Troubleshoot?

A Global Mapping of AI in Museums

Isabel Hufschmidt

This paper introduces a global mapping on the use of artificial intelligence in museums. It was conducted in collaboration with students on the master's program in Expanded Museum Studies at the University of Applied Arts Vienna as part of the seminar 'Troubleshoot? AI in the Museum' in the winter semester of 2022–23. In connection with the German network AI & Museums at the Badisches Landesmuseum, Karlsruhe, the results of the mapping led to a WikiProject in the attempt to create a first comprehensive visualization of data on AI in museums worldwide.[1]

The seminar took its cue from a central research question: What are the motivations, contexts, goals, and challenges surrounding the use of AI in museums? In this regard, its title highlights a fundamental aspect: troubleshooting denotes proposing solutions to a problem, and above all algorithms—the DNA of AI—function as the instructions that promise solutions. However, in which areas is this applicable in an effective manner, or to what degree can AI be relevant and offer solutions? What kind of issues lead up to AI-assisted troubleshooting? Does AI possibly also give rise to new 'troubles'?

The mapping not least aims to help assess the relevance and development prospects of AI in the museum sector, both from a global perspective and on a comparative basis. It thus facilitates the evaluation of how AI as a tool in museums has evolved to date and may unfold in coming years and decades. The mapping explores different areas of application for AI technology in museum work processes and contexts, including collection management, exhibition planning, research, conservation, networking, facility management and security, education, outreach, language, visitor service, and visitor experience. The comparative approach to the various countries and regions took into account the relevant geopolitical and economic dispositions as well as the different types of museums and possible ethical implications.

In what follows, this paper provides a representative snapshot of the current state of research, thus painting a sample picture of AI roll-out in museums world-

1 https://www.wikidata.org/wiki/Wikidata:WikiProject_Museum_AI_projects.

wide. This review of research from the field was the starting point for the seminar to comprehensively compile data and cases regarding the way AI is being deployed in museums the world over. An outline of the extensive mapping that was then conducted for each continent will add to this presentation of research. The concluding summary evaluates the results of the mapping based on the following questions: Is a certain type of museum a forerunner with respect to AI? Is there an operational area in which the use of AI occurs proportionately quite frequently? Which region dominates, in other words, which region or country currently leads in the field of AI in museums, if it is possible to speak of dominance or leadership in the first place? What are the similarities in the global overview, and what are the differences?

State of Research: AI in the Museum Today

The seminar was devoted to the most recent developments featuring AI in the museum sector internationally, but with regard to the historical evolution as well. To this end, three research initiatives that have been intensively dedicated to the field of AI in museums since 2020 and focus on regional and international networks were chosen as pivotal points: LiviaAI,[2] University for Continuing Education, Krems, Austria; The Museums + AI Network,[3] Goldsmiths, University of London, in cooperation with the Pratt Institute, New York; AI & Museums, Badisches Landesmuseum, Karlsruhe, Germany. The latter two gave rise to the *AI Toolkit* publication (Murphy/Villaespesa et al. 2020–2) which offers an introduction to AI applications for museums, case studies, and a first overview of AI initiatives. Elena Villaespesa, based at the Pratt Institute, New York, and project head of The Museums + AI Network, has created a corresponding List of Artificial Intelligence (AI) Initiatives in Museums, available online.[4]

An additional survey of pertinent research literature, selected mainly from the last three years, helped to identify the various areas in which AI is used in the museum sector, but simultaneously also reflects the international spread of AI in the museum world as well as the research interest globally. In this context, research contributions from China, Italy, Korea, and the United States, among others, address the heterogeneous fields of deployment in an exemplary manner. They represent both pilot experiments and actual implementations in the field. The authors, researchers, and developers, based at universities and research institutions, come from a wide range of disciplines such as computer science, programming, behavioural and cognitive science, linguistics and literary studies,

2 https://themuseumsai.network (all URLs here accessed in June 2023).

3 https://livia-ai.github.io.

4 https://www.artsmetrics.com/en/list-of-artificial-intelligence-ai-initiatives-in-museums/.

neuroscience, physics, mathematics, industrial and civil engineering, industrial design, art history, cultural studies, educational and social sciences, media studies, and archaeology.

Figure 1: DALL·E / OpenAI; prompt by Claudia Larcher, 2023.

Topics include the use of AI for exhibition scheduling (Lee/Lin 2010), camera placement (Li 2013), security systems (Garzia 2022), conservation concepts (La Russa/Santagati 2021), acoustic comfort in exhibition spaces (D'Orazio/Montoschi et al. 2020), visitor tracking (Onofri/Corbetta 2022), visitor flow management (Centorrino/Corbetta et al. 2021), predictive analysis of tourist flows (Gao 2021), routing (Hsieh 2017) and route planning (Xu/Guo et al. 2021) for visitors, and even the creation of attractive branding (Chiou/Wang 2018) and deepfake presentations (Mihailova 2021). In many cases, the papers provide insights into and information on the development and training of different types of algorithms intended to improve processes at various operational levels in museums, including curatorial and conservation practices, database management, collection tagging, facility management, security and surveillance, PR work, marketing, and presentation strategies. Particularly intriguing is the interest in AI-based research and analysis, often in connection with visitor services. This includes data collection via automated

counting and tracking, with the aim to predict visitor behaviour and thus improve assistance with information, to personalize tours through the museum space, and, in turn, to optimize educational benefits. Various AI technologies and AI-powered devices and applications are utilized here for the different purposes. To mention a few, natural language processing (NLP), computer vision, data mining, machine learning, deep learning, and neural networks in the context of a transition to a sort of self-administration in work processes and within the exploration and experience of the museum all play a central role here.

Mapping

The following sections summarize the results of the mapping by continent. Case studies illustrate in which contexts and areas AI is already being used and experimented with in museums, how widespread, short- or long-term the use in the region is, and whether national AI strategies play a role. Details of the examples mentioned and a comprehensive picture of AI deployments can be viewed in the WikiProject, which indexes: the respective AI technology used by each museum and/or related institution; the context and/or type of implementation; the development companies involved; the date of launch and/or run period; and bibliographical sources and links.

To compile data, in addition to the literature that had already been surveyed, a multilingual internet keyword search was carried out, primarily in English and, when possible, the respective national languages. This led to further literature, press releases, online sources, and websites of museums and other institutions with corresponding references to projects involving and implementing AI in museums. Based on this quantitative data collection, the countries and regions were evaluated qualitatively with respect to goals and challenges, as will be outlined below and in the concluding summary based on the abovementioned core questions.

Africa

The development of AI in the museum sector will be determined in African countries[5] over the coming years. The key questions are: Does AI provide agency for the continent's emancipation in the wake of a Pan-African movement? Does AI add to this empowering path for African societies to underscore their rejection of allowing the museum to continue to play out its Western and primarily colonial hege-

5 The cases mentioned with regard to North Africa and Sub-Saharan Africa are partially taken from the research conducted by Manon Fougère (master's student, Expanded Museum Studies) in the context of the mapping.

mony? With the annual conferences PA-AI&SS,[6] since 2021 in Namibia, Senegal, and Ethiopia, as well as PanAfriCon,[7] held in Addis Ababa since 2021, AI is being made a priority subject in the realm of a Pan-African vision. In this context, Ethiopia, with the strong support of Chinese investors (N.d.-b 2022), is already emerging as a hot spot for science and technology and for the digital transformation of the continent. The institutions playing a major role in this process are the Museum of Art and Science in Addis Ababa, opened in 2022 on the occasion of the PanAfriCon, and the Ethiopian Artificial Intelligence Institute (EAII).[8]

The use of virtual reality and digitization can already be seen across the board (Alexandria National Museum, Egypt; El Jem Museum, El Djem, Tunisia; Pan African Heritage Museum, Winneba, Ghana; National Museum of the Democratic Republic of Congo, Kinshasa). However, examples of genuine AI applications in museums on the African continent are currently still limited to a few specific cases. In North Africa, the Grand Egyptian Museum in Cairo used AI for automated decision-making in 2018 in order to safely erect a colossal statue of Ramses II. To this end, a 3D model of the statue was created, and the installation simulated on it. The AI was also used to determine the optimal location for the statue in the museum.[9]

In Sub-Saharan Africa, Looty, launched in 2022, stands out against the backdrop of decolonial emancipation through new technologies. Chidi Nwaubani, the founder of Looty, uses the tokenization of African objects in Western collections to draw attention to the fact that most African cultural heritage is located outside the continent (Tattoli 2023; Charr 2022). Nwaubani's aim is to reclaim African cultural heritage. As part of this, members of the Looty team create 3D scans of artifacts held in Western museums. These scans are then converted into NFTs that can be purchased for the benefit of African artists. In recent press coverage, Nwaubani 'declare[d] his project as an alternative form of repatriation, by which digital technologies are used to reclaim a measure of control and ownership over artifacts still held far from Africa' (Ukomadu/Shirbon 2022).

Asia

A unique feature shared by China and Korea are state initiatives to establish smart museums, in other words, the process of 'smartifying' existing museums, and building new museums in line with 'smartification'. These overall concepts include, for instance, the use of AI embracing the actual construction of the museum, collection research, management, branding, marketing, visitor support, exhibition displays,

6 https://paaiss.com.

7 https://panafriconai.org.

8 http://www.aii.et.

9 https://redshift.autodesk.com/articles/grand-egyptian-museum.

the creation of exhibits, and the combination with virtual and augmented reality. In China, the Smart Museum Pilot Initiative, which was launched by the State Administration of Cultural Heritage (SACH) in 2014, covers a total of six museums, including the Inner Mongolia Museum, Gansu Museum, Guangdong Museum, Suzhou Museum, Jinsha Site Museum in Sichuan, and Emperor Qinshihuang's Mausoleum Site Park in Shaanxi Province (Minyo/Yang 2016; Wang/Duan et al. 2023). In 2018–19, Korea launched a five-year Smart Museum Program, which supports the transformation of 86 public and 18 private institutions into smart museums and also includes the construction of new museums (Kim 2021). The flagship project in this scheme is the National Museum of Korea in Seoul.

A significant role similar to that of the Smart Museum is played by robotics, since this field is also prominently represented particularly in Japan and Korea (Morita 2022), not least in the museum sector. Worth mentioning here are the Mitsubishi Ichigokan Museum and the Miraikan: National Museum of Emerging Science and Innovation in Tokyo, the Ohara Museum of Art in Kurashiki, as well as the Ewha Womans University Museum in Seoul. That said, this is simultaneously a thoroughly international phenomenon. Robots are used not only to support the visitor service as tour guides. The new Robot Science Museum in Korea, for instance, is to be constructed solely by robots, based on plans by Melike Altınışık Architects from Istanbul. Actually, the use of robotics in museums dates back to the 1990s, among others in the form of *Rhino*, one of the first robot museum tour guides, at the Deutsches Museum in Bonn, Germany (Königs 2017). Since 2014, *Pepper*, a so-called telepresence robot developed by the French company Aldebaran (part of the German United Robotics Group since 2022) has made a particularly prominent appearance (Tyagi 2021). *Pepper* is used in museums worldwide and impresses with its multilingualism, including Swahili. Before the Smithsonian, for example, began using *Pepper* in 2018 to improve its visitor experience, it had as long ago as 1998 introduced AI-supported robotics in museum operations with the short-term experimental use of a tour robot called *Minerva* (Thrun/Beetz et al. 2000). An essential aim of, partly humanoid, robotics with human robot interaction (HRI) is to provide knowledge representation, powered mostly by natural language processing. This facilitates dialogical access for visitors and content-related support, among other things, with respect to historical and collection-specific information supplied during tours of the museum. Robots as so-called docent guides are not least intended to support museum staff with visitor services, and increase educational benefits by offering an enhanced experience.

In Southeast Asia,[10] the role of AI in the preservation of cultural heritage is emerging alongside the optimization of visitor experience. Singapore is particularly prominent in this regard. The Y-Lab, launched at the National Gallery in 2021, is developing various AI applications paired with mixed reality for improved storytelling and thus enhancing the museum experience.[11] Thailand, like China and Korea, has been focussing on a Smart Museum Initiative since 2017, which includes the National Museum of Bangkok (Read 2017). AI adoption is, however, not unique to the capital. The Museum of Art and Culture of Loei is working with AI in the field of character recognition to digitize ancient manuscripts (Puarungroj/Boonsirisumpun et al. 2019). Not far away, in Vietnam, the Southern Women's Museum in Ho Chi Minh City has dedicated itself to providing a personalized museum experience since 2018 through the Bao Tang PNNB mobile app, which facilitates customized museum tours and supplies information on collection objects (My 2018).

South and Central Asia[12] show no less interest in the use of AI in the museum sector. Noteworthy here are recent developments for smart navigation in visitor routing (Dir Museum Chakdara, Pakistan) (Khan/Rahman et al. 2022), or HRI via tour robots (Nur Alem Museum of Future Energy, Astana, Kazakhstan). This is complemented by research on museum collections, such as the INTERWOVEN[13] project on the website of the Museum of Art & Photography in Bengaluru, India, launched in 2022 in collaboration with Microsoft. Machine learning, computer vision, and text analysis serve here to connect and search textile collections worldwide. Another project is Magnify Miniatures at the National Museum of New Delhi, which aims to find similarities between paintings, enabled by machine learning.[14] The project started in 2020 in cooperation with Google. Farther north, Uzbekistan, too, offers a distinctive feature in terms of AI, namely the country's first smart museum in Samarkand, which has provided a mobile tour guide and AR since opening in 2019 (N.d.-a 2019).

The Middle East and the Arabian Peninsula are also home to avant-garde uses of AI, among other things: The architecture of Dubai's Museum of the Future, which opened in 2021, was created based on algorithms, executed by Killa Design, Dubai (Montjoy 2022). The museum also relies on the use of robotics for visitor assistance.

10 The cases mentioned with regard to Southeast Asia are partially taken from the research conducted by Katharina Enzinger (master's student, Expanded Museum Studies) in the context of the mapping.

11 https://ylab.sg.

12 The cases mentioned with regard to Central and South Asia, the Middle East, and the Arabian Peninsula, are partially taken from the research conducted by Samira Plunger (master's student, Expanded Museum Studies) in the context of the mapping.

13 https://interwoven.map-india.org.

14 https://artsexperiments.withgoogle.com/magnify-miniatures/.

Starting this year, in 2023, the National Museum of Qatar in Doha has applied Microsoft's NMoQ Explorer, a knowledge mining tool, on its website to map epochs and objects in relation to each other.[15] In Israel, the Yaacov Agam Museum of Art in Rishon LeZion has been offering *TIMA*, an AI-powered guide that can be downloaded on tablets and smartphones, since 2020.[16] With respect to preservation, since 2021 in Turkey,[17] the Museum of Anatolian Civilization in Ankara, the Istanbul Archaeological Museum, and the Çorum Archaeological Museum have been pursuing AI-supported documentation and translation of Hittite tablets by applying NLP and automated reasoning in order to make them accessible for further research (Keskin 2023). Even earlier, as of 2017, the Ministry of Culture and Tourism supported the development of the AI-powered database MUES (Museum National Inventory System), which uses deep learning to optimize the storage and processing of data, as well as tagging. Its purpose is also to facilitate the detection of smuggling and counterfeit artifacts.[18]

In 2021, Turkey also published its National Artificial Intelligence Strategy[19] with six strategic priorities: '1) Training AI Experts and Increasing Employment in the Domain 2) Supporting Research, Entrepreneurship and Innovation 3) Facilitating Access to Quality Data and Technical Infrastructure 4) Regulating to Accelerate Socioeconomic Adaptation 5) Strengthening International Cooperation 6) Accelerating Structural and Labor Transformation.'[20]

This leads us to neighbouring Russia. There, too, we occasionally find AI applications in the museum sector, including AI-powered digitization of archival data using ABBYY (Bolshoi Theatre Museum, Moscow), a 3D reconstruction of St. Basil's Cathedral via scanner drones (Federal History Museum, Moscow), and overall AI deployments for interactive experience (in planning: Kamchatka National Nature Preservation Museum). In 2019, Vladimir Putin presented a National AI Strategy at the AI Journey conference in Moscow. In this context, AI was defined in general as: 'a collection of technological solutions that allow one to simulate human cognitive processes (including self-learning and the search for solutions without using a previously-supplied algorithm) and to get results, when accomplishing concrete tasks, that are at least comparable with those of the human intellect' (Nocetti 2020, 19). In

15 https://news.microsoft.com/en-xm/2023/03/28/the-national-museum-of-qatar-in-partnership-with-microsoft-launches-nmoq-explorer/#:~:text=The%20NMoQ%20Explorer%20is%20an,the%20National%20Museum%20of%20Qatar.

16 https://www.tima-online.com/index_de.html?v=0.05.

17 The cases mentioned with regard to Turkey and Russia are partially taken from the research conducted by Charlotte Fuchs-Robetin (master's student, Expanded Museum Studies) in the context of the mapping.

18 https://b3lab.org/en/sayfa/mues_museum_national_inventory_system_project-32.

19 https://cbddo.gov.tr/SharedFolderServer/Genel/File/TRNationalAIStrategy2021-2025.pdf.

20 https://cbddo.gov.tr/en/nais.

the race for leadership in AI, investment, networking and connections to the international community are decisive, but Russia's access to them is not least at risk due to growing military conflicts (Nocetti 2020). Moreover, AI development in Russia is in the hands of a state-owned bank (Petrella/Miller et al. 2021). One should underestimate neither to what extent AI is key in the competition for geopolitical relevance nor how this may be misdirected towards military armament instead of fostering social and educational objectives.

The Americas

North America, especially the United States, has a high profile in the field of AI, not least due to the major players in the industry that are based there, such as Microsoft, IBM, Google, or the Massachusetts Institute of Technology (MIT), which continue to dominate the development of applications and software worldwide. Google Arts & Culture, which facilitates virtual tours of museums and has gained in significance since 2020 (especially during the pandemic) is used in museums around the globe. When it comes to AI, major players in the museum scene are active, such as the Smithsonian, the Museum of Modern Art (MoMA), The Metropolitan Museum of Art (The Met), the Harvard Art Museums, or the Art Institute of Chicago. In general, AI in US museums is used to personalize the museum experience, improve collection research, and evaluate operational structures. There is, however, even more. Since 2019, the Dalí Museum in Saint Petersburg, Florida, has already been using a deepfake—of the artist Salvador Dalí—to enhance the museum experience. In 2018, the National Soccer Hall of Fame in San Francisco implemented facial recognition and automated planning via an AI-powered touchscreen at the entrance to the exhibition space that serves to personalize museum visits.[21] The East and West coasts have the country in their grip when it comes to AI. A bit further inland, AI has also long since been deployed in everyday museum life, with chatbots as a popular format (Akron Art Museum, Ohio; Field Museum, Chicago; Carnegie Museum, Pittsburgh). In neighbouring Canada, the Ontario Regiment Museum caused a sensation in terms of innovations in visitor service and dialogue with its AI-based virtual humanoid chatbot *Corporal Lana*, which launched in 2020.[22] This is comparable to the use of virtual chatbot *Ophelia*, released the same year, at two other Canadian museums: the Canadian Science and Technology Museum in Ottawa and the Canadian Museum for Human Rights in Winnipeg. The country is already committed to the long-term use of AI, and, unlike its neighbour, has a national AI strategy, the Pan-Canadian AI Strategy, published in 2017 by the Canadian Institute for Advanced Research (CIFAR),

21 https://www.nationalsoccerhof.com/visit/experience.html.

22 https://www.intel.com/content/www/us/en/customer-spotlight/stories/ontario-regiment-museum-customer-story.html.

with the core objectives of educating and developing 'global thought leadership on the economic, ethical, policy and legal implications of advances in AI'.[23] National AI strategies, such as those of Turkey, Russia, or Canada, all raise the question of the extent to which museums play a clear role in them. Museums do not seem to be explicitly mentioned. Yet, the mapping reveals how museums benefit from the various fields involved in the development of AI when it comes to experimenting with and adjusting work processes, visitor and educational services.

Not to be underestimated are AI deployments in the regions of Central and South America,[24] which are quite intriguing and revealing in terms of innovations. AI is being widely used with a specific focus on the museum experience as well as on personalized visitor services with educational benefits. This includes not only chatbots and equivalent conversational mobile apps and guides (*IRIS+*, Museo de Amanhã, Rio de Janeiro; *Bio-Cosmos*, Museo de Arte Moderno de Buenos Aires; *A Voz da Arte*, Pinacoteca de São Paulo; Museo Nacional de Antropologia, Mexico City), but also a variety of research and implementations involving machine learning, computer vision, and neural networks, for instance. Of particular interest is robotics or rather HRI in museums. In this area, the production and implementation of the tour robot *Pablo Bot* in Lima since 2022, introduced by San Pablo Catholic University's Mechatronics Engineering School, and based on *Pepper's* blueprint by SoftBank Robotics, is geared towards spurring its widespread distribution in museums throughout South America (Marina 2022). Similarly, in Peru, the Museo de La Recoleta in Arequipa has collaborated on the implementation of tour robots with sensor-based object detection and convolutional neural networks (CNN) (Tejada-Mesias/Dongo 2019). Worth noting as well is the Museu Paulista in São Paulo. In cooperation with the *demonumenta* project at the School of Architecture and Urbanism of the University of São Paulo (FAUUSP), it welcomed computer vision and machine learning experiments focussed on datasets to analyse normativities and colonialist continuums in art historical narratives and collections (Moreschi/Jurno et al. 2022).

Australia

Australia, New Zealand, and Oceania[25] are a busy hot spot in terms of the use of AI in museums, especially with their interactive and personalized museum experiences

23 https://cifar.ca/ai/#:~:text=Our%20vision%20is%20that%20by,positive%20social%2C%20economic%20and%20environmental.

24 The cases mentioned with regard to Central and South America are partially taken from the research conducted by Samira Plunger (master's student, Expanded Museum Studies) in the context of the mapping.

25 The cases mentioned with regard to Australia, New Zealand, and Oceania are partially taken from the research conducted by Konstantina Hornek (master's student, Expanded Museum Studies) in the context of the mapping.

in the context of optimized storytelling. For more than a decade now, this has involved mobile apps and NLP-powered chatbots, partly equipped with recommender systems, such as at the Museum of Old and New Art in Tasmania, the Auckland Art Gallery, the Auckland War Memorial Museum, and the Museum of Australian Democracy in Canberra. With its NLP-powered interactive installation *Dimensions in Testimony*, launched in 2021, the Jewish Museum in Sydney has provided visitors with the possibility to converse with virtual twins of Holocaust survivors. In terms of collection management, the Serjeant Gallery in Whanganui, New Zealand, has been using automated tagging in their online collection via Google Vision API and NLP since 2017.

Especially outstanding is Dexibit, founded by Angie Judge in Auckland in 2015, as an internationally successful company that 'exports' AI. It provides museums with solutions for visitor analytics, including automated visitor counting and tracking, so as to enhance operational structures through prediction models for the improvement of visitor experience and services. No less exceptionally, the University of Melbourne and the Australian Centre for the Moving Image (ACMI) have been collaborating in an equally innovative way since 2018 on creating a dynamic web application that geo-visualizes museum soft power.[26]

Processing the history of injustices against the Indigenous populations of Australia, New Zealand, and Oceania, which goes hand in hand with the research and documentation of the relevant holdings in collections in local museums, is a particular field in which AI is now also being integrated. The Indigenous cultural heritage has thus been addressed in the context of AI-supported research. In this area, the University of Auckland started a project in 2021 on the analysis of Māori stone artifacts using classifiers, computational modelling, and machine learning.[27] The Otago Museum in Dunedin, New Zealand, is involved as cooperation partner.

Europe

The use of AI in museums of in Northern, Central, Western, Southern, and Eastern Europe differs significantly in terms of type and spread. Chatbots are particularly popular in Germany, France, Italy, and the Netherlands. Their application has been widespread in museum operations since around 2004 (Kölbl n.d.). Chatbots support visitor services as well as the visitor experience, among other things, mostly via mobile applications for visitors' smartphones or tablets. Powered by NLP and machine learning, they communicate relevant information about the venue and the exhibition, and may at some point even provide personalized recommendations. In some

26 https://arts.unimelb.edu.au/research/digital-studio/projects/deep-mapping.

27 https://www.auckland.ac.nz/en/news/2021/09/20/using-technologies-of-the-future-to-piece-together-the-past.html.

cases, this is accompanied by a game feature in the form of a treasure hunt through the museum, as, for example, in several museums in Milan (Casa Museo Boschi di Stefano, Museo Bagatti Valsecchi, Museo Poldi Pezzoli, and Villa Necchi Campiglio). There is also experimentation with the use of robotics; but apart from the HRI export success *Pepper*, permanent implementations such as in Japan or Korea are quite rare. One example of long-term use is, however, represented by a standalone version of the telepresence tour robot *Virgil* at the Castello di Racconigi, Italy (Lupetti/Germak et al. 2015).

Furthermore, in Central Europe, the use of AI for collection documentation, research, and conservation as well as general operational structures such as facility management has been part of various experimental short-term applications and projects, including the use of neural networks and machine learning (*Operation Night Watch*, Rijksmuseum, Amsterdam, Netherlands, 2021[28]; *Klimt vs. Klimt*, Belvedere, Vienna, Austria, 2021; *Building Whisperer*, Louvre, Paris, France, 2012; *INSIGHT*, Royal Museums of Fine Arts of Belgium[29]). In terms of inclusion, the Abbey Museum of the Dunes in Koksijde, Belgium, provides AI-supported virtual reality created especially for visually impaired visitors.[30] With a view to research, various projects on the topic of AI-supported museum work are located in Europe, too (LiviaAI, Krems, Austria, 2021–2; AI & Museum, Karlsruhe, Germany, 2021–3; 'intelligent.museum', ZKM, Karlsruhe, Germany, 2020–24).

Northern Europe[31] is particularly involved in AI-assisted crosslinking and research of museum collections (*Kratt Sälli*, Estonia, 2020–21[32]; *SMK Open*, National Gallery of Denmark, Copenhagen, 2016–20[33]). In Eastern Europe,[34] the use of AI takes place, for instance, in the context of historical memory and current war events. Examples include the 2019 installation *Reflection: I am like you, surely* with AI-powered mirrors equipped with facial recognition at the Warsaw Rising Museum, Poland, or the 2022 exhibition *Save Ukr(AI)ne*, at the Ukrainian House in Kyiv, showing AI-generated images. Moreover, knowledge representation and NLP are combined in the form of smart tour guides that help visitors to navigate through exhibitions, including the chatbot of the National Art Museum of the Republic of Belarus in Minsk,

28 https://www.rijksmuseum.nl/en/whats-on/exhibitions/operation-night-watch.

29 https://hosting.uantwerpen.be/insight/.

30 https://alfavision.be/project/abbey-museum-dunes.

31 The cases mentioned with regard to Northern Europe are partially taken from the research conducted by Katharina Enzinger (master's student, Expanded Museum Studies) in the context of the mapping.

32 https://stacc.ee/stacc-help-the-national-heritage-board-using-artificial-intelligence/.

33 https://www.smk.dk/en/article/smk-open/.

34 The cases mentioned with regard to Eastern Europe are partially taken from the research conducted by Manon Fougère (master's student, Expanded Museum Studies) in the context of the mapping.

which was launched in 2016, or the humanoid *Robo Copernicus*, recently introduced at the Copernicus Science Center, Warsaw, Poland, in 2023.

Summary

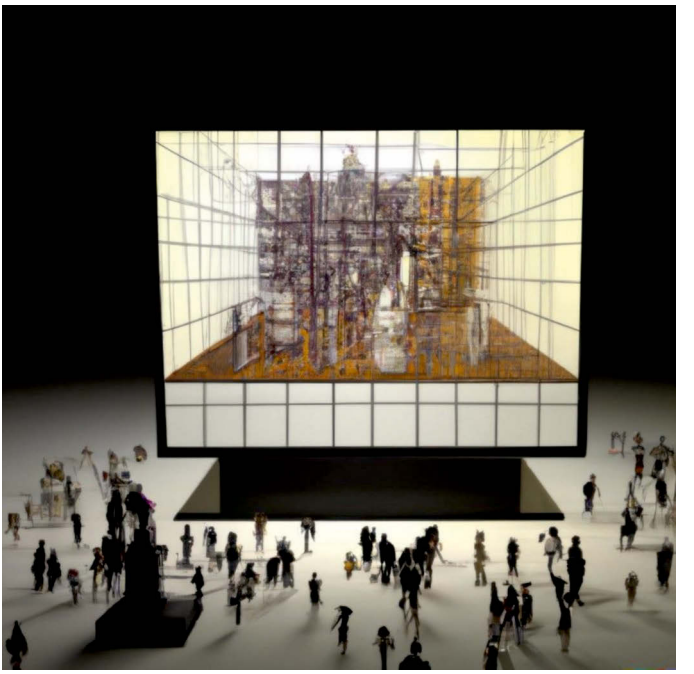
The mapping as conducted provides a first global overview of AI deployment in the museum sector. Its result is unmistakable: the utilization of AI is an ongoing and not to be underestimated trend in the museum scene internationally. Thus turning to the questions previously articulated: Is a certain type of museum particularly involved in the use of AI? Art museums and cultural history and/or historical museums as well as musealized cultural heritage sites seem to be at the forefront. Typologically, the picture is nevertheless quite heterogeneous on the global level, in that museums of natural history, archaeology, technology and science are also represented in a variety of ways. In addition, there are several types of thematic museums, be they, for instance, dedicated to sports or military history.

Which operational context is affected proportionally often when it comes to the implementation of AI? The focus on visitor services and improving the visitor experience in the sense of optimizing educational benefits essentially forms the baseline, but also goes hand in hand with applications for collection research and management systems for museum operations, including overarching initiatives aiming at the preservation of cultural assets.

Is there a region or country that dominates the field? Here, it is important to distinguish between quantitative and qualitative use of AI in museums and/or research. This means that in addition to actual implementation and experimentation with AI, pioneering developments that also have an international impact or are geared towards international distribution play an important role in the significance of a particular country or region. In terms of publicity and the backing of relevant development companies, the United States continues to be the international benchmark for AI development. Nevertheless, China, Japan, and Korea lead the way with their applications, research, analysis, smart museum initiatives, and robotics, particularly through the overall conceptual and long-term implementation of AI. By contrast, Australia is in a league of its own in that Dexibit has emerged as an innovative big player in AI for predictive analysis tools in museums worldwide. This means that the countries and regions that are pursuing overarching and internationally influential solutions, applications, and research are ahead of the game when it comes to AI. This is also evident in the field of robotics with the tour guide *Pepper*, for instance, and similar creations with a humanoid appearance that hold the potential of an even greater reach and long-term implementation of robotics in the museum sector.

The needs and goals are clearly diverse, but there are common red threads. What is supposed to be achieved, and which 'troubles' are supposed to be resolved? Four core areas of application have been identified in particular: visitor services/experience, operational procedures, preservation, and research. The objectives are to optimize management processes, general workflow, and collection care, strengthen networks, improve visitor services, and boost educational benefits through enhanced museum experiences. At the same time, museums barely address possible ethical issues associated with AI deployments.

Figure 2: DALL·E / OpenAI; prompt by Claudia Larcher, 2023.



In many ways, AI has already emerged from the purely experimental and pilot phase and has been implemented in day-to-day operations in both the short and longer term. Whether using it is sustainable and economically efficient still remains to be seen. And, above all, of course, if AI truly embodies essential solutions for museums, it bears remembering that AI may potentially create new 'troubles'. How can they be weighted in comparison with the benefits? Will AI become a self-evident tool in the museum sector? At the same time, it will be crucial to examine whether ethical challenges and conflicts are actively addressed and not simply tolerated in the name of technological progress. For example, in what way may AI threaten to re-

place service and curatorial staff, if we consider popular applications such as chatbots and robots, or neural networks? Or even: In what way may the datasets chosen for the training of the AI lead to the reproduction, in the course of knowledge representation, among other things, of structural racism, colonial ideologies, and gender inequalities?

Museums are not least expected to fulfil a pioneering sociopolitical role as responsible authorities when they get involved in the use of AI and compete to innovate in the field. They must take a stand on a topic that simultaneously both manifests and questions the human factor in a striking way.

References

Centorrino, Pietro/Corbetta, Alessandro et al. (2021). Managing Crowded Museums: Visitors Flow Measurement, Analysis, Modeling, and Optimization. Journal of Computational Science 53. https://doi.org/10.1016/j.jocs.2021.101357.

Charr, Manuel (2022). Looty NFT Project Challenges Museums That Refuse to Return Looted Works. Museumnext.com, 5 May 2022. Available online at https://www.museumnext.com/article/looty-nft-project-challenges-museums-that-refuse-to-return-looted-works/.

Chiou, Shang-Chia/Wang, Yun-Ciao (2018). The Example Application of Genetic Algorithm for the Framework of Cultural and Creative Brand Design in Tamsui Historical Museum. Soft Computing 22 (8), 2527–2545. https://doi.org/10.1007/s00500-017-2507-9.

D'Orazio, Dario/Montoschi, Federico et al. (2020). Acoustic Comfort in Highly Attended Museums: A Dynamical Model. Building and Environment, 183. https://doi.org/10.1016/j.buildenv.2020.107176.

Gao, Yuan (2021). Forecast Model of Perceived Demand of Museum Tourists Based on Neural Network Integration. Neural Computing & Applications 33 (2), 625–35. https://doi.org/10.1007/s00521-020-05012-4.

Garzia, Fabio (2022). The Fellini Museum of Rimini in Italy and the Genetic Algorithms-Based Method to Optimize the Design of an Integrated System Network and Installations. Heritage 5 (2), 1310–29. https://doi.org/10.3390/heritage5020068.

Hsieh, Yi-Chih (2017). An Efficient Encoding Scheme for a New Multiple-Type Museum Visitor Routing Problem with Must-See and Select-See Exhibition Rooms. International Journal of Computational Intelligence Systems 10 (1), 677. https://doi.org/10.2991/ijcis.2017.10.1.45.

Keskin, Buse (2023). Turkish researchers use AI to read cuneatic Hittite tablets. Daily Sabah, 5 January 2023. Available online at https://www.dailysabah.com/arts/turkish-researchers-use-ai-to-read-cuneatic-hittite-tablets/news.

Khan, Muhammad Nawaz/Rahman, Haseeb Ur et al. (2022). An IoT-Enabled Information System for Smart Navigation in Museums. Sensors, 22, no. 1: 312. https://doi.org/10.3390/s22010312.

Kim, Jiwon (2021). Korea's AI·VR Smart Museums in 2021. DataDrivenInvestor, 26 February 2021. Available online at https://www.datadriveninvestor.com/2021/02/26/koreas-ai·vr-smart-museums-in-2021/.

Kölbl, Antonia (n.d.). Talk to me! Chatbots in Museums: A Chronological Overview. Available online at https://zkm.de/en/talk-to-me-chatbots-in-museums.

Königs, Philipp (2017). Roboter im Deutschen Museum Bonn. Rhino schrieb Wissenschaftsgeschichte. Bonner General Anzeiger, 27 February 2017. Available online at https://ga.de/bonn/stadt-bonn/rhino-schrieb-wissenschaftsgeschichte_aid-43250995.

La Russa, Federico Mario/Santagati, Cettina (2021). An AI-Based DSS for Preventive Conservation of Museum Collections in Historic Buildings. Journal of Archaeological Science, Reports 35. https://doi.org/10.1016/j.jasrep.2020.102735.

Lee, Hsin-Yun/Lin, Yu-Cheng (2010). A Decision Support Model for Scheduling Exhibition Projects in Art Museums. Expert Systems with Applications 37 (2), 919–25, https://doi.org/10.1016/j.eswa.2009.03.003.

Li, Shang (2013). Algorithm to Deal with the Problem of Placing Cameras in Museum. Applied Mechanics and Materials, Linear Drives for Industry Applications IX, 416–17. https://doi.org/10.4028/www.scientific.net/AMM.416-417.1404.

Lupetti, Maria/Germak, Claudio et al. (2015). Robots and Cultural Heritage: New Museum Experiences. Electronic Visualisation and the Arts (EVA 2015), 322–29. https://doi.org/10.14236/ewic/eva2015.36.

Marina, Diego Lopez (2022). Meet Pablo Bot, the first robot tour guide from Peru. Perú Reports, 21 July 2022. Available online at https://perureports.com/meet-pablo-bot-the-first-robot-tour-guide-from-peru/9623/.

Merritt, Elizabeth (2023). Chatting About Museums with ChatGPT. Center for the Future of Museums Blog. American Alliance of Museums. 25 January 2023. Available online at https://www.aam-us.org/2023/01/25/chatting-about-museums-with-chatgpt/.

Mihailova, Mihaela (2021). To Dally with Dalí: Deepfake (Inter)faces in the Art Museum. Convergence 27 (4) (London, England), 882–98. https://doi.org/10.1177/13548565211029401.

Minyo, Lucy/Yang, Yunzhen (2016). People First for China's Smart Museums. BOP Consulting, 17 April 2016. Available online at https://bop-consulting.medium.com/people-first-for-china-s-smart-museums-280414bb144.

Montjoy, Valeria (2022). Overcoming Design Challenges with Technology: Museum of the Future in Dubai. Archdaily, 23 June 2022. Available online at https://www.archdaily.com/983458/overcoming-design-challenges-with-technology-museum-of-the-future-in-dubai.

Moreschi, Bruno/Jurno, Amanda et al. (2022). Historical Continuum and Normatization in Art Collections and Datasets: Experiments with Artificial Intelligence at Museu Paulista. MODOS. Journal of Art History. Campinas, SP, v. 6, n. 2, 236–267, May 2022. https://doi.org/10.20396/modos.v6i2.8667715. Available online at https://periodicos.sbu.unicamp.br/ojs/index.php/mod/article/view/8667715.

Morita, Mutsumi (2022). Art Museums Exploiting IT to Attract Visitors. The Japan News. 6 April 2022. Available online at https://japannews.yomiuri.co.jp/culture/art/20220406-18779/.

Moss, Sebastian (2021). Turkey Publishes its National Artificial Intelligence Strategy. AI Business, 8 September 2021. Available online at https://aibusiness.com/verticals/turkey-publishes-its-national-artificial-intelligence-strategy.

Murphy, