Museums Scotland, 2013).

EMERGING TECHNOLOGIES

The *New Media Consortium Horizon Report Series* are recognized all around the world for the longest-running exploration of emerging technology trends in museums. On the *2016 Museum Edition*, the expert panel identified some categories of emerging technologies that they believe will be widespread use in museums over the next five years (Freeman et al., 2016). Based on this work and research of recent projects being developed in museums, this section will explore five types of emerging technologies that are changing interaction and opening new scenarios of exhibitions' communication, providing, as well, examples of their implementation in museological institutions.

3D-Printing and Scanning Technologies

According to Hancock (2015), 3D-scanning and printing technology provide myriad possibilities to increase engagement and depth understand of museum pieces, because visitors "can feel and look at objects previously only view under glass" (p. 33), which provides sensory information that allows to feel and experience the exhibit in new and direct ways.

Currently, there are three main uses of 3D-printing by museums, pointed out by Professor Daniel Short, from the Environmental Science Department at Robert Morris University: for hands-on studies and educational purposes by scanning and replication of original pieces, for educational exhibits about 3D-printing (including Maker Faire and Fab Labs) and for restoration of damaged artefacts and exhibits (Schuster, 2015).

Some museums, like The Art Institute of Chicago are using 3D-technologies, in this case, to allow visitors to hold and touch tridimensional replicas of selected objects from the collection (which were scanned, 3D-modeled and printed at a 1:1 scale when possible) with the aim of creating multi-sensory tours for adults with Alzheimer's and low vision, where discussions and learning about the original works of art are promoted (Association of Art Museum Directors, 2015). Despite the three dimensional printed representation of objects not being perfect in most cases, the original ones remain preserved and safe from close contact (Hancock, 2015; Neumüller, Reichinger, Rist, & Kern, 2014).

Another example of using those technologies in museums is the *Ancient Lives, New Discoveries* exhibition from the British Museum and the Samsung Digital Discovery Center, in which visitors, after handling three replicas from the collection, could recreate, design and 3D-print their own Egyptian amulets, while discovering the different themes associated with each. As complement of the experience, participants were able to animate an Egyptian river scene and 3D-print their models, with the help of a professional 3D artist (Biggs, 2014).

At the Metropolitan Museum of Art, some activities were developed to educate and encourage visitors to explore 3D-technologies to construct replicas of artefacts in exhibition in the museum, by taking pictures of the objects from all sides (using the *123D Catch* free program). In turn, if a visitor is not comfortable with using these technologies, the museum provides models available online, in an effort to enhance the experience. After this, the sculptures can be 3D-printed and visitors can take them home (Undeen, 2013).

To finish, another project using three dimensional technologies to extend museum objects besides their physical spaces is the *Smithsonian X 3D*, from Smithsonian Institution, which offer pieces from its collection that have been digitalized and placed online, with the aim to make museum collections and scientific specimens more widely available and contribute to improve education all around the world (Clough, 2014; Smithsonian Institution, 2016): lectures can now download data from a new Smithsonian website and generate precise replicas for students to inspect using a relatively inexpensive 3D printer" (Clough, 2014). With this project, even students from the other side of the world can get to know the physical objects and engage with them.

Virtual Reality

When the subject is virtual reality, there are being current debates about it at the most important world-wide institutions, since it is expected to be the next digital trend on entertainment, gaming, tourism, culture and information industries, among others.

In fact, the conceptualization of virtual reality is not so recent and some works in the past were developed in museums:

In 1992, Apple Computer's Virtual Museum was one of the first documented implementations, which consisted of a demonstration disc for Apple's QuickTimeVR (Freeman et al., 2016, p. 42).

However, the high costs associated to virtual reality were an obstacle to museums in general, until the recent development of devices, such as HTC Vive, Samsung Gear VR and Oculus Rift, that, by the fact of being powerful, user-friendly and low-cost, started to become commercially available (Adams, 2016; Jung, tom Dieck, Lee & Chung, 2016).

Virtual reality refers to computer-generated environments that replicate places, presence of people and objects, or fictional worlds, allowing realistic sensory experiences by the full immersion in a digital environment (Adams, 2016; Freeman et al., 2016; Jung et al., 2016). Virtual reality differs from augmented reality, since the first offers the user digital immersive environments where they have the ability to move around and interact with them, opposite to augmented reality, that allows to add digital information to images and real-life contexts (Adams, 2016; Guerra, Pinto & Beato, 2015).

Taking these nuances into account, Adams (2016) clarifies that 360-degree cameras cannot be considered virtual reality: despite users can look around within an immersive visual experience, they can't navigate through the environment, neither interact with anything in them, not controlling the experience as a whole.

The Natural History Museum exhibited the *First Life* virtual reality experience, to allow visitors to explore the world's ancient oceans – using Samsung Gear VR headsets – and interact with sea creatures that existed 500 million years ago, three-dimensionally reconstructed based on the Museum's research about those extinct specimens. The 15-minute adventure is narrated by the nature commentator Sir David Attenborough, transporting visitors to non-existing places and providing a new scenario of experiencing the museum's collection (Natural History Museum, 2015).

At the British Museum, visitors were able to explore a *Bronze Age* site and interact in their historic context with 3D scans of objects from this period (belonging to the museum's collection), with Samsung Gear VR headsets put on to look around and using a touchpad to navigate within the environment. This exhibition enabled the testing of how virtual reality can be applied to enhance the family audience's understanding of a historic collection, and the results showed that feedback received reveals enthusiasm and confirms the positive impact of this experience on learning about the museum's pieces made available (Rae & Edwards, 2016).

In addition to allowing new discoveries about real objects from the collection, a project is using virtual reality to expose inaccessible heritage. The Museum of Stolen Art is a virtual space dedicated to display artworks that have been stolen by criminals, during wars or dubious historical agreements, that cannot be viewed in any exhibition from any museum in the world. Available as a smartphone app, virtual reality is employed to allow "visitors" to navigate virtual galleries, look at works and activate and read pop-up didactic texts, completed with audio tours to contextualize rotating exhibitions (April, 2016).

At the Salvador Dalí Museum, visitors can experience multiple interactions and feel what it is like to be inside a painting, at the *Disney and Dalí: Architects of the Imagination* exhibition, created by a partnership between the museum and Disney. According to Nofuente (2016), the *Disney and Dalí* experience provide a multi-sensory three-dimensional environment of moving image and soundscapes, while views are moving in the picture itself as other visuals from Dalí's works like elephants, birds, ants, using Oculus

Rift headsets as mediators of the surrealist's creations. The author refers that projects like this one, built using virtual reality, are being developed in museums once they offer new and innovative scenarios of communicating the collections, with the expectation of bringing even more foot traffic back to museums.

Beacons for Location Intelligence

According to Freeman et al. (2016), location intelligence is a digital strategy to the mapping of positioning and its association with data. Providing location-based services, it can be used to deliver specific information in response to visitor's surroundings and enable in-depth analytics on their behaviours, contributing to the promotion of formal and informal learning in museums space.

As seen before, triggering content on mobile devices is something that some museums are familiar with, allowing the use of mobile applications to interact with exhibitions through QR Codes or NFC tags disposed near objects in exhibition, for instance. However, beacons enable automatic content delivery to nearby smart devices via Bluetooth, functioning as wireless tools that can be installed anywhere – since the chosen location has no barriers like walls, vitrines and objects – and are almost invisible. This reality enhances the interconnection between objects and digital devices, playing a significant role in advancing the "internet of things" concept (Bernstein, 2015; Nilsson, Blackwell, Hogsden & Scruton, 2016).

In a collaboration between the University of Kansas and the Spencer Museum of Art, a mobile app using iBeacon technology was developed to encourage a deeper engagement with the collection and enhance onsite visitors' experience. The devices were placed strategically throughout the museum and, when someone is near, the app alerts with a pop-up message that there are items of interest approaching, offering additional images, video and text about the objects of the collection (Association of Art Museum Directors, 2015).

The Australian Maritime Museum uses a Beacon solution to monitor the visitor's behaviour inside the museum spaces, to better manage exhibit space and public engagement. Given that this project is not to visitors interact directly with the exhibition, there was no necessity of requiring them to download a specific app. Instead, the solution adopted was by attaching a Beacon as a key ring that it's given to visitors when they use the storage locker service of the museum. While moving inside the museum, iPods paced throughout the museum detects the Beacons and send live data via Wi-Fi to an online dashboard, where staff can access the information (Nomad Agency, 2016).

The University of Cambridge Museums consortium designed a mobile game named *Ghosts!* that use the beacons placed through the gallery spaces and across the eight museums that compose the consortium, to lead visitors through the different museums. The narrative unfolds while walking, so the app pop-up on the screen of the visitor' mobile device some 'ghosts' that are lost and need help finding their way back to their home artefacts – each one equipped with its own Beacon – while feedback about the directions is constantly being provided (Nilsson et al., 2016). From the designers' perspective, the great advantage of using Beacon technology to develop games for museums is "the ability to create an ongoing dialogue between objects (or their digital representation in a mobile app) and visitors where the communication between the two is constantly changing according to how visitors move through, and around, gallery spaces" (p. 135), without the need for expansive technical infrastructure.

To finish this section, it is referred the experiments across different departments at the Metropolitan Museum of Art with location-aware content delivery through Beacons. Positive aspects pointed out about the use of this technology are the potential in informing and alerting visitors about locations of special exhibitions, about current tours and events happening near to them, and the learning value that can be

achieved by providing supplementary audio and video content for communicate the objects. Nevertheless, efficacy issues such as temperature changes and human traffic were reported, since these phenomena affect the signal of each Beacon device (Doljenkova, 2015).

Wearable Technology

Taking into account the growing trend of wearable devices, such as smartwatches from Apple, Samsung, Sony and Pebble, bracelets from Jawbone, Nike and Fitbit, and Google Glass, among others, museums are exploring the potential of these technologies in their spaces because they allow new scenarios of storytelling and interaction.

Wearable technology refers to computer-based devices that take the form of a portable and lightweight accessory that can be worn by users, and can integrate tools to track social media interactions, movement, vital signs, perform productive tasks like check emails, etc (Johnson, Becker, Estrada & Freeman, 2015).

The exhibition *Body Metrics* at the Tech Museum of Innovation allow visitors to explore and understand their body metrics, using a wearable Sensor Kit that measures and displays their activity level, tension, mental focus, talkativeness, attitude and the number of people nearby, in real time. The aim of the exhibition is to let visitors learn more about how some activities affect their physical and mental wellbeing, by exploring the metrics collected by the kit: a smartphone is worn around the neck to explore the surrounding environment, a NeuroSky wireless headset measures brainwaves and a Somaxis EXG sensor is worn on the skin to register muscle tension and heart rate (Tech Museum Of Innovation, 2014).

According to Corine (2014), the San Francisco de Young Museum was the first to offer a tour where visitors could wear Google Glass to see digital content and learn more about the artworks, on the *Keith Haring: The Political Line* exhibition. This wearable was chosen because of being a non-intrusive solution for augmenting the exhibition and being a light-weight device, so visitors can walk around the gallery and immerse themselves into the exhibition: when approaching an artwork, visual and audio content about the artist' life and work is presented automatically – trough Beacon technology embedded at the museum space – eliminating the necessity of interaction with the wearable device. Augmented reality effects are provided as well, so hidden details not easily visible can be observed as the explanation about the pieces occurs (Corine, 2014; Gąsiorek, 2015).

Most recently, the Oscar de la Renta Retrospective exhibition at the same museum (de Young) designed a mobile app that integrates a smartwatch to acts as an invisible tour guide, delivering additional interpretative information in real time, so visitors can always be concentrated in the art itself, without needing to look to the screen of a device: anyone with an Apple Watch can go "through the museum and hear recordings about the nearest display when alerted by a vibration on their wrist… Tap the watch and Andre Leon Talley or de la Renta himself will discuss the influences behind the piece" (Kelly, 2016, para. 3).

As a last example, it is mentioned that the Design Museum is working on designing the *Fear and Love: reactions to a Complex World* exhibition that aims to track visitor's vital signals to interact with installations by manipulating their biometrics with breathing exercises. Smartglasses are embodied with sensors to measure heart rate, breathing and brain waves, and the data is processed by an oversized belt that allows influencing the digital art that is being presented. For instance, a green square covers or reveals the image of a rose depending on how stressed a visitor is; the calmer he/she is, the less a busy crowd is displayed and according to his/her breathe, the rope being pulled in two directions, in a video, becomes more or less tense, as organic signs are being measured (Charara, 2016).

Tangible User Interfaces

The beginnings of the concept of tangible user interfaces dates back to 1993, when the publication of *Back to the Real World*, which warned that the digital environment of computers and augmented reality did not constitute natural habitats for humans, so it was evident the need to develop practices that allow a more balance interaction between the real world and the virtual one, in which the physical dimensions were enriched by digital elements (Shaer & Hornecker, 2010).

