Museums have used computers to develop exhibition interactives and games over the years. This paper provides early case study examples and historical context. During the 1980s, computer-based displays in museum exhibitions were largely standalone. In the 1990s, the availability of the web allowed networked interactivity. In the 2000s, access via smartphones became increasingly widespread, enabling mobile access from personal devices. As well as the early examples, the paper provides an overview of more recent developments. Online gaming, including serious games with the purpose of not just entertainment, but educational and cultural, has increased in prevalence. Preservation and access to these digital resources have their own unique issues, and these are reflected in the paper, especially for early examples.

Computer interactives. Digital culture. Digital preservation. Museum exhibits. Online gaming. Serious games.

1. INTRODUCTION

This paper records some case study examples of museum-based computer interactives and games that have been developed over the years. Museums and digital culture have become increasingly intertwined through the decades (Giannini & Bowen 2019), with the Covid-19 pandemic accelerating the transformation even more since 2019 (Bowen et al. 2021; Giannini & Bowen 2021; 2022).

Heritage conservation and preservation has traditionally been concerned with analogue physical objects (Bowen 2017). However, it is increasingly the case that cultural resources are digital in nature. As well as digitised material, much is now “born-digital” in the digital revolution (Negroponte 1995; Palfrey & Gasser 2016), started by computing and information pioneers such as Alan Turing and Claude Shannon in the mid-20th century (Giannini & Bowen 2017). These digital resources now include material produced for exhibitions and outreach. There is a question as to how these digital resources can be preserved, while continuing allowing them to be accessed and appreciated. The techniques needed are very different from traditional preservation and conservation approaches (Deegan & Tanner 2006; van der Wal & Arts 2015).

In the following sections, we present some examples of museum-based digital resources from the 1980s onwards. These illustrate the changing technologies used and some of the issues in preserving and accessing them for the future. Section 2 presents
some early examples of museum exhibition interactives, including issues concerning their preservation due to changing technology and media. Section 3 presents an example of an online interaction 3D reconstruction in a heritage context. Section 4 discusses developments in online serious gaming more generally, from a cultural and educational perspective. We conclude with a poem on cyber games and some thoughts concerning the use and preservation of museum interactives for the future.

2. THE 1980S

Changing Technology

Within a lifetime, I (Jonathan Bowen) have seen digital media move from paper tape and punched cards in the 1970s through to magnetic tape, floppy disks (in three formats, 8, 5¼, and 3½ inches, from the 1970s onwards), various forms of hard disk, different types of magnetic cassette tapes and cartridges, CDs, DVDs, and more recently SD cards and USB sticks, all with increasing capacity and at dramatically decreasing prices per bit stored (see Figure 1).

Software works typically depend on a specific version of operating system or computer hardware configuration. Special custom-written software may form part of the material, particularly if it is dynamic and interactive. Software is typically very dependent on the environment in which it runs, and available facilities tend to change rapidly with digital developments in both software and hardware. This is applicable to early computer-based museum exhibits which could now themselves be of interest for preservation (Mayall 1980, p. 31; NMPFT 1983, p. 7).

Different operating systems such as Unix (later Linux), Windows, Apple macOS, Android (for mobile devices), etc., add to the complication of formats. Text may be stored as ASCII text, Word, PDF, HTML, etc., with the possibility of embedded images in many formats. Individual images may be available in a variety of formats such as GIF, JPEG, PNG, TIFF, etc. Audio may be in AIFF, OGG, MP3, WAV, WMA, etc. Video may be in AVI, FLV, MOV, MP4, WMV, etc. All these different formats have various advantages and disadvantages in terms of quality, size, etc. Software is needed to view and convert formats, which may be easy or difficult depending on the formats involved.

Some older digital material may only be available in printed format (e.g., text, programs, and images on various types of paper and film). It may be desired to re-digitise such resources to animate them again. Sometimes printed versions of digital resources can allow easier access and longer-term preservation compared to a digital artefact (Diprose et al. 2018), although technologies such as fading thermal paper have their own issues (see Figure 2).
Museum Interactives

In 1980, I (Jonathan Bowen) produced an animated monochrome demonstration of a CMOS (Complementary Metal-Oxide-Semiconductor) transistor, written in the BASIC programming language on a Commodore PET personal computer for the Challenge of the Chip exhibition at the Science Museum in London, UK (see Figure 3). This exhibition covered developments due to the increasing power and miniaturisation of integrated circuits, especially for computing (Evans 1979; Augarten 1984). As well as museum exhibits, I also produced an early index system for the Science Museum on the PET computer (Bowen 1981).

In 1984, I produced a colour demonstration showing different focal lengths of lenses, using BBC BASIC on a BBC Micro personal computer for the National Museum of Photography, Film and Television in Bradford, UK (see Figure 4). The exhibit was located with a panoramic view of Bradford from the museum and a computer-generated version of the view, and the associated camera lens, using a lens with a focal length selected by the visitor.

