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University of Leicester

School of Museum Studies

How can advanced technology be beneficially used in the heritage sector?

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MA in Heritage and Interpretation

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Abstract

The heritage sector is exposed to many challenges such as visitor attraction, visitor engagement, stakeholder management, funding or proving its value to the community. Investigating in how far advanced technology can help to overcome these challenges and what museums can learn from peers that implemented projects with this technology is the purpose of this paper.
The conducted research was mainly based on the case study method.
I identified three categories of advanced technology currently used in the heritage sector: Firstly, big data analytics and the usage of dashboards, secondly, robotics and thirdly, artificial intelligence including machine learning and neural networks. Those technologies can be useful in different segments of a heritage organisation, for curation, collections management or for visitor understanding and engagement. Moreover, for ticket pricing, visitor prediction and marketing purposes advanced technology could be useful. No specific examples were found at the time of the conducted research and this might be an area for later research projects.

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Introduction

How can heritage organisations use advanced technology to remain relevant for their audience and fulfilling their tasks towards society is the topic of this thesis.

As heritage institutions I consider organisations according to the definition of ICOM (2007):

> *"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."*

I will use terms such as museums, heritage organisations or cultural institutions as synonyms and in the same context. This can also include GLAM organisations (galleries, libraries, archives, museums).

Museums fulfil several functions related to collecting and preserving objects, being an educative institution, supporting the local community or being a site for providing leisure opportunities.

Depending on how the museum defines their visitors' needs, the organisation will have a different mandate. Doering (1999, quoted in Sandell and Janes, 2007, p.332) defines three types of museum visitors. If visitors are defined as strangers, the main focus of the museum will be on providing access to their collection and supporting with research. For visitors seen as guests, the museum defines their main responsibility in an educational mandate. The third category contemplates visitors as clients. Here the museum tries to understand the needs of the visitor in order to best serve the client.

There is an increasing focus towards defining visitors as clients, especially due to the challenges which heritage institutions are exposed to. Museums need to stay financially healthy and with decreasing public funding the convincing of sponsors, collecting donations or attracting members becomes ever more important. Exhibitions need to be curated in a way that it is interesting, relevant and entertaining so that it attracts enough (paying) visitors to not make loss. At the same time, the offerings of a museum need to be informative and should serve the educational mandate. How can it be achieved that the visitor is inspired, engaged and learns something new? How can all parts of the society be included? Museums need to find effective ways in how they can manage, preserve and making the collection accessible for research purposes and for future generations.

In current exhibitions, digital technology is seen to a greater extent. Touchscreens, videos, virtual reality glasses or mobile phone apps with augmented reality features are used for making the visit more engaging and interactive. With my research, I investigate in how far advanced technology that currently isn't often applied within the museum sector can help to tackle the above-mentioned challenges. In the context of my thesis Advanced Technology contains Artificial Intelligence (AI), Robotics and Data Analytics. AI is the capability of computers to mimic human intelligence (Merriam-Webster, 2019). Robotics is the science of mechanical, humanoid and video robots. Data Analytics is the science of analysing large data sets. Further definitions can be found at the individual chapters.

At the moment, these advanced technologies are mostly used in the commercial sector and only partly by heritage institutions. The purpose of this paper is it to give an overview in how far advanced technology is already used in the heritage sector and whether it might be useful for other museums. Especially AI is expected to have disruptive influence on our society in the coming decades (House of Lords, 2018, p.120). Technologies for image recognition, recommending systems or pattern detection are already used in many industries (The Royal Society, 2018a). In the Financial Services and Insurance industry it is used to detect payments or claims fraud. In Health Care it might help with diagnostics or in the Education sector it can be used for personalised learning (House of Lords, p.35, 87). AI will make driverless car riding possible; jobs currently done by humans could be (partly) replaced by machines; virtual assistants could make our lives easier and in future AI could predict crimes before they take place, to name just a few examples (The Royal Society, 2018b).

The commercial sector has embraced those technologies and is faster in implementing them compared to the not-for-profit sector. Therefore, it is

interesting to investigate what is currently done in this respect in the heritage sector and analysing what opportunities or threats this could imply.
Historically, museums have always been adopters to change whereas information and communication technologies (ICT) have been implemented to adjust to changing environments (Parry and Sawyer, 2005, p.39-40).
Parry and Sawyer (2005) developed a schema which epitomizes how technology was introduced to galleries and museums since the 1950s exemplified with the British heritage sector. They identified six phases on the evolution of ICT within galleries or museums.

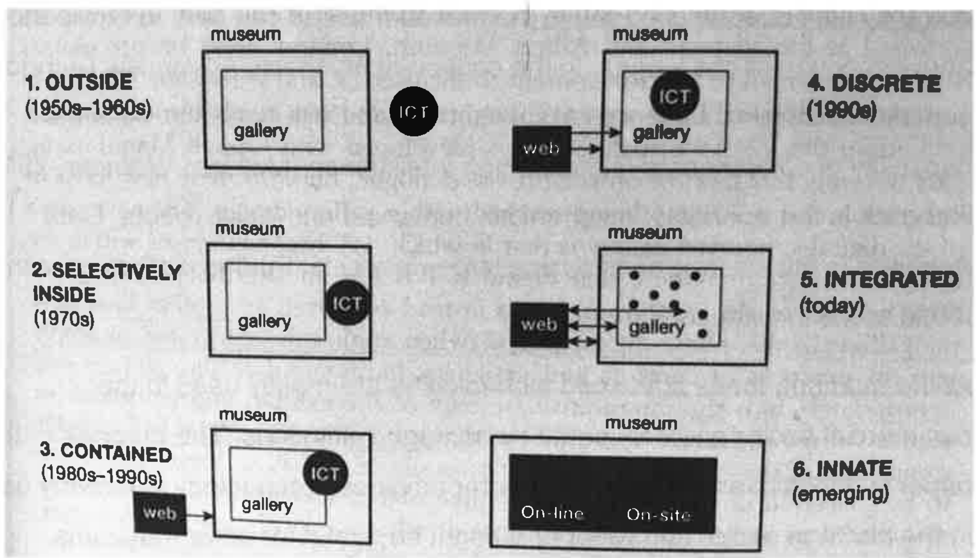

Figure 1 Digital interactivity in galleries (Parry and Sawyer, 2015)

The first phase starts in the 1950/60s where computers were sporadically used by museum employees outside the museum. During the 1970s first museum employees experimented with using computers mostly for research purposes, documentation and collections management. In the third phase (between 1980-1990s) the use of technology found its way into the gallery space. Museums created “hived-off galleries” (ibid, p.46) to separate the exhibition space from the space where technology was used. The National Gallery, for example, launched the ‘Micro Gallery’ in 1991 (Keene, 2014). It was a room that offered visitors the use of computers. They could search for high-resolution images of the National Gallery paintings and finding additional information about them. In phase four (1990s) computers and interactive stand-alone kiosks were

displayed within the exhibitions. Also, online services such as museum websites were offered and gave the opportunity to extend the physical presence virtually. In the 2000s the fifth phase was coined by an integrational approach of technology within the exhibitions. It was blended into the storytelling and engaging with the audience. For instance, the Victoria & Albert museum offered their visitors the possibility to send content of the exhibition like pictures and information to their own email account. Moreover, the internet presence and offerings became more interactive. The sixth phase (innate phase) describes the current situation where technology is seen as a tool to support learning, engaging and interactively communicating. When Parry and Sawyer created this model current display technology like virtual reality or augmented reality were not common. However, the increasing usage of this technology either via VR glasses (e.g. at Tate's Modigliani exhibition) or via smartphone apps is visible and provides an immersive experience.
The model can be extended with a seventh phase. Currently, the heritage sector is on the brink of introducing advanced technologies to be used in the frontend, i.e. within the gallery as well as in the backend. At the moment, advanced technologies are used by a limited number of museums, but I foresee a more regular applying in the coming years due to learning effects of the pioneering museums and cheaper ICT costs. This is another reason for examining this topic now, because knowing how advanced technology can be useful can help cultural institutions in planning for the future.
My research does not contemplate specific digital exhibition display technologies like virtual reality or augmented reality.

The first chapter shows a brief overview of the advanced technologies currently used in the museums sector. The following chapters elucidate on the individual advanced technologies and their use cases. The research showed that Big data analytics, Robotics and Artificial Intelligence can be used for curation, collections management or for visitor engagement and understanding. Subsequently, the threats of the advanced technology, in specific Artificial Intelligence are sketched. The thesis ends with the chapter 'conclusion' to assess the technologies' impact compared to its costs. Moreover, additional fields for using the advanced technology within the cultural sectors are explored.

Methodology

The research methods used to answer the thesis' research questions is a mixed method approach containing a literature review, case studies, field trips to museum exhibitions to test technology tools, visitor observation and trials to set up interviews or email conversations with museum staff of the Smithsonian Museum and the Akron Art Museum. Underlying understanding for the topic was gained by attending the MCN conference on 'Advancing digital transformation in museums: Humanizing the Digital' in Denver and the Royal Society panel discussions and events on the topic. During my investigations, I encountered different projects in museums using advanced technology all over the world. The projects were selected because the advanced technology used are unique and innovative within the museum sector. For example, the Smithsonian museums and Van Abbemuseum are the only museums that use robots for their interaction with the visitors. Using machine learning techniques for collections management are not common in the heritage sector and unique examples were only found at the Vatican Secret Archive and the National Museum of Natural History. The Akron Art Museum and the Pinacoteca de Brazil use chatbot technology in a creative way. The Barnes Foundation offers a curation tool so the visitor can sort the collection in an individual way. Those are examples where other museums can learn from, hence I investigated them. The Cooper Hewitt showed an interesting way of collecting visitor data and the Dallas Museum of Art was one of the first museums worldwide to implement data analytics tools and dashboards. Therefore, I found those case studies interesting as the organisations gained experience in a relatively untouched field for museums.

Overview of advanced technology used in the heritage sector

Table 1 depicts a list of different advanced technologies currently used by heritage institutions. As this table does not claim to be complete, it should be used as a help to keep the overview of museum projects, using, Big Data & Audience Data Analytics, Robotics or Artificial Intelligence including machine learning and neural networks. Those technologies can be helpful in several fields within the museum work, e.g. for visitor engagement, gaining a better understand of the visitor's needs and wishes or for curation and collection management. In the following, every project that implemented those technologies are either briefly sketched or investigated in more detail in form of a case study to explore why and how the respective museum started using the advanced technology.

Tech-nology	Project name	Museum/partner involved	Category	Further explanation
Big Data/Audience Data Analytics				
	DMA Friends	Dallas Museum of Arts	Understanding visitors	Usage of Big Data and dashboards
	The Pen	Cooper Hewitt	Understanding visitors	
	Big Data	National Gallery, British Museum, Dexibit	Understanding visitors	
	Smartify	Several collaborations with museums	Visitor engagement and understanding	Smartphone app for object recognition. Used in museums to offer additional information.
Robotics				
	Pepper	Smithsonian Museums, Washington, USA; Softbank Robotics	Visitor engagement	Humanoid robot
	Video robot	Van Abbe Museum, Eindhoven, NL	Visitor engagement	Used to provide remote attending of museum collection and inclusion.
	'Robocase'	Bruns and Kiss the Frog	Collections management	Robot arms present artefacts. Overcoming limited exhibition space by using a smart showcase.
Artificial Intelligence (including machine learning or deep neural networks)				
	The Voice of Art	Pinacoteca de Brazil, IBM Watson	Visitor engagement	Attracting new visitors who have never visited a museum before.
	'In Codice Ratio'	Vatican Secret Archives	Collections Management	Digitising of historical handwritten documents by using machine learning for object character recognition.
	Analysing imaged herbarium specimens	Smithsonian	Collections Management	Using AI method of neural networks
	Barnes Collection	Barnes Foundation	Curation	Machine learning and AI is used to curate objects based on similar criteria like colour or shape.
	Dot	Akron Art Museum	Visitor engagement	Chatbot based on Facebook messenger app, used as tour guide

Table 1 Overview of advanced technology examples

Big Data and Audience Data Analytics

Big data analytics is defined as data analysis of very large data volumes that common tools like spreadsheets cannot handle. The input for the analysis can come from various sources and might comprise different data types. Also, the sources can have a constant accumulation of new data. In Data Science this is summarized in the three V's: volume, velocity and variety of data assets (Berman, J. 2013).

Big data analysis is possible nowadays because of the improved computer capacity and the amount of information generated via the internet, for example, due to social media, video/image sharing or digital transactions etc. While in the 1970s a computer processor was able to process 92,000 instructions per second, a contemporary smartphone can accomplish billions of commands (Royal Society, 2018a). The human brain has a data storage capacity of 2.5 Petabytes (PB). Online services like Ebay store 90 PB of data, Facebook 300 PB and it is estimated Google saves 15,000 PB of data as of 2016 (ibid). Thus, nowadays computer have enough processing power and the necessary amount of data is available to identify patterns. Given that the data to analyse can come from different sources, the powerful part of Big Data is in making connections between large data sets of different sources.

The evolution of data analytics is sketched in Figure 2. The analytics methods include backward looking tools like Descriptive Analytics to answer the question 'What happened?' (e.g. How did the visitor numbers evolve in the first quarter?). Diagnostics complements this by answering 'Why did it happen?' (e.g. Which reasons could have resulted in the lower visitor numbers in Q1? Bad weather, other big social events that distracted the audience or a lack of marketing etc.). Forward looking are Predictive Analytics that focuses on 'What could happen?' (e.g. Increasing the marketing investment in Q2 will lead to 10% more visitors). Prescriptive Analytics covers 'What should happen?' and gives recommendations based on the descriptive, diagnostic and predictive analytics (e.g. a decrease of the exhibition entrance fee by 2£ will be the most effective way to increase the number of visitors by 20% in Q2). Cognitive Analytics is the mingling of Data Analytics with Artificial Intelligence and machine learning. Cognitive Analytics make something happening (e.g. creating a smart chatbot tool to increase the visitors' engagement and to attract visitors to the museum who would normally not come).

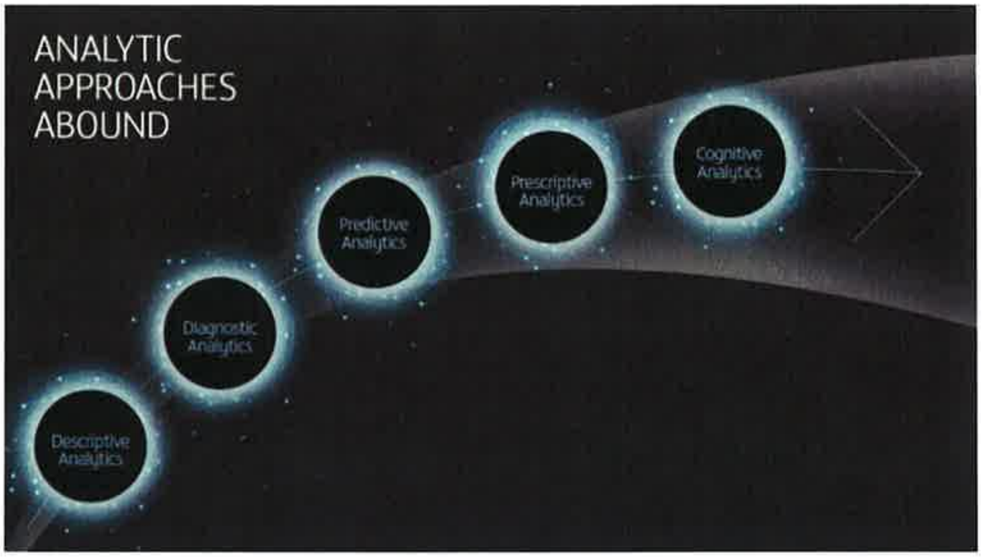

Figure 2 Evolution of Data Analytics (Ulster University, no date)

A potential use of Big Data in the cultural sector can be very diverse and beneficial in different departments (Cuadra and Hirugami, 2016). Big Data can use visitor data for understanding the audience and making decisions, for instance, on exhibition set-ups, sponsor outreach or marketing initiatives (Gamerman, 2014).

Big data analysis has already been used by large museums. For example, the British Museum has a dedicated Big Data team (The Alan Turing Institute, no date) or the National Gallery in London predicts visitor behaviour and wants to "understand how we can serve our audience." (Dexibit, 2017a). In 2017, the National Gallery started a cooperation with Big Data analytics firm, Dexibit. In a 3-months project, museums employees filled the Dexibit platform with data sources from the museum's website, social media, the generated Wifi data which visitors used in the museum and other related information like weather data (Dexibit, 2017b). This information is now available to employees in the different departments in form of a dashboard. A dashboard helps to visualise data. It builds the foundation for a data driven decision making, for instance on ticket prices, topics for exhibitions or visitor engagement. An illustration of a dashboard can be found in Figures 5 and 6 in the Dashboard chapter.

Some museums, like the Guggenheim museum in New York use beacon technology to collect visitor data that can be further used for Big data analysis. A beacon is a little transmitter placed at the museum's walls. The beacon sends and receives signals from/to the visitor's smartphone with the downloaded Guggenheim app. When a visitor approaches an object with a beacon nearby, notifications can be sent to the phone in form of text, video or audio files. This technology only works with a Wifi network and is very sensitive. Too many people gathered around an object can confuse the sensors and disturb the signals. With the beacon technology it can be analysed how fast a visitor walks through the museum or where they linger (Gamerman, 2014).
There are critics who question whether Big Data, popular in a business context, should be used in the non-profit context at all. Marc Rotenberg, professor for Law at the Georgetown University and leader of the 'Electronic Privacy Information Center' claims that museum audience is not keen on giving private information for receiving a more individualised museum experience but that data analytics merely serves the purpose of marketing, advertising and increasing profit (ibid). Another concern is the fear of launching 'blockbuster' exhibitions because the prediction tools forecast a large visitor number instead of setting up socially or historically significant exhibitions that potentially will attract less visitors (ibid).
One of the main tasks of heritage institutions is to serve society by offering learning and recreational possibilities. Therefore, it is important to understand the audience so that the museum can be relevant. Also, sponsoring and funding are important factors for the museum to remain sustainable, otherwise the fundamental financial basis is not given. Data analytics can be helpful in all of these dimensions. This might help the institution to keep the balance of being commercially successful and providing 'niche' offerings.
While data analytics is a useful tool to help with quantitative analysis, it has its limitations. For measuring the long-term social value that museums add to their community, qualitative research tools will be more suitable as it is difficult to define clear performance indicators to measure the social value.
In the following section, I will investigate in detail how the Dallas Museum of Art (DMA) and Cooper Hewitt used Big Data Analytics to gain audience insights and as foundation for their decision-making processes.

The Pen - Cooper Hewitt

Cooper Hewitt, the New Yorker Design Museum, introduced an effective tool to understand which objects their audience are interested in the most and how the visitor goes through the museum. In other sectors, like supermarkets, knowing the trail of a customer and understanding where the customer spends the most time generate interesting insights. In the museum context, knowing this information could, for example, help to improve the exhibition set-up or could help in predicting visitor numbers. Also, for marketing activities it could be effective by placing advertisements for becoming a museum member at strategic places.

With the Cooper Hewitt admission ticket, the visitor receives 'The Pen', which is a digital pen to electronically collect or mark items, the visitor finds interesting. Collecting happens by pointing and clicking the pen at the plus symbol shown on the display board. The entrance ticket shows a unique code, which is connected to the pen. After the visit, this code enables the visitor to login online to the museums website to see which objects were collected and to engage even after the physical visit by looking at images and reading further background information regarding the collected artefacts. In the museum, 'The Pen' can be used to draw on the interactive screens or tables for example to create a pattern for a wallpaper as depicted in the photos of Figure 3.

Figure 3 The Pen (Cooper Hewitt, no date d)

Having a digitised collection is a fundamental requirement for 'The Pen' to work. At Cooper Hewitt the collection is digitised as high-resolution images for up to

90%. The objects can be searched and looked at on their website (Geismar, 2018, p.57).

With 'The Pen' the museum aimed to encourage the visitor to be more playful with the collection, being more socially interacting for instance by watching others creating a wallpaper pattern, spending more time looking at the objects and lingering in the museum as well as providing opportunity to engage with the objects and the museum after the visit by looking at their own selection (ibid, p.59).

When the pen was introduced in March 2015, it caused strong visitor interest. During the first ten weeks, 90% of the visitors used the pen and 31% created an account with the museum (ibid, p.60).

The museum uses the aggregated data for understanding "how visitors move through our physical galleries and interact with exhibition content." (Cooper Hewitt, 2018). In addition, if a visitor creates an online account and pairs with the pen. Cooper Hewitt will send emails with recommendations of upcoming interesting content like exhibition or talks (ibid).

Technology like this needs large investments to provide the needed infrastructure and it will not be easily applicable for other museums. For instance, labels need to be adjusted, interactive display screens need to be installed or the museum website needs to be adapted with applications for the visitor's online accounts.

DMA Friends

In 2013, DMA launched a visitor loyalty program called 'DMA Friends' to increase the engagement and the number of local visitors as well as recurring visitors (Chan and Cope, 2014).

The museum introduced a digital badge system that helped the visitor to gain points for participating by visiting exhibitions or attending activities. The points could be redeemed for free parking, free exhibition entry at future visits or for gifts from the gift shop etc. To keep it attractive the visitor engagement team constantly changed the rewards. Kiosks were installed where the visitor had to login with the respective activity code so that it could be added to the visitor's account. Figure 4 illustrates what the visitor would see at the kiosk and how to earn a badge.

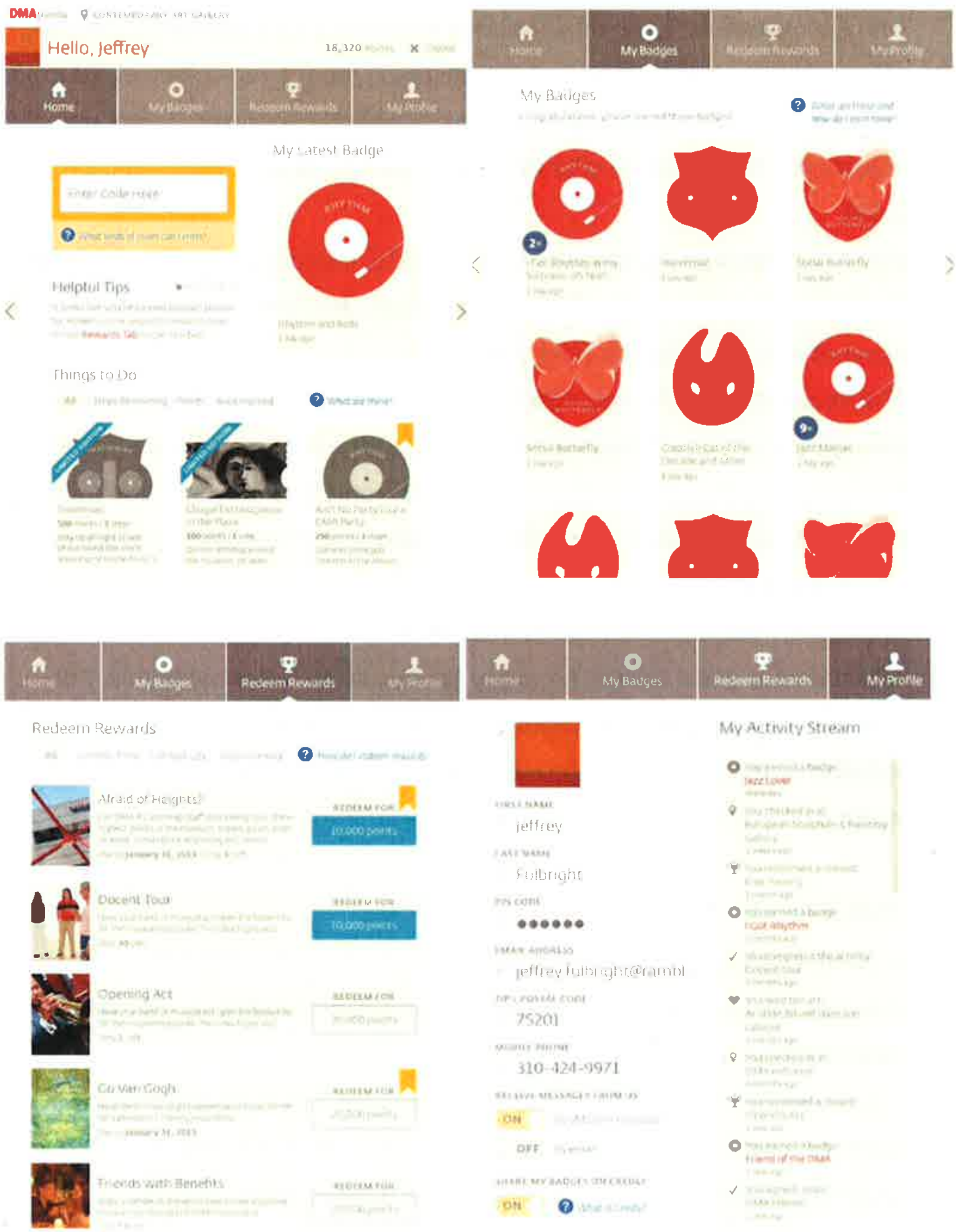

Figure 4 DMA Friends - Badge earning (DMA, 2019)

The program created a huge amount of visitor data, e.g. which activities were visited, how long did the visit take, was the visitor alone or with a companion

etc. Yearly, the DMA Friends program resulted in nearly 22 million data fields (Stein and Wyman, 2014). With Big Data analytic tools, the DMA was able to analyse and draw conclusions on their visitors in a more comprehensive way compared to standard visitor analysis like manually counting the amount of visitors or conducting surveys and questionnaires. Those activities are very labour intensive and might be limited to the amount of visitors interviewed.
The initial scepticism of the visitors regarding surveillance and sharing of data was solved by providing an "opt-in option" (ibid) that enabled the visitor to choose when and which data to share. This helped to create trust. Another important success factor was the support by the front desk staff because they advertised the program as ambassadors and supported by answering questions or by helping with the handling at the digital kiosks. Collecting badges was made easy for the visitors, either via the kiosks or via the own mobile phone (ibid).
The DMA achieved very successful results with their DMA Friends program. Between 2008 and 2016 the number of first-time visitors increased by 35 percentage points from 4% to 39% (ibid). During the first year of the program, the recurring visits of DMA friends increased by 10.2% (ibid). In 2008, most DMA visitors stemmed from the age group 54-64 years. This changed by 2016 as the age group 18-29-year-old became with 46% the predominant visitor group. Also, the participation of minority groups increased. Between 2008-2015 the amount of Hispanic audience increased by 20%.
Despite the success, the program was ended in December 2017 to focus on "new ways" for serving the visitors (DMA, 2019).