Two years passed till Fitzmaurice, Ishii and Buxton (1995) introduced the term *Graspable User Interface*, where tangible blocks – *bricks* – were used to manipulate digital objects, making it possible, among other actions, to control the position of the digital material and make use of both hands at the same time. These authors highlight that space-multiplexed input, contrary to time-multiplexed input, provide a new way of human-computer interaction, since a specific transducer can be associated to a unique function, which occupies its own space and allows any of these points to be accessible at any time to the user, and to be handled simultaneously.

Based on these works, the conceptual model of *Tangible User Interfaces* was proposed as a combination of the architecture of ubiquitous computing system with the conceptual model of augmented reality and physical computing, turning the world into an interface. To this end, there are three key concepts: "coupling of bits and atoms" to the allocation of digital data to tangible objects, which gain expression when they come into contact with the "interactive surfaces" – solid interfaces adapted to the coexistence of both worlds. Finally, the "ambient media" includes elements that discretely allow influence human perception, including changes in sound, light and air movement (Ishii & Ullmer, 1997).

With this, tangible objects simultaneously allow the representation and manipulation of digital content, opening space to the inclusion of this concept in many aspects of daily life, in which they have proving to be effective, such as in the educational and learning areas, new scenarios of information visualization, problem solving and planning, entertainment and games, music and performances, social communication Shaer and Hornecker (2010), amongst others, and for museum exhibitions, which constitutes this chapter main focus.

At the Lille Natural History Museum, visitors can discover the collection of more than one thousand mineral samples of the collection – that cannot be in exhibition due to lack of space, while ensuring their conservation – by manipulating tangible disks on a surface, which represent atoms. Each one of these is associated to geological samples made of that particle and it is possible to combine various elements, on a horizontal interface, to form more complex atoms aggregation. At the same time, a vertical screen shows images and textual information about the rocks (Dalbavie, 2014). The author points out that the *Tangible Lille* installation is available for use by one or more visitors at the same time, promoting collaborative learning and a high level of personalization, since three modes (scientific, simples and game) allow access to several layers of information about the minerals.

Another example of using this technology in museums exhibitions is the *SynFlo* exhibit, a project developed for The Tech Museum Of Innovation, that utilizes physical objects with integrated displays and laboratory objects, with which visitors can interact to explore bio-design activity: when manipulating real lab items, it is possible to add virtual plasmid or toxins to the previous gene selected and observe the results of these reactions in the active tangible tokens (Okerlund et al., 2016). The authors suggest that the combination of gestural interaction with active tangible tokens in exhibitions foster visitor's involvement and provide more serious context to the activity.

Belongings is an interactive tangible table top display developed to explore the intangible cultural heritage and the belongings as a cultural knowledge, using replicas of unearthed Musqueam objects, as well as other elements used by the community nowadays. During the exhibition *c̓əsnaʔəm: the city before the city*, through the installation, visitors could learn about ancient knowledge, culture and technology, by interacting with the material objects, which according to Muntean et al. (2015) encouraged interactions between visitors, the sharing of information and informal discussion about the themes explored. This project was a partnership between the Museum of Vancouver, the Museum of Anthropology, the Musqueam Indian Band and the University of Waterloo.

The *Diplomacy and Sèvres Porcelain, Prestige and the French art of living in the 18th century* exhibition included a tangible user interface dedicated to the exploration of the artefacts at the Louvre DNP Museum Lab –a museum created by collaboration between the Louvre Museum and Dai Nippon Printing. Visitors were provided with a set of physical miniatures of some of the objects in exhibition which, when placed in a specific area, allowed to visualize and manipulate a three-dimensional virtual representation of the objects, providing access to extra details and complementary information (Musée du Louvre & Dai Nippon Printing, 2010). Also at the Louvre DNP Museum Lab, the exhibition *El Niño Azul, Goya and Spanish Painting in the Louvre* had a space dedicated to understanding the factors related to painting, through an installation named *The painting, a material object*. Visitors could handle eight physical elements that allowed to virtually act in the different layers of the work, in order to get to know the various stages of its creation and the alterations in the original work caused by weather, humidity, heat and light exposure (Musée du Louvre & Dai Nippon Printing, 2012).

To end this section, it points out that the major potential of this technology is that tangible objects can be handled, revealing new scenarios of interaction and communication of exhibitions. According to Classen (2007), in most cases the artefacts in museums can only be looked at, ignoring one of the major human senses that allow interaction with the world: the touch. The possibility of being able to establish physical contact with the exhibits has the advantage of complementing some sensory aspects that vision cannot grasp by itself, such as weight, texture, shape, materials and hardness of the objects (Classen, 2007; Damala et al., 2016; Morgan, 2012).