The exhibit was based on wireframe versions of the buildings in the view. In parallel, I worked on multidimensional hypercubes in BASIC on a Research Machines microcomputer (Bowen 1982) and the C programming language on a Silicon Graphics workstation (Bowen 1984). I also produced a BASIC geometrical plotting library of subroutines (Bowen 1983) and 3D wireframe software (Bowen 1984b; 1984c).

The change of storage media and formats, available software, hardware, etc., over the years, has made it difficult to conserve digital material in a useful way that can still be accessed and viewed by humans (Bowen 2017). For older digital material, the necessary hardware and software may be difficult to obtain or even no longer exist. What is more, the physical storage itself may deteriorate. Magnetism gradually disappears over a relatively short period. CDs and DVDs may become unplayable. Paper tape and punch cards last longer but can still have issues over a significant period if not stored well.

Since the 1980s and the time of microcomputers (Clark & Davis 2021), online resources have become increasingly important compared to hardware storage technologies. Earlier FTP (File Transfer Protocol) servers have been replaced by much more user-friendly web servers (very briefly via Gopher servers), with the “cloud” now available through facilities like Google Drive and Dropbox for widely accessible digital storage. Various web facilities allow the convenient storage of media online, such as Flickr for images, YouTube for video, and social media like Facebook allowing multimedia to be saved. The next section provides an example of a museum-based online interactive resource from the 1990s.

3. THE 1990S

The decade of the 1990s saw the rise of the web and increased use of computers by museums (Gill 1996). This enabled museums to achieve global outreach with online information and exhibitions (Bowen 1995; 1999; Gaia et al., 2020). Online gaming became practical, and museums were able to start exploring the possibilities from their own perspectives.

From Online Games to Virtual Museums

Online 3D games, as outlined in the previous pages, started to gain traction during the 1990s, along with the diffusion and strengthening of the Internet infrastructure together with the spreading of the World Wide Web.

The image of virtual 3D worlds was being shaped by cyberpunk novels, such as Snow Crash by Neil Stephenson (1992), where we can find the first definition of the Metaverse as an online 3D Virtual Reality environment shared by millions of users simultaneously.

At the same time, in 1999, the movie The Matrix, starring Keanu Reeves, gave visual identity to a digital online world where people conducted fictional lives. Even if VR (Virtual Reality) technology was (and still is) far from getting that degree of realism, the notion of online multi-user worlds was becoming more and more widespread.

When we (Giuliano Gaia and Stefania Boiano) were working at the National Museum of Science and Technology (Milan, Italy) in 1999, we were...
dreaming about the possibility of recreating an online copy of the museum where visitors could meet and interact. When we discovered that Prof. Paolo Paolini of the Milan Polytechnic was working on a technology capable of doing exactly that, the WebTalk technology, we quickly made contact and offered the museum as a testing environment for the technology.

The result was Virtual Leonardo (Barbieri & Paolini 2001a), an online 3D reconstruction of the two cloisters of the Science Museum (see Figure 5), with animated Leonardo da Vinci’s machines scattered around the virtual space (see Figure 6). Visitors could have their avatars walk and fly around the cloisters and rooms, chat with a guide or with other visitors, and set in motion the machines. The tour guide avatar had the special power to force all users to see what she was seeing in that moment, in order to make guided tours easier (Paolini et al. 2000).

![Figure 5: Screenshot from Virtual Leonardo. Users can see each other and chat using the chat window in the bottom part of the screen.](image)

From a technological point of view, Virtual Leonardo consisted of a combination of VRML (Virtual Reality Modeling Language) technology, a markup language proposed in 1994 to create a standard for 3D visualisation in the World Wide Web (Raggett 1994) for the 3D environments and Java for the infrastructure allowing users to chat between themselves and to interact with the guide and the animated objects.

A problem was that the technology was still immature and not user-friendly. The user had to download and install a specific plug-in, Cosmo Player, to be able to visualise VRML and needed a good computer with a strong Internet connection to make the system work smoothly, something that was not common at the time. The result was that only 20% of the users were able to have a successful experience interacting with the system (Paolini et al. 2000); an interesting insight was that the average connection time among successful users was nearly one hour, confirming that the experience was “sticky”.

The system went online on 7 June 1999 and raised much interest, winning an Honorable Mention at the Museums and the Web “Best of the Web” awards in 2000 and being featured in the New York Times.

![Figure 6: One of the da Vinci machines, operable by online visitors.](image)

![Figure 7: Screenshot of the ideal city project. Beneath the 3D navigation area, the chat window (bottom left) and the collaboration area (bottom right) allow users to communicate with each other and with the virtual guides.](image)

In this case, the system was more reliable and easier to install and launch, provided the user had a good Internet connection and a computer powerful enough to execute some 3D graphics rendering. The virtual environment included not only da Vinci’s machines but also artificial avatars operating them, in order to make the place more populated and to show first-time visitors what they could do in the environment.
Even if the Science Museum lacked the resources and the will to develop the project beyond the prototype phase, both projects demonstrated that a cooperative virtual environment, where users can interact with each other and interact with exhibits, has a strong educational value and is, therefore, useful to pursue. Whether this has to be done by building your own virtual environment, as we did, or by using an already existing environment, as some museums are doing with Minecraft (Charr 2021), is still open for debate; both solutions have pros and cons. However, in the end, we believe that museums will be an important contributor to developments in the new metaverse.

4. THE 2000S

In the 21st century, mobile devices have become increasingly important for the digital interactive provision made available by museums (Filippini-Fantoni & Bowen 2008) and for cultural heritage in general (Boiano et al. 2012). The rise of serious gaming in the cultural sector has a significant history associated with mobile and desktop devices largely developed for widespread use during the 2000s.

Online Serious Games

The term “serious games” can be credited to Clark C. Abt (1987), originally in 1970, who referred to (video) games created for purposes other than entertainment, especially for learning and education, training, skill transfer, or persuasion. Serious games have since become pervasive in military, education, healthcare, engineering, and cultural sectors, among others. (Borda & Bowen 2019).

Precursors to serious games in digital heritage reveal an integral relationship to early computing and video game technologies (Djaouti et al. 2011; Mortara et al. 2014). The Sumerian Game of 1964, for example, was largely a text-based strategy video game designed by elementary school teacher Mabel Addis (credited as the first woman game designer) and programmed by William McKay for the IBM 7090 time-shared mainframe computer using a teleprinter to input commands (Willaert 2019). The game, set around 3500 BC, has players act as three successive rulers of the city of Lagash in Sumer over three segments of increasingly complex economic simulations.

A long-running precursor to serious games, The Oregon Trail also started as a text-only computer game programmed in BASIC and designed by three history teachers. Released by the Minnesota Educational Computing Consortium (MECC) in the 1970s, the game casts the player as an American settler in 1848, whose goal is to travel by wagon train from Missouri to Oregon facing various challenges on route based on historical facts (Djaouti et al. 2011). The game was re-released several times with a graphical version of the game in an open-source format, followed by versions for Apple, Atari, Commodore, and Radio Shack computers. In 2010, mobile phone versions of the game were released on Windows, Android, iOS, as well as Facebook.

Although these early computer games were influential in shaping subsequent developments of serious games, it was not until the 2000s that serious games became truly popularised, culminating in internet, mobile-based, and VR (Virtual Reality) examples, in line with increasingly accessible and affordable technology platforms. Developments such as the Serious Games Initiative (Wilson Center n.d.), founded in 2002 at the Wilson Center in Washington, D.C. (Djaouti et al. 2011) and the growth of academic studies on serious games within digital culture reinforce their educational role.

Serious games have been variously categorised in relation to their increasing presence in digital heritage. Anderson et al. (2010) proposed a taxonomy of prototypes, demonstrators, virtual museums, and commercial historical games. Mortara et al. (2014) categorised serious games as supporting cultural awareness, historical reconstruction, and heritage awareness. Paliokas & Syliaou (2016) proposed a framework to describe the features of serious games in digital heritage, including elements such as technologies, categories of users, user experience, and game content. Rowe et al. (2017) focus on serious game design in science museums, highlighting the importance of free-choice learning environments. Wang & Nunes (2019) considered educational goals and genres.

The use of emerging VR has become a prominent characteristic, often focusing on the preservation of historical structures and artefacts reminiscent of...
past cultures. Such preservation has been mainly “through digital capture or detailed reconstructions, both having digital accessibility as an outcome” (Ch’ng et al. 2018).

For example, The Virtual Egyptian Temple (launched in 2004–5) presented a realistic 3D model of an ancient temple to understand ancient Egyptian life and culture (Jacobsen & Holden 2007). Two versions were implemented: a VRML lightweight application and an Unreal Engine (Epic Games n.d.), supporting a higher level of visual detail and multiplayer capability networked over the internet, where each player drives a humanoid avatar.

Similarly, The Forbidden City: Beyond Space and Time (IBM 2008) was an educational VR game where players can interact as avatars and explore the Forbidden City in Beijing, China as it was during the Qing dynasty (1644–1912, see Figure 9). This initiative was a partnership between the Palace Museum and IBM, utilising a ‘Second Life’-like world and built using a Torque game engine.

![Figure 9: Avatar in the Hall of Mental Cultivation in the virtual Forbidden City. Image by Mary Harrsch, 2009. Flickr CC BY-NC-SA 2.0.](https://tinyurl.com/2p8vbcv)

European Union funding contributed further to the development of several advanced virtual heritage demonstrators using serious games and digital storytelling. One example is ThiATRO (The Immersive Art Training Online) – a prototype of the Virtual 3D Social Experience Museum exploring the bidirectional interaction between museums and visitors on a Web3D basis (Froschauer et al. 2013). ThiATRO was built in the Unity Game Engine and 3D models designed with Google SketchUp (https://www.sketchup.com). ThiATRO aimed to immerse the player in the role of a museum curator in a virtual 3D exhibition to find artworks to create their own exhibition. It was primarily intended to be played online in a web browser.

At the time of THIATRO’s development, data for the game was drawn from newly available online resources such as the Web Gallery of Art (https://www.wga.hu/). In the context of art history, there were already major projects exploring virtual heritage environments like the Google Art Project launched in 2011 (now Google Arts and Culture) where users can take virtual tours through selected museums via web-based browsers.

Early mobile serious games like Art Tournament (Froschauer et al. 2012) ran on mobile device platforms, which were becoming more ubiquitous post-2010, but offered less computing power for immersive capability in older mobile devices.

Rather mobile geo-locative games were readily being adopted for outdoor exhibitions and self-guided tours and games, such as M-Heritage Hunt (Tan et al. 2011), an app to explore the cultural history of George Town in Penang, Malaysia, and Eye Shakespeare (Creative CH 2013), an Apple app developed by Hewlett Packard for the Shakespeare Birthplace Trust. The American Museum of Natural History launched an innovative mobile gaming app MicroRangers in 2015, as a way for the public to experience the museum’s collections in situ, ‘shrinking’ the user down to microscopic size to combat threats to biodiversity. The app utilised AR (Augmented Reality) technology, like that seen in popular gaming apps such as Pokémon Go.

Currently, more highly immersive serious games are crossovers with VR experience interactivities, and usually the result of a commercial partnership between a heritage organisation and VR design companies. A drawback is the need for VR headsets and/or gaming computers in some instances. The serious game Chauvet: The Dawn of Art (Tanant 2020) is a project of Google Arts & Culture, supporting mobile-based AR and VR interactive narratives and using photogrammetry and physical-based rendering. The Chauvet Cave is a UNESCO World Heritage Site located in the Ardèche gorges in southern France, with cave paintings dating from 36,000 years ago that are inaccessible to the public.

Ace Academy: Black Flight is one of several serious games developed from the collections of the Canada Aviation and Space Museum (2017). The mobile game is available on Apple Store and Google Play, and players can climb into a cockpit to fly with real First World War squadrons, over actual historical locations and engage in aerial combat. The game won a gold medal in the 2017 International Serious Game Play Awards.

Personalisation of the learning narrative in a game is a consideration of the Getty Museum’s recent collaboration with Nintendo’s Animal Crossing, allowing users to import art masterpieces into their digital homes using the International Image Interoperability Framework (IIIF, https://iiif.io) in an online game activity called Art Generator (Getty n.d.). The Generator is also linked to a uniquely generated QR code that holds information on the
5. REFLECTION

**Cyber Games (by Tula Giannini)**

- Is life the game in a digital frame
- Going to cyberspace
- Choose your avatar face
- No place for reality where love’s a fatality

- Come join the game
- Leave life behind
- Don’t look back
- Stay on track
- Revel in your new identity
- Future serenity
- No place for reality where love’s a fatality

- Haven’t played games since Hopscotch and Double Dutch
- Missing you so much
- Take me back to reality
- Oh – a Covid fatality

6. CONCLUSION

This paper records some case studies of museum-based computer interactives and games over the decades. The changing technology over this time means that these can rapidly become difficult to animate, even if the software is available on some media.

It is possible to write emulation or simulation software that mimics a computer system, but even this can have issues (Bowen 2017). Often it can run faster than the original system and dynamic material may depend on the speed of the emulator/simulator as well as its functionality for satisfactory operation. Simulation can be achieved typically through the use of software. Emulation provides much more precise behaviour and can be undertaken using programmable hardware for example, such as Field Programmable Gate Arrays (FPGAs).

The redisplay of early digital artefacts can involve any of the issues described above, depending on the complexity. While a traditional painting can be physically conserved and then hung for display, the same process for a digital work is potentially much more complex, even after a period of only a few years from its origination. This will be an increasing added complexity for museums in the future wishing to preserve their digital artefacts and resources in a meaningful way. Meanwhile, the boundary between real life and digital will become more and more blurred as time progresses (Borda & Bowen 2019; Bowen & Giannini 2014; 2019; 2021).
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