Dashboards

The DMA used an online reporting tool called Chartio to create a dashboard. Figure 5 shows an example of the performance overview that the staff could use for real-time monitoring. The dashboard provided data represented as graphs and bar charts to make it easy for analysing and identifying patterns. By monitoring the performance data, it enabled the front office team to act quickly and to adjust offerings. Furthermore, with the data visualisation program Tableau data was viewed as geographical mapping. Figure 6 depicts how the tool made the demographic zip code information of the DMA Friends graphically visible. This tool helped the DMA decision makers to decide if measurements needed to be taken to address visitors from underrepresented areas of Dallas.

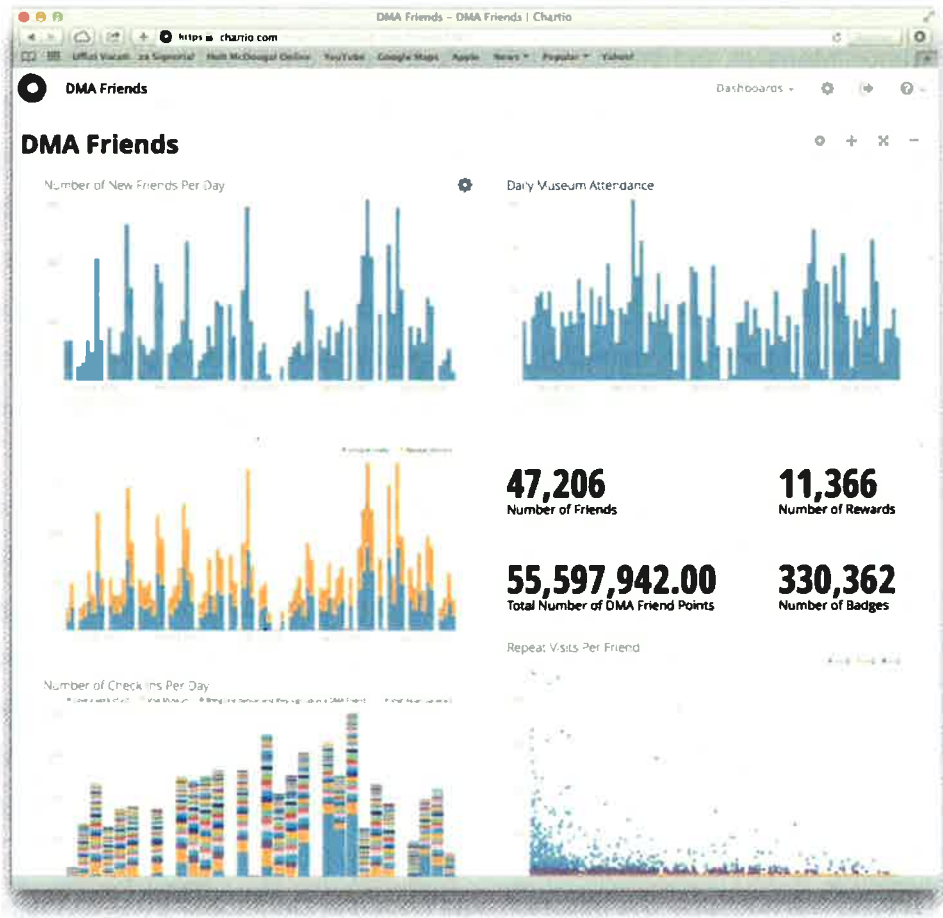

Figure 5 DMA Dashboard (Stein and Wyman, 2014)

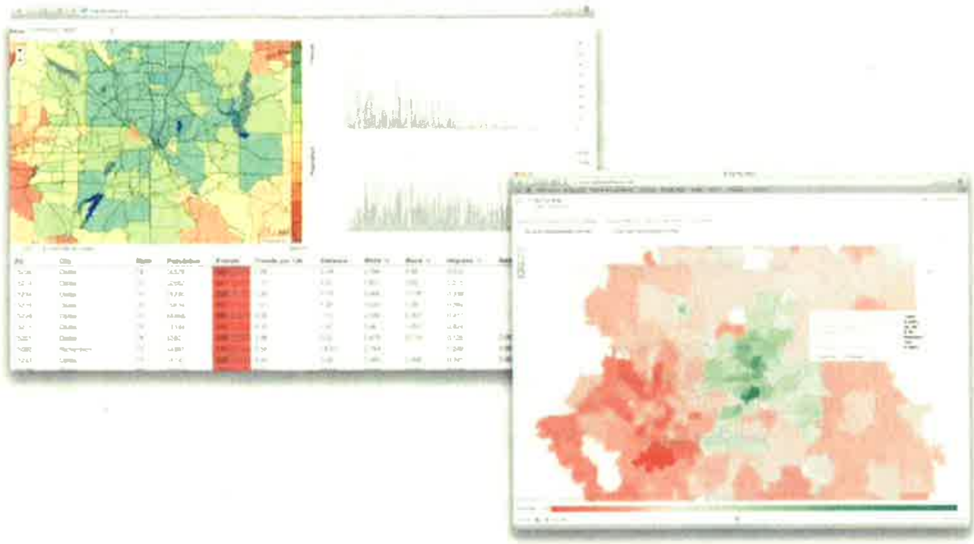

Figure 6 DMA Dashboard - Geographical Mapping (Stein and Wyman, 2014)

Chartio is a gratis tool, while Tableau is charge-based, although it also offers some limited cost-free functions. Both programs are easy to learn without any statistical knowledge needed, which makes it interesting also for smaller heritage institutions.

In the USA, the Southern Methodist University in Dallas and DataArts offer a free dashboard and benchmarking tool where art institutions can compare their performance to others. The 'KIPI Dashboard' contains 'key intangible performance indicators'. Comparing the own organisation to nine financial or operational performance indicators of similar national institutions might help to answer strategic questions and with planning in general. It can result in insights, ideas or collaboration opportunities (SMU DataArts, no date). An example of a dashboard for large theatres can be found in Figure 7.

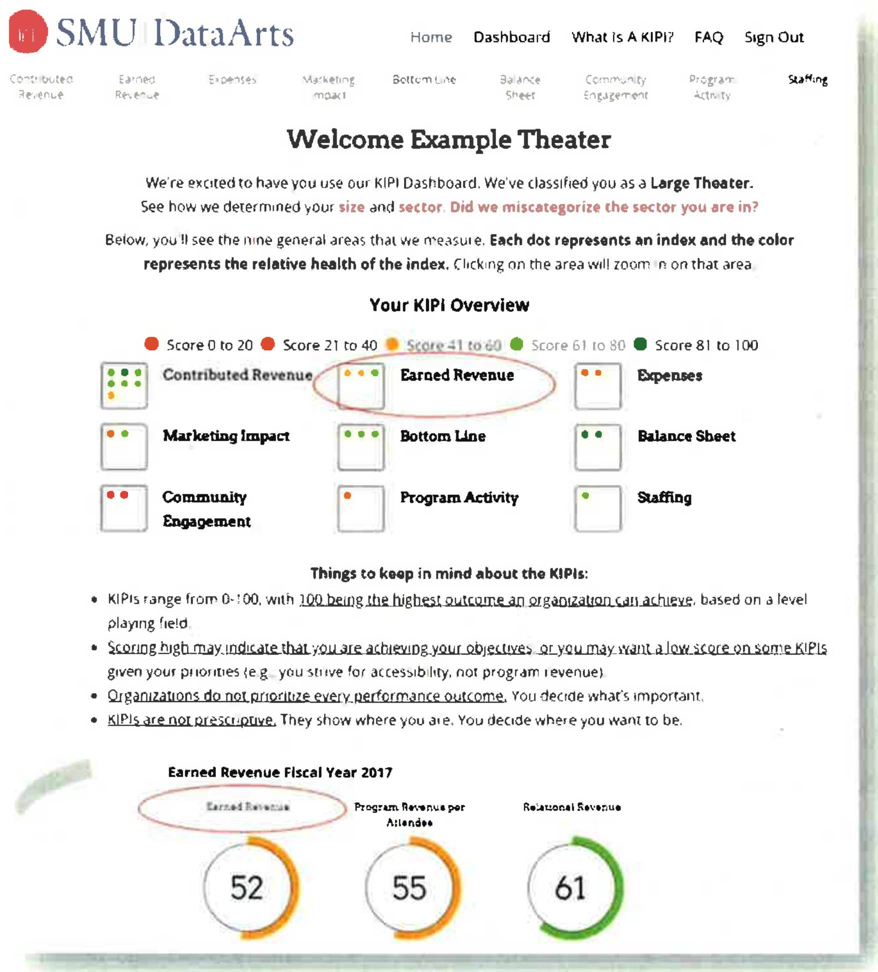

Figure 7 SMU Dashboard example Theatre

Nine categories such as revenues, expenses, balance sheet, marketing/impact, community engagement activities or staffing offer further deep dive key performance indicators. Each dot symbolizes an indicator and shows how one's own institution compares to the benchmark pool, consisting of institutions from a similar size and sector. The colours show how high one's own institution scores in the individual indicators. The scoring reaches from low (red) to high (dark green). In Figure 8 'Earned Revenue' is illustrated as example.

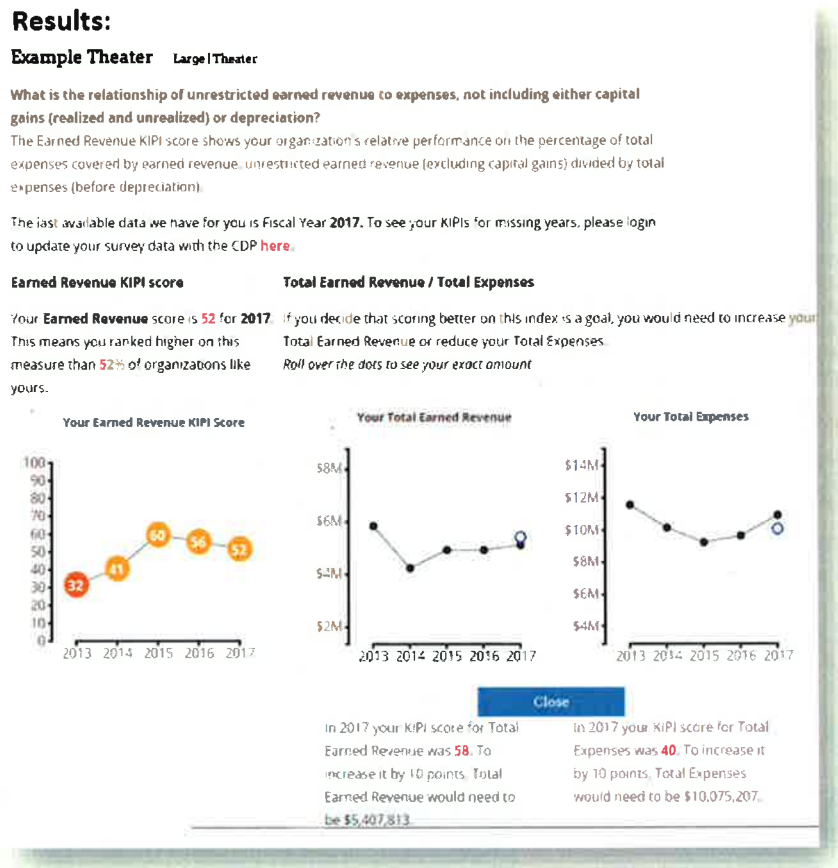

Figure 8 Example of Cultural Dashboard (SMU DataArts, 2017)

In the United Kingdom, a similar dashboard is available. The ‘Audience Finder’ from The Audience Agency offers free tools like a national benchmarking or audience mapping tools. Charges are applied for enhanced tools around data metrices or website analytics and for benchmarking one’s own institution data with a benchmark pool (Audience Finder, 2019).

Information by individual heritage organisations and the statistical office ONS is combined to provide insights on audiences in different regions and for different art forms. Figure 9 exemplifies the ticketing data for the South East region.

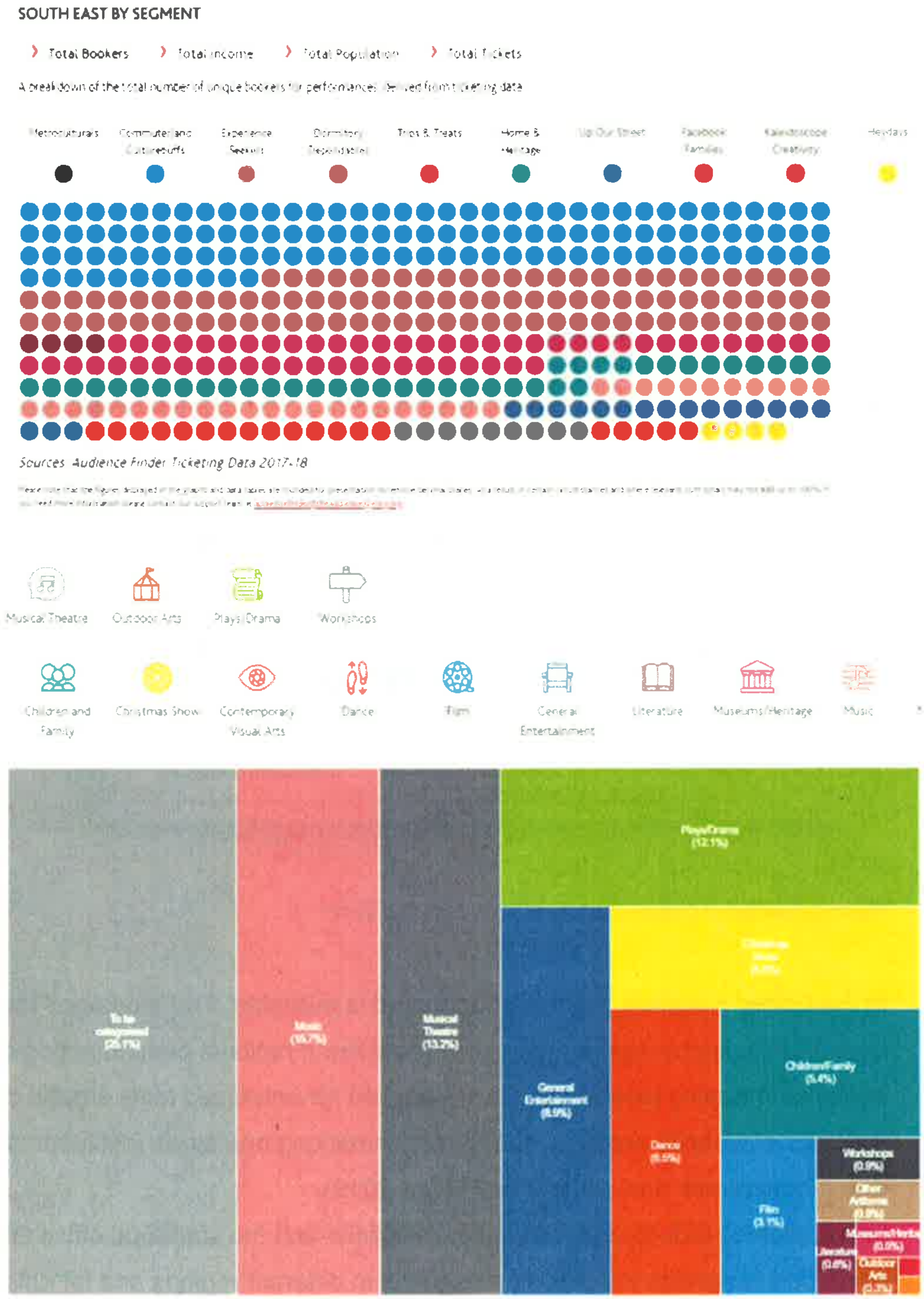

Figure 9 Audience finder (no date)

Smartify – Visitor engagement and understanding via collaboration

Smartify is a mobile phone app which allows visitors to scan an object (mostly paintings) and receiving background information about the object and the artist. Smartify's mission is it to help bringing art closer to an audience and helping art institutions in reaching audience (Smartify, 2019). They try to achieve this by using smartphones to enhance the visitor's engagement. The app is gratis for the museum visitor. Museums that start a collaboration with Smartify need to pay an annual membership fee. A partnership with Smartify has the advantage that the museum does not need to create an own app which can be time and cost intensive. Smartify offers analytics data on the visitors who used the app within the collaborating museum. This contains information about visitor demographics, patterns or behaviours etc. Smartify can also be used as marketing tool because foreign visitors might become aware of the heritage institution. In the UK, I tested Smartify in the National Gallery and the National Portrait Gallery. The concept can only be successful if the museum has digitised their collection. In the National Gallery the app offered me the same information that can be found on the museum's website. Using the app is very easy and the object scanning was reliable and worked. Given the limited physical space, labels and explanations are short. Here, the app provided more information. With the app the visitor can learn more about a painting and the artist in an easy and engaging way. Especially for school classes and young people this method of digital learning might be encouraging to understand more about art (Stewart, 2018). Also, for further learning after the gallery visit, Smartify can be useful because saving a high-quality picture and the informative text can help at a later time to look back on paintings that the user found interesting.

The next chapter covers the usage of robots within the museum sector.

Robotics

The term 'Robotics' describes the science "related to the engineering, construction and operation of robots" (Techopedia, 2018). In the context of the cultural sector, I identified three different kinds of robots currently used. Firstly, a robot that is machine-like and only consists of arms to move objects from one area to another. Secondly, a robot that is steered by the remote visitor via video connection and that moves physically through the museum. Thirdly, a humanoid robot that looks in the widest sense human like. In the next section, it will be shown how those robots are used and which different purposes they fulfil.

Robocase

The Dutch firms Bruns and Kiss the Frog developed the Robocase which is a large glass display. Inside there is a cupboard with shelves and drawers, containing the artefacts. At the outside, the visitor can select an object via a touchscreen for closer contemplation. The robot inside the glass case will collect the chosen object by using two mechanical arms and will place it in front of the visitor or might rotate it for a 360-degree viewing.

Figure 10 Robocase (Bruns, no date)

As of February 2019, no museum was identified which would use a Robocase yet. With the limited physical space that museum curators have at their disposal for showing objects and materials in an exhibition, the Robocase offers a good alternative for displaying more items of the museum's collection within a smaller amount of space.

Moving video robot

In 2015, The Van Abbemuseum in Eindhoven was the first European museum that introduced a video robot to give visitors who cannot be physically present the chance to virtually visit the museum.

Figure 11 Video robot at Van Abbemuseum (2019)

A pre-booking of a one-hour timeslot is needed as well as a stable internet connection, a camera and microphone. Also, a special software (Beam software) needs to be downloaded to steer and move the robot. The robot is always accompanied by a person at the site. This is either a museum's volunteer or a tour guide. The fee for the visitor is similar to the ticket price of 13€ or 70€ (when the tour is led by a tour guide). Sensors prevent the robot to accidentally touch or overrun objects or other visitors. The remote visitor sees three windows (Figure12): what is in front of the robot on camera level, what is in front at the wheel level and the visitor's camera view which is projected on the robot's screen for communicating with the museum employee at the site.

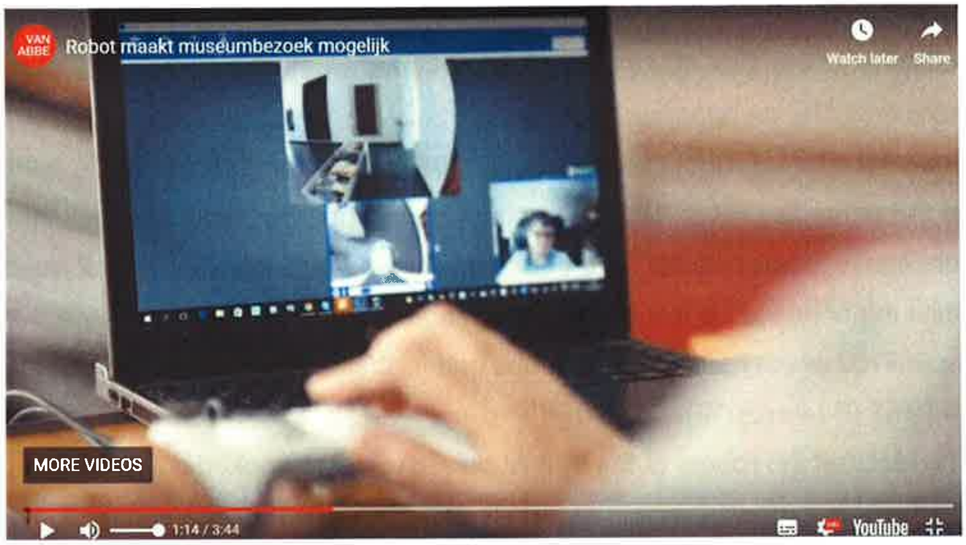

Figure 12 Video extraction showing remote visitor view (Van Abbemuseum, 2019)

Offering remote audience the possibility to virtually visit the museum in this interactive way is an interesting concept. The visit with a moving robot is a different experience compared to digital wandering through the museum via the Google Street View application, for example, in the British Museum. While digitally walking through an empty British Museum, the video robot suggests the idea of a real visit as it adds the human touch with the interaction of the museum staff or other visitors.

However, this form of visiting has its limits because the wide-angle camera lens causes lens distortion which makes the encounter and contemplation of the art difficult. This shortcoming is due to the fact that the video robot was originally designed for video conferences (Boiano and Gaia, 2018).

The moving video robot helps regarding the museum's task of inclusion of physically impaired audience. The remote visit might not be able to fully replace a physical visit but for impaired audience it is a possibility to prevent potential isolation by participating in a social and inspiring activity. Interestingly, the physical distance can be overcome with the robot. According to Marleen Hartjes, Coordinator for special guests at the Van Abbemuseum, visitors at the gallery are curious when the robot is present and interaction between the visitor behind the screen and the visitors at site happens (Van Abbemuseum, 2015). Here technology helps to encourage communication between the audience.

For other remote visitors, the robot can be a helping tool to find out what the collection of the Van Abbemuseum is about and whether it's worth visiting when there might be an opportunity.

Costs for a Beam robot ranges from 2,140$ for the standard version to 4,990$ for the enhanced robot. One of the most important differences between the versions is the battery life. The battery of the standard robot lasts for 2 hours, while the enhanced one lasts for up to 8 hours. Prices for BeamPro and BeamPro2 which have larger screens and further additional features start from 14,945$ (Beam, 2018).

The fact that the robots at the Van Abbemuseum are booked out up to five days in advance, suggest that this service is popular and a successful way of attracting visitors who would not come to the museum.

Humanoid robots: Pepper the Robot

A humanoid robot is a machine with human-like outside features, e.g. arms, legs, a head and oral verbalisation skills (Reuters, 2015).

In April 2018, Softbank Robotics donated 25 humanoid robots to the Smithsonian Museum in Washington (Olsen, 2018; Smithsonian, 2018b). The robots were distributed to 6 institutions within the Smithsonian organisation to pilot in how far the robots can be useful for visitor engagement and education. Of special interest during the investigation is if the robot can attract more visitors to an underutilised part of the museum or if it can abolish hurdles for visitors to ask questions.

Currently, the possibilities of Pepper are limited. Figure 13 shows the three options the visitor can choose from when interacting with Pepper at the Smithsonian Castle. The robot uses voice and gestures to answer predefined questions. It reacts to voice command or to the touchscreen installed at its front. Pepper can tell stories and show videos or pictures on the touchscreen. The robot can entertain by dancing while playing music and posing for selfies (Smithsonian, 2018a). Pepper's presence is limited to certain days and mostly 1-2 hours per day in most of the museums, except for the Hirshhorn Museum, where Pepper is available on all days during the opening hours (ibid).

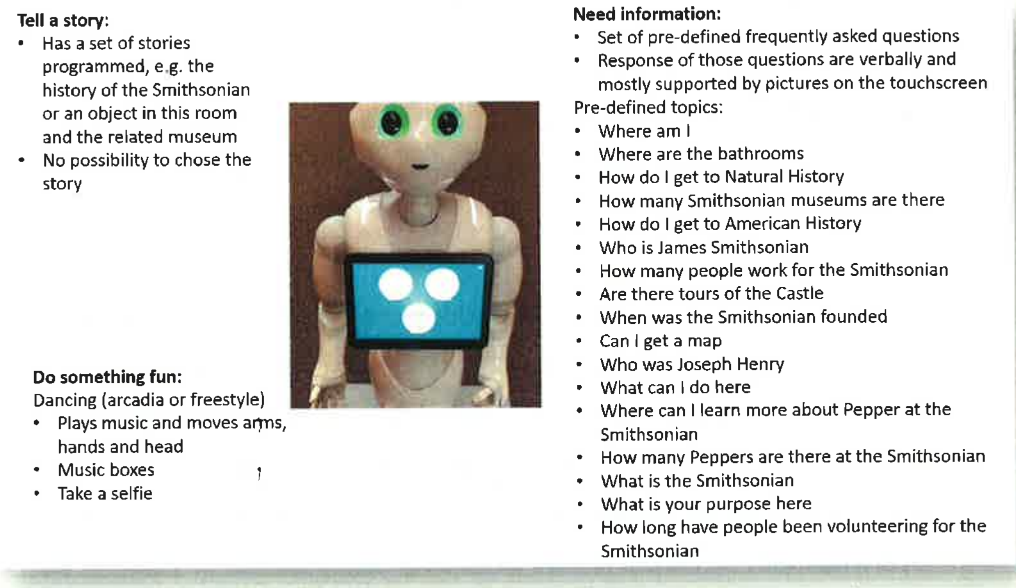

Figure 13 Smithsonian Castle's Pepper Robot

I tested Pepper's abilities during a field trip and collected information via a visitor observation.

The research was conducted on Tuesday, 13 November 2018, between 10-11am, at the Smithsonian Castle and at the Hirshhorn Museum between 11.30am-12.30pm. The number of visitors observed were limited:

	Visitor type	**Number of visitors**
Smithsonian Castle	A school class with two teachers and ten pupils, two older engaged couples, a younger couple and an older couple that didn't show any interest in Pepper	18
Hirshhorn Museum	Three couples, one man, a school class consisting of seven pupils and one teacher	15

Table 2 Visitor overview

It should be noted that given the limited amount of time and visitors the concluded insights might not be representative and further visitor observation on different days and time might be advisable. Also, categorising the visitors into older or younger visitors is not based on factual visitor insights but on the researcher's estimates.

The Smithsonian Castle tries to attract more visitors to its gallery where examples of the different Smithsonian museums are presented to inspire visits to one of the Smithsonian organisations (VOA News, 2018). Pepper is placed in the middle of the room to make an overlooking unlikely. A board explains how the robot works and warns to be "patient and wait for my response as I can get overwhelmed." A carpet shows where the visitor needs to stand to interact with Pepper. According to Rachel Goslins, Smithsonian Museum Director, the programming of the robot is simple and is similar to creating PowerPoint slides (ibid). I observed the set-up in the gallery. It took approximately 3 minutes. The museum employee simply had to press a button to get it started.
Nearly all visitors were curious and interested in Pepper. Even if some of the visitors didn't interact with the robot, nearly all had at least a look at it. As shown in Table 2, only two people out of the 33 observed visitors did not look at Pepper. This can have various reasons, for instance, they might have had previous interactions with Pepper before or in general, they were not interested in robots.
The visitor can give commands via the voice recognition feature or alternatively via the touchscreen. Even when the choice was between yes or no, Pepper did not understand my verbal reply at the first try. I had to repeat myself and I observed the same with other visitors. The information board also mentions that Pepper can talk to one person only. Surrounding noises might impact the voice recognition next to a possible accent of the visitor.

The Hirshhorn Museum operates two Pepper robots. Figure 14 illustrates an overview of their different functionalities, which are similar to the descriptions of the 'Castle' Pepper. They are used for marketing purposes. Pepper1 on the ground level promotes the Hirshhorn HI app and provides more information by

showing a video on how to install the app. Figure 14 also depicts the environment of Pepper2 on the upper level of the museum. Pepper2 shows artist videos that can also be watched via the HI app.
While all other mentioned Peppers work with a set of pre-defined questions, Pepper2 does not. It offers the visitor the possibility to verbally formulate a question or command. I asked: Tell me about the objects on this floor; Tell me about the objects in this museum; What is Big Man? (an object on this floor); Tell me something about Smithsonian; Where are the toilets? On all of the asked questions and commands Pepper replied that it does not understand.

Figure 14 Pepper robots at the Hirshhorn museum

As described above, the voice recognition feature did not work. Given the Smithsonian museums attract an international audience, it's important that this feature improves to be useful. If only the touchscreen functionality works, Pepper merely acts as a normal digital kiosk often used in museums.
While Pepper raised curiosity with the audience, this level of interest could not be kept for long. It might be amusing to see the robot dancing or listening to one of its stories, however given the limited usefulness and possibility to interact, the visitor fatigues quickly. This can also be seen in other

environments where Pepper has been tested. For example, a Pepper robot was used in a Scottish grocery store. Customers could ask questions and one frustration customers raised was that the replied answers were not useful (Mogg, 2017).

It is questionable if the robot increases visitor engagement. Goslins (VOA News, 2018) states that Pepper makes visitors smile and my observations confirm this, but I did not see that any of the human visitor engagement employees would use Pepper as a tool to get into contact with the visitors.

As the technology evolves over time, Pepper could be used as a tour guide and if the voice recognition works, visitors could ask questions that they might not dare asking to a museum employee. In this context, it will be important that Pepper will be able to handle ambiguous questions, e.g. What do you know about Washington? The robot would need to ask what is meant, either the historical person or the city.

The appropriateness on having a robot instead of a human being who can empathize needs to be carefully assessed, for example, for dark heritage sites that cover topics like holocaust, genocide or slavery. A human guide can assess the mood of the visitor group and can react accordingly.

For the future, in the workspace a combined effort of human and machine can be expected where both complement each other (Royal Society, 2018b). A similar combination could take place in museums with human and robotic tour guides.

The value of one Pepper robot at the Smithsonian is $25,000 (Carter-Conneen, 2018). I argue that the current price does not add much value to Smithsonian's visitor engagement because the visitor interaction I observed was short, and the provided content seemed limited compared to digital information kiosk seen at other museums.

I reached out to The Smithsonian Information Centre to ask for a comment on how successful the Pepper pilot is evaluated at the museum. Unfortunately, I didn't receive back a response before the due date of this thesis.

A robot is best equipped to fulfil tasks that are repetitive, and which can be automated. Tasks where creativity, empathy or emotional intelligence is required will remain typical areas for human beings. Therefore, I claim that museum employees should not fear the new technology but should embrace and leverage it to complement one's own human capabilities.

The next chapter contemplates how Artificial Intelligence is used in the museum sector.

Artificial Intelligence

The term 'Artificial Intelligence' (AI) was coined by U.S computer scientist, John McCarthy in 1955 (Childs, 2011). In the media and public discussions AI is used in different meanings. For the purpose of this thesis I will use AI according to the definitions of Max Tegmark's publication 'Life 3.0' (2017):

Term	Explanation
Artificial Intelligence	Non-biological intelligence
Narrow Intelligence	Ability to accomplish a narrow set of goals, e.g. play chess or drive a car
General Intelligence	Ability to accomplish virtually any goal, including learning
Universal Intelligence	Ability to acquire general intelligence given access to data and resources
Artificial General Intelligence (AGI) (also known as Strong AI or Human-level AI)	Ability to accomplish any cognitive task at least as well as humans

Table 3 Artificial Intelligence terminology (Tegmark, 2017)

Artificial Intelligence mimics human abilities. Machine learning and deep learning are branches of AI. Machine learning is a method of training a machine how to learn. This can be accomplished in different ways. A common tool is supervised learning where a machine is fed with labelled examples. For instance, a machine can learn to identify photos which show a cat. Firstly, the machine needs to learn how a cat looks like and the human trainer teaches the machine with a training set by selecting and tagging cat photos versus non-cat photos. The machine learns to generalise and to predict for new incoming pictures, whether it depicts a cat or not. This output is based on the machine's learning process.

Another machine learning method is unsupervised learning where the AI needs to find a structure or patterns in large unlabelled data sets. There is no predefined correct answer and the machine makes own decisions (Brownlee, 2016). Unsupervised learning is mostly used for cluster analysis to group objects with the same characteristics to one cluster.

A more complicated version of machine learning is called deep learning. For deep learning, the scientists use an artificial neural network. Neural networks

are based on the learning processes of the human brain, consisting of neurons connected with each other and sending or receiving impulses. Artificial neural networks (ANN) use multiple layers which enable the AI to solve more complicated tasks like autonomous driving (Royal Society, 2017, p.25).
In an ANN the equivalent to neurons are called units. The units are organized in different layers in which calculations and processing take place to interpret the data that was fed into the input layer. In the input layer the AI receives information that needs to be interpreted. For example, the AI's task is to understand what an image depicts. At Figure 15 the process is shown graphically. Here, the input layer is the image of a turtle. At the output layer the AI gives its answer based on the processing in the hidden layers in between. The hidden layer(s) is also often referred to as black box because even the programmers cannot reconstruct how the AI came to its results. In most variations of neural networks, the layers and units are connected with each other. When data goes from unit to unit to filter the relevant information the connections receives a weight to mark its importance and priority. Through this process the network learns about the input data.

When data is fed into a deep neural network, each artificial neuron (labelled as "1" or "0" below) transmits a signal to linked neurons in the next level, which in turn are likely to fire if multiple signals are received. In the case of image recognition, each layer usually learns to focus on a particular aspect of the picture, and builds up understanding level by level.

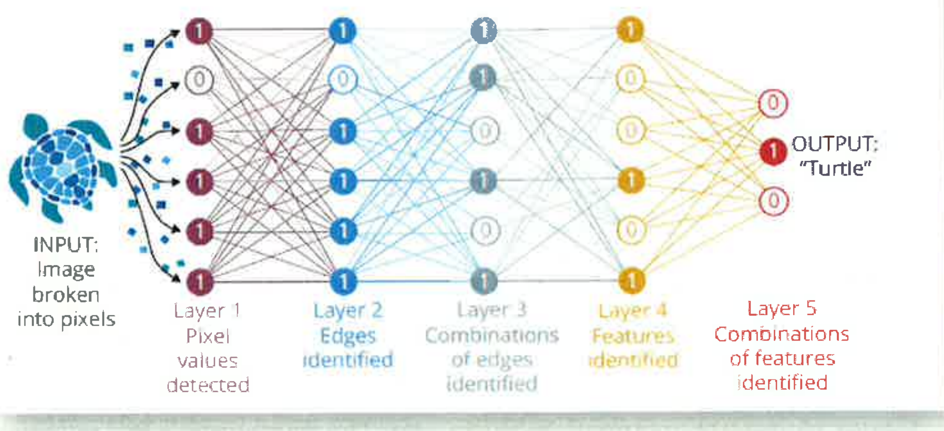

Figure 15 Artificial Neural Network (House of Lords, 2018 and Simonite, 2018)

Projects described in this chapter were solved with structured machine learning and deep learning techniques.
The next paragraphs will explain how heritage institutions use AI for visitor engagement and educational purposes.

Interacting with visitors via Chatbots and Online Collections

A Chatbot is a computer program that simulates an intelligent human conversation via voice or text interactions (Technopedia, no date). Especially banks and insurance companies use chatbots to help customers with payment transactions, account management, claims management or general advice (Digital Finance Institute, 2018). It is expected that the importance of chatbots will increase in the future and becoming the most important method for businesses to interact electronically with their customers (Duhaime, 2016). Messaging services like WhatsApp, Facebook Messenger or We Chat offer possibilities to create chatbots. In the heritage sector, museums often have a Facebook page and there are examples of using Facebook Messenger to create chatbots for their audience. For example, Mary King, Digital Engagement Specialist at the US National Archives developed a Chatbot to answer frequently asked questions, among other things (Wright, 2018). The next example shows another creative way on how the Chatbot technology can be used.

Dot application – a tour guide at Akron Art Museum

In summer 2018, the Akron Art Museum launched a Facebook Messenger chatbot, called Dot. The goal was to increase the visitor engagement by offering Dot as a tour guide. Dot informs about 60 pieces of art and creates a trail through the museum whereby the visitor will learn about 6 artefacts. The downloaded Dot app and an activated connection to the free museum Wifi network is needed. The chatbot informs in written form only as there is no verbalisation feature.
Figure 16 depicts screenshots of the app. The tour starts in the museum lobby in front of a Sol LeWitt object. Dot helps to find the correct artefact to start or to continue the tour by showing an image of the object (part A). The chatbot waits

with further explanations until the user(s) confirms the arrival at the right spot. In the following, Dot sends messages about the artefact (part B). In general, a lot of visitors like to visit a museum together with friends or family (Bitgood, 2002, quoted in Kuflik and Dim, 2013). This is also the assumption of the Akron Art Museum. Therefore, the app tries to encourage discussions about art and objects (part C). The users are given choices on what to look at next, for example, by choosing between "art that explores color and shape or large artwork made by a team" (Facebook Messenger, 2018). By clicking on the respective pictogram, the app user delivers the decision (part D). A short description on where to find the next artefact follows (part E).
The app is very easy and intuitive to use. No Facebook account is needed, although it is a Facebook messenger application.
The set-up of the trail helps to find new ways through the museum and to discuss about the exhibited art.