ACCESSIBLE INSTALLATIONS FOR DISABLED PUBLICS

The International Classification of Functioning, Disability and Health defines disability as an umbrella term for impairments, action limits and participation restrictions (World Health Organization, 2016), and estimates that over a billion people worldwide (about 15% of the world's population) have some form of disability. Taking this data into account, it is understood that museums, as cultural institutions in the service of society and its development, have the responsibility of improving accessibility of their exhibitions, facilities and create programs for disabled populations.

According to Freeman et al. (2016), "developments in technology have the potential to increase access and enable opportunities for disabled persons" (p. 26), allowing these members of the public having more inclusive available ways to understand and interact with exhibitions, contributing to a better experience while visiting museums.

As an example of using technology to reintegrate touch and other non-retinal senses into a museum space, an accessible exhibitor based on tangible user interfaces was developed for MM Gerdau – Mines and Metal Museum, allowing visitors the handling of four geological samples of the collection. When interacting with the exhibits, the interface presents augmented information about the pieces and, at the same time, voiceovers provide to blind and other visual impaired visitors the same information to those that don't have disability, plus a detailed description about the shapes, textures and roughness of which geological sample, for an easy identification. In order to increase learning during the exhibition, whenever two pieces were handled at the same time, the presenting themes relates to a comparison of the pieces (Vaz, Fernandes & Veiga, 2016). This project received a prize on museums education practices, by Ibermuseus Program, so an accessible circuit of interactive exhibitors based on this one will be developed in order to enhance the visitors experience and provide a larger access to samples of the MM Gerdau's collection (Ibermuseus, 2016).

Other museums, like the North Carolina Museum of Natural Sciences, are designing mobile apps to provide an enhanced experience for visitors with some kinds of disabilities. By providing audio feedback through map features and integrating a high contrast option, individuals with visual impairments can move inside the museum and zoom information for high-resolution text, so they can learn more about the museum's exhibits while moving. Also, for people with hearing impaired and autism, the app includes descriptions with photos and captions for videos, which proved to be a robust solution to enhance the experience of those persons while visiting the museum (Institute of Museum and Library, 2015). At the Canadian Museum of Human Rights, the app includes an interactive map that tells where visitors are and guide them to a specific destination and, by using iBeacons, voices of museum staff members describe each gallery and provides highlights of exhibits and architecture, so blind visitors or with low vision can appreciate the exhibition. As well, the app was designed to assist deaf or hard of hearing publics, including additional sign-language content for several exhibits (Murphy, 2015).

Technologies like 3D printing and scanning are expected to bring visitors closer to exhibits, paintings and artworks – that cannot be directly touched – as a multi-sensorial form of experiencing culture for all visitors (Bernardo, 2016), providing, as well, "a great benefit for the accessibility of cultural heritage, especially for persons with learning difficulties, for children, the elderly, for blind or visual impaired visitors" (Neumüller et al., 2014, p. 119). The *Hoy toca el Prado* exhibition at the Prado Museum carried out three dimensional copies of six representative works, which could be touched by visitors with visual disabilities, in order to allow them to recreate painting mentally by feeling and understanding their space, depth and perspective (Museo del Prado, 2015).

As seen until now, technology can be beneficial to visitors with blindness or deafness, opening new possibilities to understand exhibitions that previously were inaccessible to them. However, people with physical disability can also enjoy the museum collections, even if they cannot go to those places: "since 2014, "telepresence" robots have been able to lead people with disabilities into every nook and cranny of a museum" (Bernardo, 2016, para. 15). The San Francisco de Young Museum allows people with disabilities to see the art in high resolution, plus enabling interaction in real time with guides and other people in the museum. Through microphone, screen, camera and speakers embedded on an ambulatory device known as Bearn, comments or questions from the visitor can be responded, allowing an independent and interactive experience (Fine Arts Museums of San Francisco, 2015).

To end this chapter, it is pointed out that some of technologies that are used to enhance the non-disabled public' experience can improve, as well, the disabled visitors' experience, coexisting simultaneously and contributing for a more interesting and accessible visit to museums.

CONCLUSION

This chapter aimed to make a contribution in the discussion of the appliance of digital technologies to enhance the visitor's experience, as well as provide practical examples of their use in real museum contexts, rather than approaching technology from the point of view of conservation of museological objects, logistics, maintenance or learning curve of professionals.

As seen, nowadays a visit to a museum must respond to visitors' high expectations for the ease of gathering interactive information about the exhibitions, at the same time that have to be effective on communicating a good message to their publics. It is important to make clear that museum artefacts and themes themselves should always be the focus, no matter what technology is being used to increase the public's experience. Instead of detracts visitor's attention from real objects and museological themes, those technologies must be properly designed to provide unique and exciting moments – that will be part of the visitor's memories in the future – as well as to ensure a magnificent and effective mixture between entertainment and education, conveying solid information and making sure that it reaches people.

The presence of museums in the virtual world enable engagement and interaction with users outside their physical barriers, involving online visitors on collaborative activities plus promoting discussions about diverse themes, at the same time as they facilitate sharing on social media, constituting, in some cases, global public spheres for deliberation that boost creativity and knowledge dissemination.

Installations like multi-touch surfaces allow the condensation of information in a restricted space –amplifying the exhibition without overloading the physical space – and promote scenarios of social living, sharing and collaboration.

In turn, interactive projections can create immersive learning experiences throughout the spatial environment, and it is common that visitors can interact with the installations by using their body gestures. Also, virtual reality – that is expected to introduce and replicate new multisensory contexts related to heritage, in the future – gives visitors the opportunity of experiencing exhibitions on a full immersion mode, in which visitors can feel like they had been transported to a whole new world.

Mobile applications are being used to augment information concerning to exhibits, to create gaming experiences, to establish dialogues between visitors and museum staff, as well as to help to create tours or facilitating navigation throughout museums. The emerging Beacon technology as proven to be effective on helping to shape a visit and for the presentation of specific content when it is supposed to happen, creating precise connections between collections communication and publics.

Due the desire to explore the authentic artefacts of a collection in person, tangible user interfaces can combine them with digital content, ensuring that details and other education content are being communicated to visitors at the same time as they handle the objects. Furthermore, when pieces of the museum cannot be directly touched (because there are associated questions of conservation, damaging, stealing, among others), digitalization and 3D printing play an important role, since they allow the direct contact

with copies of pieces in exhibition which, otherwise, would be absolutely inaccessible. Additionally, the digitalized content can allow the building of partnerships and collaborations between museums and other institutions, like schools, for instance, increasing the easier access to objects to other publics that cannot come to these institutions.

Lastly, wearable technologies are presented as being non-intrusive and light-weight solutions that can augment the people's experience while visiting museums, since they allow the constant attention on the exhibition, instead of having to look to a screen, as well as they represent a new opportunity for designers on creating completely new interactive experiences.

The final main goal of this chapter was to highlight the role of technology in helping to promote physical, cognitive, sensory, in short, cultural accessibility of museums exhibitions, supporting, on one hand, the dissemination of information about the exhibits and, on the other, contributing for an inclusive museum that are committed to providing outstanding learning experiences and enhancing the disabled visitors' experience.

As future work, and once during the study wasn't found a solid guide of rules about when to use and in which objects should be or not used technology in a museum context, it could be very interesting conduct a research regarding these questions, in order to provide easy and assertive guidelines for those who already work with technologies in museums and for other persons that relate to this area.

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KEY TERMS AND DEFINITIONS

Augmented Reality: A technological way to access digital information integrated in the user's environment, in real time, using, normally, apps designed for mobile devices.

Fab Lab: The abbreviation of *Fabrication Laboratory*, a program started in the Media Lab at Massachusetts Institute of Technology (MIT) that intends to offer workshops of digital fabrication, so that products can be built by anyone interested on the theme.

Kinect: The name of a device for motion sensing created by Microsoft, originally as a game controller, that is used in numerous projects to allow recognize gestures and movements.

Maker Faire: Events related to innovation and experimentation across the spectrum of science, engineering, art, performance and craft, where people can design and create things on publicly-accessible places.

NFC: The abbreviation of *Near Field Communication*, a wireless technology to data transfer in close proximity, without the need for an external connection, like the internet.

QR Code: The abbreviation of *Quick Response Code*, a two-dimensional barcode that can be read by some digital devices, by using a camera, and points to information about the object to which is attached.

Social Media: Computer-mediated technologies that are used for sharing, creating and visualize information, via online virtual communities and networks.