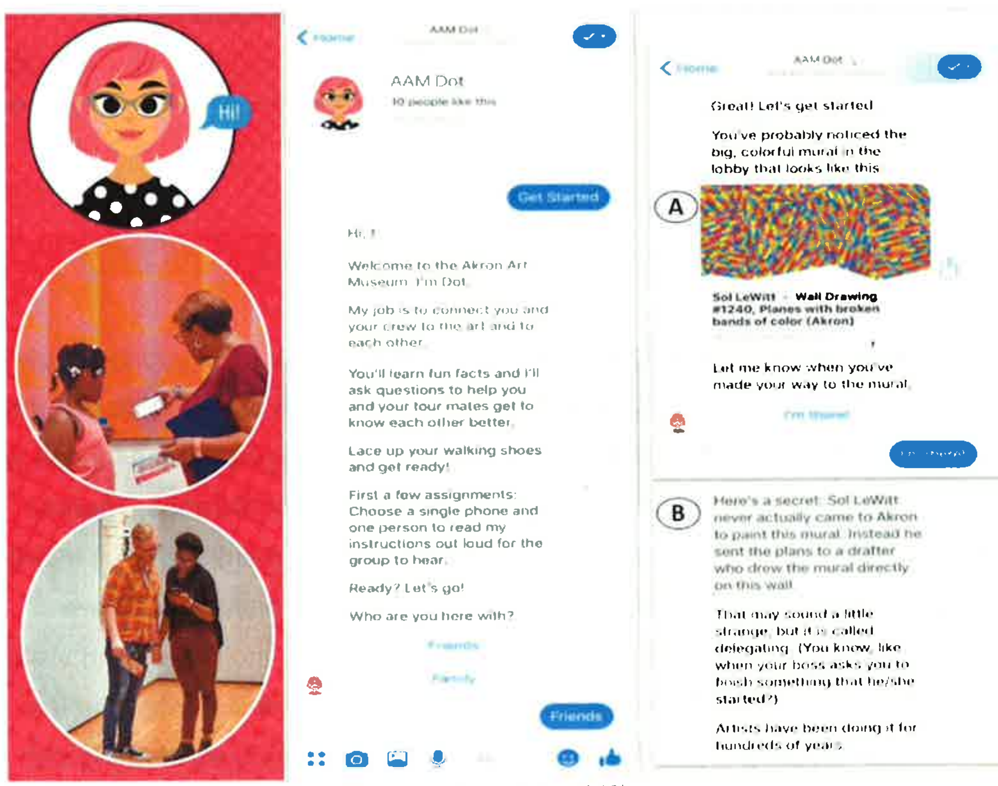

Figure 16 *Screenshots of Dot app (Facebook Messenger, 2018)*

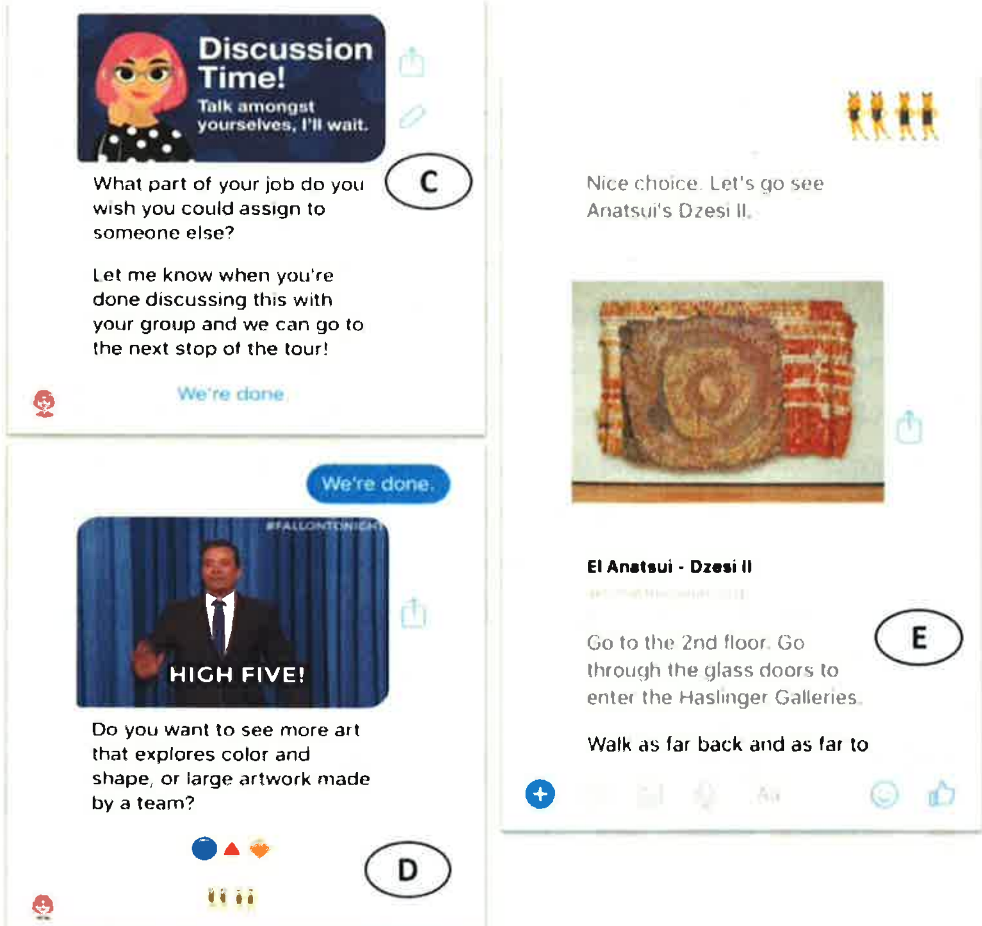

Figure 16 Screenshots of Dot app - continue (Facebook Messenger, 2018)

According to the Digital Finance Institute (2018, p.16) a lot of young people feel more comfortable in talking to a chatbot than to human beings. This can also be confirmed with the Akron team' observations. The Dot project was funded with $173,000 by Knight Funding (Litt, 2018). At the MCN conference, Theresa Bembnister (Associate Curator at Akron Art Museum) mentioned that in order to find out how this funding could be best used, different possibilities were investigated. For instance, the museum curators sat in the gallery and visitors had the opportunity to ask any questions. This experiment showed the low interest in chatting to the curators but instead visitors enjoyed chatting with each other. Thus, the museum decided to set up a tool to help with audience interaction.

According to Jayson Shenk (2019), Digital Content Specialist at the Akron Art Museum, 381 users interacted with the Dot app by 25 February 2019. However, this number does not include accompanying visitors and as Dot targets a group experience, the number of users is assumed to be higher. Also, it does not take into consideration if a user conducts several tours via Dot. The monthly costs for maintain the app via the Chatfuel platform are approximately $15 (ibid).

Collection at the Barnes Foundation

The Barnes Foundation, an art museum in Philadelphia, found a different way of engaging the visitors and created a tool for exploring their collection. The museum displays the collection of Dr Albert Barnes. Barnes gathered paintings and objects from different time periods and cultures. In the 1920s he developed an education program that was based on displaying objects due to their "visual similarities" in terms of light, lines, colour and so forth (Bernstein, 2017a). Figure 17 shows an example on an "ensemble" as Barnes called this teaching technique. Objects from different materials, time periods, art styles, cultures etc. are displayed together instead of exhibiting artefacts according to the historical epoch.

Figure 17 Barnes Collection (Barnes Foundation, 2019)

Since 2017, the museum offers an online collection tool on their website which is similar to the way of presenting the collection in the physical space. Instead of a curator, it's the visitor together with an artificial Intelligence that curates the collection depending on specific characteristics. The tool enables the visitor to choose several visual characteristics, as a result, pictures of visually similar objects are shown that can be further investigated by the visitor. With the help of Artificial Intelligence new ways of looking at art could be discovered. Ways that human curators would have never thought of before.
Figure 18 shows a search using different possible parameters like searching and displaying the collection of objects with a chosen colour, line, lights, space or keywords.

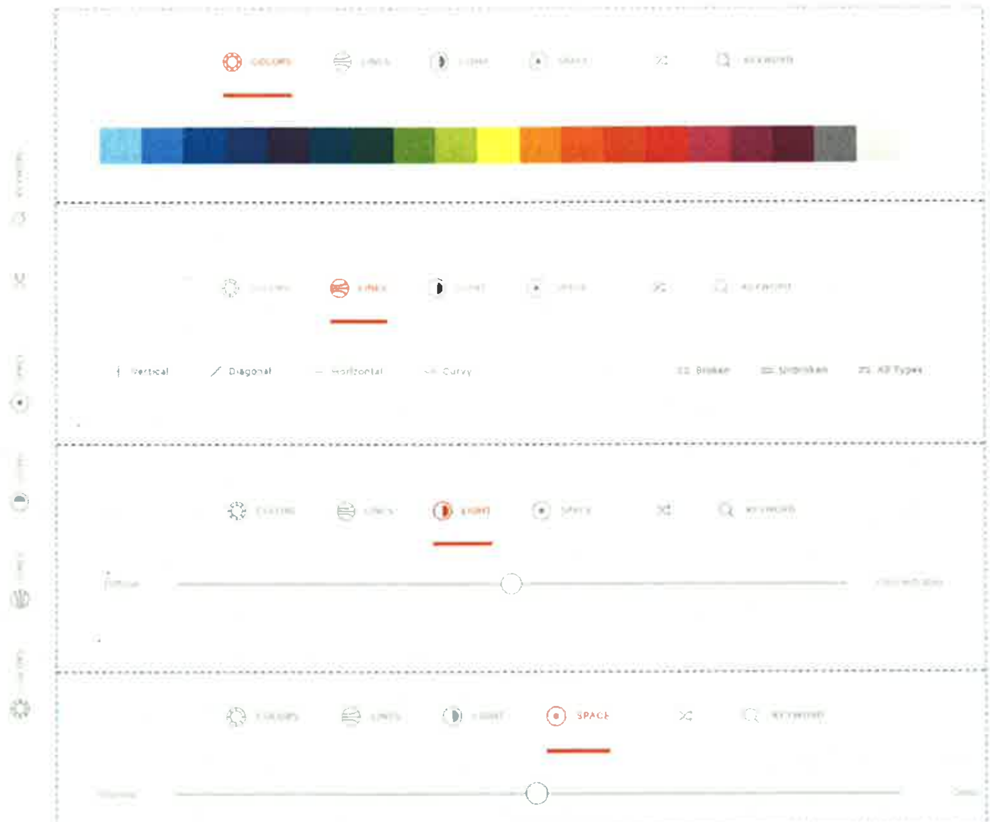

Figure 18 Barnes selection criteria (Barnes Foundation, 2019)

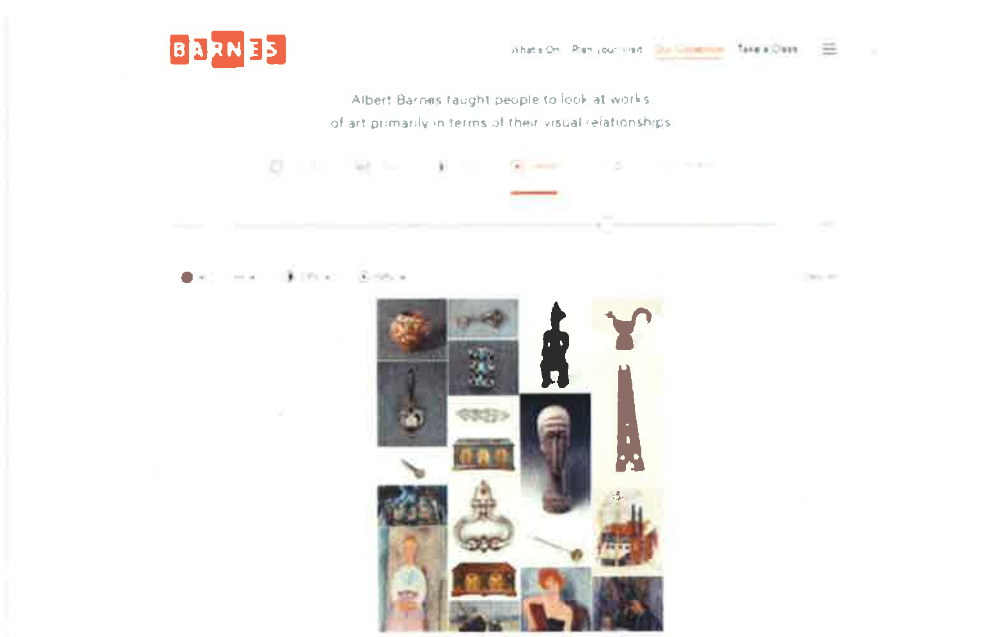

Figure 19 Barnes - Results page (2019)

For creating the online collection in the 'Barnes style' the project team used an Artificial Intelligence algorithm to find similarities of the collection items. According to the similarities, the AI curates objects together as illustrated in Figure 19. The project team used structured machine learning by teaching the AI with labelled data of the collection items. This means the algorithm was fed with photos and the respective keywords or tags. Different machine learning tools are available on the market. For this project the team used the standard services of several providers like Microsoft Azure, IBM Watson, Google, AWS Rekognition, TensorFlow and Clarifai. In the next step, the AI received unlabelled photos of the collection and the AI had to analyse what the photo showed and had to tag it with keywords.

The first outcomes after the teaching process generated a lot of errors but also resulted in interesting similarities that the AI found. Shelly Bernstein (2017c) gives the example of searching of paintings that contain cherubs and the AI returned cherub-like paintings (see Figure 20). She explains: "This gets you thinking and making connections; it's this magic that we want to keep."

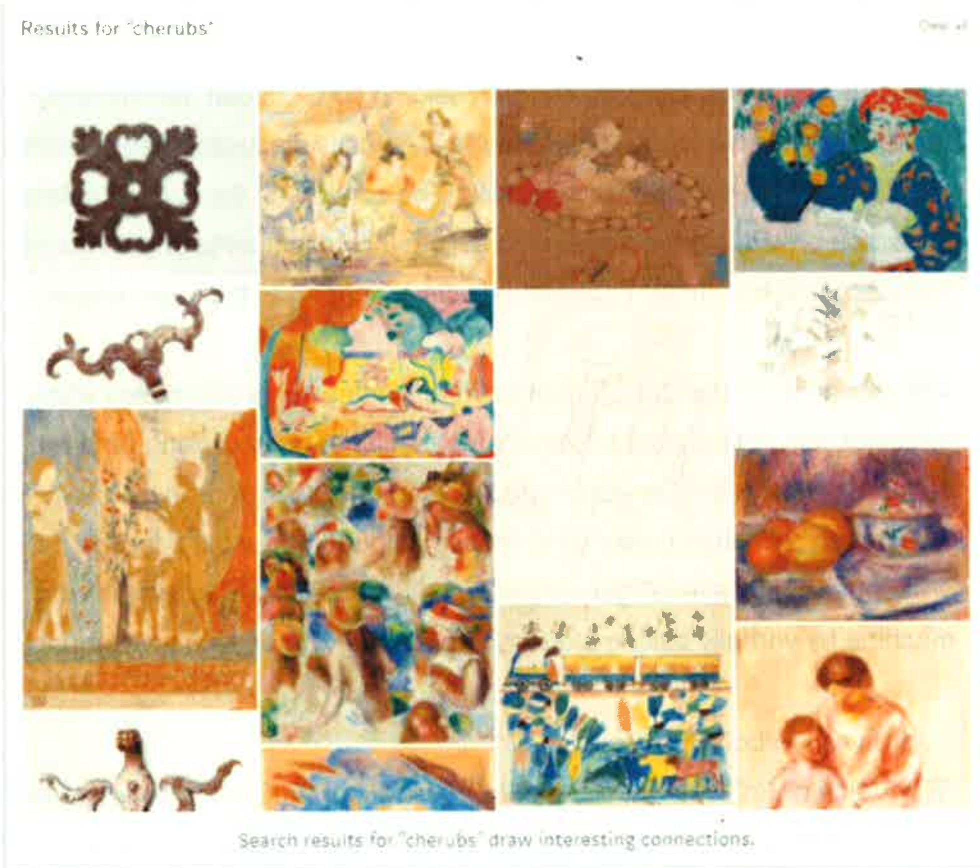

Figure 20 Results for searching for cherubs (Bernstein 2017c)

Especially with impressionists' paintings the algorithm had difficulties as in the beginning phase the AI identified a lot of stuffed animals within the paintings which was not correct (Bernstein, 2017b). According to Martha Lucy (2017), curator at the Barnes Foundation, Renoir, whose paintings make 19% of the collection, tried to evoke a "sense of touch" in particular with babies and nudes. This could be the reason why the algorithm interpreted those objects as stuffed animals.

Although the AI came up with interesting connections, the team tried to minimise the rate of error of the misjudged tagging. The team members had to manually tag objects which was used to further train the AI. In cases, where several AI systems gave the same tagging on an object, it was considered correct. Tags that would create a higher level of errors like gender-specific terms or words like religion were dropped because the AI was not good in distinguishing between men or women and an abstract construct was difficult for the machine to understand.

The question if only experts, like professional curators can 'tell the story' of a topic with 'correctly' curated exhibitions is a vastly discussed debate within the heritage sector (Harrison, 2012 p.109). The concept of the Barnes online collection provides a tool for democratising the collection to enable the visitor to compose and encounter museum objects according to their own interest.

The examples of the Dot Chatbot and the Barnes collection viewer show offerings with limited possibilities for interacting, e.g. by clicking on a pre-defined choice in the Dot app to decide where to go next or to decide to look at the Barnes collection based on a chosen colour. In the next section, I will present an Artificial Intelligence tool that allows the visitor to truly interact with a machine by verbally asking a question and receiving an oral answer back.

Cognitive Chatbot: 'The Voice of Art'

'The Voice of Art' was a project of the Pinacoteca de Sao Paulo in collaboration with IBM and Ogilvy. For four months in 2017, the audience could use the Voice of Art smartphone app to ask any question related to seven exhibits of the pinacotheca (WPP, 2017). Entering a question or receiving a reply by the cognitive assistant (IBM Watson) worked either verbally via a headset or in written form via typing to allow best possible accessibility for all visitors. Next to the seven paintings, beacon transmitters were installed. When the app user approached the artefact, the transmitter sent out a signal to begin the interaction.

IBM Watson is a machine learning AI. For six months, Watson was 'fed' with information about art history that was collected by the curators. The information derived from diverse sources like books, press, interviews, internet etc. One characteristic of machine learning is the possibility for constant learning, i.e. also during the audience facing period, the system learned from the interactions with the visitors.

According to a survey conducted by the Brazilian Institute of Economic Research in 2010, 72% of the Brazilian population has never visited a museum (Baeck, 2017). This project tried to show how art can be engaging and

immersive. It gave the opportunity to “talk to art”. In the first month alone, the visitor number has increased by 340% and more than 10,000 people interacted with Watson (WPP, 2017). This shows that an interest in interacting with art can be evoked with non-traditional tools like the machine learning applications. Potentially new museum audience can be attracted.
Another field in which machine learning has helped in the cultural sector is a project regarding collections management. The next section investigates on how object character recognition can help to manage handwritten documents and making them accessible.

Neural Networks

‘In Codice Ratio’ – Vatican Secret Archives

Historical libraries and archives often have a large number of handwritten documents. Those documents can be made available at the site or potentially in digital form by scanning it. The Vatican Secret Archives (VSA) has a collection equivalent to “53 linear miles of shelves dating back more than 12 centuries” (Kean, 2018). So far only a very little amount of VSA documents have been made available online as scanned or transcript documents. Currently, scholars who wish to use the collection, need to ask for special access to manually go through the material. A project, called ‘In Codice Ratio’ launched by the Roma Tre University investigated how the digitisation of the VSA collection can be made accessible and searchable online. For this, the team used Artificial Intelligence in combination with OCR (optical character recognition) software. The goal was to create transcripts of the manually written documents. This would help scholars to research this material because then no special skills in reading Caroline minuscule script would be needed in which many of those documents are written.
Commonly used OCR software is often applied for scanning printed documents but for the handwritten material of the VSA this software is not suitable as it only works well with typeset text. With the Caroline script the OCR software cannot identify where a letter ends and the next one starts as the space between letters is very narrow. Therefore, the scientists of ‘In Codice Ratio’

developed a software that conducts a so called 'jigsaw segmentation', whereas the breaking down of a word does not happen by individual letters but by smaller segments similar to pen strokes. The software groups the jigsaw pieces together in different ways to form a potential letter.

Figure 21 Jigsaw puzzle (Kean, 2018)

In the next step, the AI had to be trained to 'read' the handwritten word and to make the right assumption on which word it depicts. For this teaching process the team used a cheap and quick crowdsourcing solution by leveraging the help of 120 pupils from 24 schools in Rome. Via a website the pupils spent several hours to 'tell' the AI by clicking and selecting which letter matches to the shown jigsaw puzzle. This helped the AI to learn and to make own correct judgements. Figure 22 shows the word anno in Caroline script. The AI could suggest the word is either: aimo, aiino, aiiiio or anno. With the help of more training data the AI was taught "some common sense" (Kean, 2018). The letter combination of nn is more likely than iiii. The scientists used a character classifier to calculate the probability of certain letter combinations. This supported the AI in deciding of the correct word. The character classifier was embedded into a neural network.

Figure 22 'In Codice Ratio': Anno (Kean, 2018)

The jigsaw segmentation and the neural network has shown successful results: 95% of the AI suggested words were correctly transformed from Caroline minuscule into modern script (Firmani et al., 2018).
The team made the code publicly available, so it could be useful by other institutions when digitising their handwritten documents. According to Rega Wood, a paleographer at Indiana University, the AI approach to OCR problems has limitations. The system might have difficulties with documents written by non-professionals, for example, with private letters or diaries. Those documents are written in different handwritings, therefore it can be more complicated to teach the AI, given a much smaller sample. For those instances it might still be faster to make a manual transcript.

National Museum of Natural History

A similar effort was conducted by Smithsonian's National Museum of Natural History in Washington (Schuettpelz et al., 2017). A convolutional neural network (CNN) was created to help analysing images of herbarium specimens. CNNs are a type of neural networks designed for image recognition by processing pixel data. The AI should determine whether the specimen either belonged to the family of clubmosses or to the similar looking family of spikemosses. Historically, some of the specimens were treated with mercuric chloride, a substance to prevent damages during the cataloguing process caused by insects. This substance is toxic for humans and in the collection it is not tagged which specimen was treated with chloride and might be dangerous for museum staff when handling it. However, it leaves a stain on the attached paper. So, the second task of the algorithm was to identify stained specimens.
The input is an image of a specimen. In the hidden layer, the algorithm analyses and gives an output to determine whether the specimen is either a clubmoss or a spikemoss and whether the image contains a mercury stain or not. The CNN was able to effectively identify these two features. The accuracy level was 90% correctly identified mercury-stained specimens and for 96% the specimen family was correctly determined.
Digitalisation of natural history collections in combination with using a CNN method to collect and identify specimens can help scientists to analyse specimens on a larger scale to benefit fields such as agriculture or public health

(Suarez and Tsutsui, 2004, quoted in Schuettpelz et al., 2017). For this project, stained and non-stained specimens had to be manually found for the training effort. Therefore, if the training data set is properly mega-tagged, for example, by acquiring and properly maintaining metadata, then training the CNN becomes quicker and less labour intensive.

Threats of Advanced Technology

In the above examples it was shown which opportunities advanced technologies can provide to the heritage sector. In the following section I will summarize the current debate about potential threats of Artificial Intelligence in specific, because it is expected to have a huge impact. We as a society need to answer particular questions in order to determine what we will allow technology to be used for and how it should shape the world we live in.
Scientists and technology entrepreneurs warn of potential dangers of AI:
"With artificial intelligence we are summoning the demon" (Elon Musk, quoted in Supply Chain Today, 2017)
Steven Hawking (quoted in Supply Chain Today, 2017):
"The development of full artificial intelligence could spell the end of the human race" and "AI is likely to be either the best or worst thing to happen to humanity."

Access and control of data are important factors for being successful players on the AI market (House of Lords, 2018, p.29,44). Big 'tech companies' (Google/Alphabet, Apple, Amazon, Alibaba, Facebook, Microsoft, IBM, Samsung, Tencent) have a market advantage given their access to huge data sets. Smaller players or start-ups are often limited in their access to large data sets. In addition, they are often acquired by one of the big players. A concentration to a small amount of market players can result in dependencies and abuse of power. Data availability needs to be open for all market players to guarantee equal chances on the AI market. A controversial example where a big player gained a huge advantage is DeepMind (a subsidiary of Google) that reached an agreement with the NHS in 2015 to access the data sets of approximately 1.6 million patients of the British health system. DeepMind built an app that helps detecting kidney damage. But the court judged that the NHS was not allowed to share the data with DeepMind (ICO, 2017).
According to the Royal Society (2017, p.8) and Research Councils UK (2018, quoted in House of Lords, 2018, p.32), British publicly funded research should provide all their data publicly as open source and as default. This would be a necessary first step to guarantee the needed data availability which is a base

for machine learning. Given it is publicly funded, they argue, the data should be possessed by the public.

The DeepMind/NHS case did not only benefit one single market player exclusively, but it also violated data protection laws (ICO, 2017). How personal data is treated and who has access to it, is another question that needs to be looked into. Every citizen should have the right to know which data is collected, who has access to it and access should require the person's consent.

The concept of machine learning is based on using a large data set to train the machine. As this data set reflects historical circumstances and potential biases in the data, it is likely that the machine will provide biased decisions. For example, for face recognition most training sets consist majorly of white males. Therefore, the machine has problems to identify all other species and skin tones (House of Lords, 2018). Google's visual identification program in Google Photos, for instance, cannot make a distinguishing between a gorilla and a black person. In 2015, a black man published photos depicting him and his friends. These photos were tagged by Google's AI with the keyword 'gorillas' (Simonite, 2018).

The problem of biased data can have negative impacts. For example, in future an AI could make recruiting decisions. Given the historical dataset most hired employees were white men, the AI's decision could result in discrimination. With this bias in the historical data women or men with a different ethnical background would not or rarely be selected by the AI as potential candidates, despite similar qualifications. In the museum sector the training with images of historical paintings can create difficulties as in previous centuries black people were either not painted or if they were then only in context with slavery.

Another form of bias can constitute a possible threat. Social media or newsfeeds allow their users to set filters to only receive specific information. Due to the overload of today's information sources, filters are a useful tool. But it might reinforce that the users are only 'fed' with information that fits to their current view of life. Anything that is contradicting might be filtered out (House of Lords, 2018, p.82). If that happens, especially in a political context, any kind of decision making will become partial.

With the potential upcoming of the virtual personal assistant (VPA) and the recommendation system, this danger can become even worse. It could happen that a person then lives in a “filter bubble” without broadening one’s horizons (ibid, p.82, p.261). This could also impact with regards to museum exhibitions. If a VPA or virtual museum tour guide leads to artefacts within the museum based on the visitors previously liked items or general interests, then it might minimise opportunities to get inspired and to encounter topics that are new to the visitor. Digital connectivity provides opportunities for cyberattacks or general criminal activities (ibid, p.98). How this can be prevented is a question that must be constantly investigated.

In current debates it is often mentioned that humans could fear to lose the control about the AI. It could make decisions which would harm mankind. Especially with current deep learning technologies the danger of not understanding why a machine made a certain decision is prevalent because of the ‘Black box problem’. The layer structure work with an input and an output layer. But the layers in between with their calculations and learnings are a black box. The current status of data science is not so advanced yet to make an Artificial General Intelligence possible at the moment. Nevertheless, there will be a need for thinking of a legal and regulatory framework. Legal rules need to be determined, to align on who is accountable. For instance, who will be reliable if a driverless car causes an accident? For insurance and legal purposes, questions like this one need to be clarified. Also, it needs to be determined what an AI is allowed to do. For example, technically it is possible that AI could be used for weaponry. The face recognition algorithm could be used for detecting and killing a person. Google researchers have signed an agreement to not develop such a tool (Wakabayashi and Metz, 2018). Technology and education researcher, Graham Brown-Martin comments on the lack of ethics within the digital space: ”Just because we can do something does not mean that we should do it,…” (ibid)

The committee that looked into the possibilities of AI, commissioned by the House of Lords, suggests five initial principles:

> *(1) Artificial intelligence should be developed for the common good and benefit of humanity.*
>
> *(2) Artificial intelligence should operate on principles of intelligibility and*

fairness.
(3) Artificial intelligence should not be used to diminish the data rights or privacy of individuals, families or communities.
(4) All citizens have the right to be educated to enable them to flourish mentally, emotionally and economically alongside artificial intelligence.
(5) The autonomous power to hurt, destroy or deceive human beings should never be vested in artificial intelligence.

(House of Lords, 2018 p.125)

There are different opinions on the ways to most effectively implement regulations into the law. Some AI experts think that current laws are sufficient, others see a need for immediate action and a third group plead for a gradual adaption of regulations (ibid, p.112). No matter how regulations are implemented, the majority of AI experts seem to agree that there cannot be one regulatory framework for AI in general because AI tools differ in different sectors (Whittaker, 2018).

Conclusion

In this thesis, case studies of advanced technology used for different purposes such as visitor understanding, visitor engagement, curation and collections management were presented.

In Figure 23 those examples are placed into a 'cost versus impact' matrix. The definition of costs includes the easiness of implementation and the costs or efforts for usage and maintenance of the technology. The impact is evaluated with regards to how beneficial the launch of the advanced technology might be. The current status of the described museum's initiatives and projects is the base for this analysis. Future potential is indicated by an arrow and shows potential movement to another quadrant. The colours categorise to which overarching technology (AI, Big Data, Robotics) the initiatives belong to.

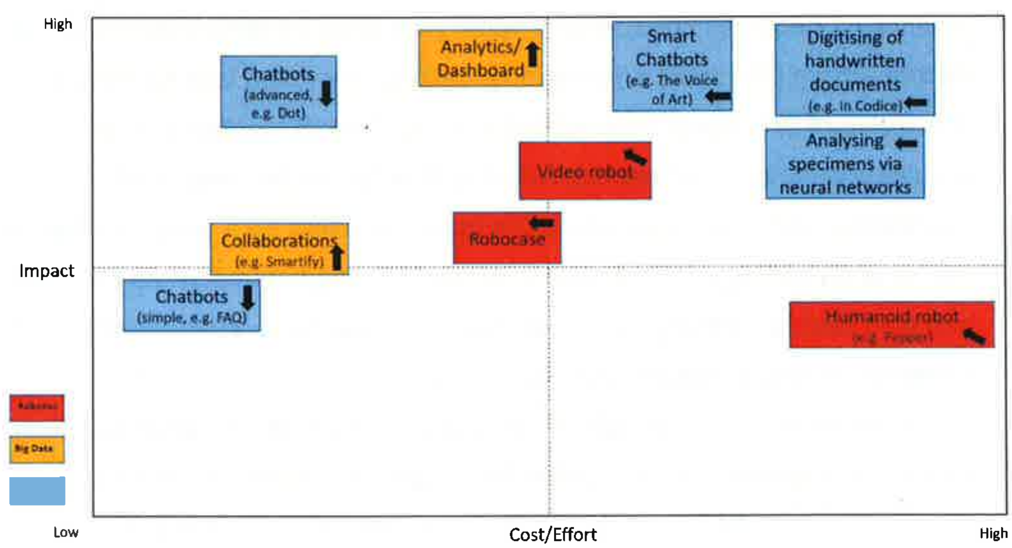

Figure 23 Cost/Impact matrix

The graph illustrates that most projects are evaluated of having a high impact. In the 'low cost-low impact' quadrant I assessed projects that use chatbots with a pre-defined set of questions like seen at the National Archives. On the contrary, chatbots like Dot have currently a high impact as it showed an increased visitor engagement and group experience. Using Robocases and offering the Smartify app are not gratis for museums and differ in their general costs but both are effective tools to either show the visitor more objects or to provide more background information. Hence, they score higher on the impact axis. Using Big Data Analytics and dashboards require training of the museum staff or a collaboration with an analytics firm, so the costs and efforts are not low. However, learning those programs is easy and a once set up 'Knowing your Customers' analysis can be reused and becomes a repetitive process.

The development of humanoid robots is still in the beginning phase. Therefore, I evaluate the costs of $25,000 for a Pepper robot as high with providing a low amount of impact. As described, the possibilities are limited, and the audience quickly loses interest in engaging with Pepper.

Video robotics is a technology that is not often seen in the heritage sector (Ellis, 2018). It is an easy tool to help with inclusion of impaired or remote potential visitors. At the moment, the costs are moderate, depending which version of the Beam robot the museum would need to invest in. Smaller regional museums could collaborate and buy one video robot together and sharing the usage. As technology becomes cheaper and better over time, I assess that this tool might become more affordable and equipped with an improved lens functionality.

The Voice of Art project showed that a smart chatbot function can attract visitors who have never been to an art gallery before because Artificial Intelligence does not judge whether a question asked by a visitor is intelligent or not. This technology can reduce hurdles by making a museum visit less elitist. It can also lead to challenge one's own point of view because the AI might make connections that a human being would not.

Using neural networks to digitise, analyse and mega-tag museum's collections was seen in the projects 'In Codice Ratio' and at the Smithsonian Natural History Museum. It will possibly improve the sectors abilities with more institutions developing algorithms and sharing it via open source. And it will reduce costs and time efforts as previously programmed code can be reused and modified.

The quadrant on the upper left is most interesting as those technologies are assessed as having high impact, while being easy to implement. The graph shows many technologies providing a high impact but for paying high costs. However, due to a constant improvement in technology I claim that those initiatives keep their high benefit but with a lower amount of effort and costs, especially due to efficiency and machine learning. Also, it can be expected that humanoid robots like Pepper will improve their voice recognition capabilities, thus I expect this technology to move to the upper quadrants. The impact might increase, too as the functionalities might become smarter and providing the audience with an individualised experience. Pepper could be a tour guide. Or it is possible that in the future, each person will have a virtual personal assistant. This virtual assistant could be a tour guide, leading through the museum based on the person's interest. The dangers of the 'filter bubble' has been discussed and should be considered when programming such tour guides to help the visitor in discovering new and surprising things within the museum. I expect technologies which are rather simple, like chatbots, only answering pre-defined FAQs or giving pre-defined decision trees, will lose impact and significance as they will be too simple.

Most advanced technology cases presented in this thesis are also feasible for small museums. I suggest museums to collaborate for projects where expenses are too high, e.g., acquiring a robot or for machine learning projects that cause high labour costs. Furthermore, when a museum starts a project from scratch, collaboration with a bigger or a digital-savvier museum might be helpful. For example, the DMA worked together with smaller local museums to pass on their knowledge on how to use Big Data analytics. Smaller museums could use open source and for free AI technology to save costs.

There are additional ideas where advanced technologies can be useful for the heritage sector in the future. So far, I didn't find examples of cultural institutions applying those technologies or if so, they only do it to a limited extend.
Chris Michaels, Digital Director of the National Gallery (2017), suggests dynamic pricing as potential tool to sell more exhibition tickets. He argues that currently exhibitions are not sold out, except for blockbuster exhibitions. At peak times, around 11am and at weekends, exhibitions are well-frequented. He asks if dynamic pricing could be used to encourage audience to visit at less favourable times for a lower price. Michaels thinks that price sensitive audience would actively search for and visit at lower price time slots. For monitoring and adapting a dynamic pricing system, advanced analytics would be useful, especially when museums ask themselves 'What happens if…' -questions.

Michaels (2017) exemplifies: "What happens if we move it up by £1? What happens if we halve the price? What happens if we double it?" With advanced analytics and the previously described dashboards it would be possible for a heritage institution to try out questions like these. With regards to pricing, Michaels purports the cultural sector could furthermore learn from digital companies like Netflix or Amazon and their monthly based subscription model which is more flexible compared to the annual membership program of museums. Such a model would force museums to constantly think about how they can remain relevant for their audience. In this scenario, it is important to have access to real-time visitor data for the analysis.

Machine learning algorithms offer a huge potential for marketing purposes. For example, Imprompdo is a planning app, developed by the University of Cardiff. The app reminds the user to start or complete tasks at the most effective moment in order to prevent procrastination. The algorithm learns about behavioural patterns of the user (Appypie, 2018). Such machine learning techniques could be used when approaching a museum visitor to renew a membership or to inform about a new exhibition (Nesta, 2017). If this approach happens at an ideal moment for the museum visitor, a positive response is more likely than via an impersonalised approach (idem).

The conducted research has limitations. For further research it is recommended to gain more insights on how visitors perceive the advanced technology used in the frontend, for instance, with further visitor observations, questionnaires and focus groups. Especially for robot technology as seen at the Van Abbemuseum and with robot Pepper. Moreover, opportunities for further research could be in the field of ticket pricing, visitor prediction and marketing purposes as there were currently no projects found where advanced technology was used for those areas.

I support the idea of a future where a collaboration between human and machine will help mankind to unleash its full potential (Future of Life Institute, 2017). In 2016, AlphaGo, an AI program for playing the Chinese strategic board game Go, defeated the top global Go players. In so doing, the AI used a decisive, unorthodox move that no human player would have made. Ke Jie, (2016, quoted in Tegmark, 2018) one of the best Go players in the world, commented afterwards:

> *"Humanity has played Go for thousands of years, and yet, as AI has shown us, we have not yet even scratched the surface… The union of human and computer players will usher in a new era… Together, man and AI can find the truth of Go."*

It is unclear what the future will bring, but AI in specific has the potential to impact our society, economy and the way we work, shop or consume. Museums need to define their role in those changing environments and if a museum's function is to reflect society, then there is a need to embrace the new technology and to provide the audience with innovative experiences (Parry, 2019).

Like in the mentioned Go anecdote, the unleashing power of advanced technology could open up new, creative possibilities for the heritage sector. For this, a curious, open mindset, as well as a sceptical view on possible threats will be needed. Generally speaking, technology cannot be an answer to a problem but used correctly, it can be a tool in helping to solve an issue (e.g. how to increase visitor numbers and increasing a museum's social, educational, economical and artistical benefit). But understanding the technological possibilities should not be part of the Digital/IT department solely. Instead it is important for museum employees throughout to have a basic understanding to see the opportunities that advanced technology can bring to their specific field. However, purely embracing the advanced technology is not enough. As discussed in the previous chapter, the disruptive nature of Artificial Intelligence, in specific, requires debates and decisions about fundamental questions. The most important ones: in which world do we want to live in? And how can we use AI to achieve that? Museums should be on the forefront to inform and to provide a forum for those discussions. What better way could there be for heritage organisations to stay relevant to society and to help bringing the debate about the future to a wider public? With this regard, I want to end with a quote by Rodney Harrison (2013, p.4):

Thinking of heritage as a creative engagement with the past in the present focuses our attention on our ability to take an active and informed role in the production of our own 'tomorrow'.

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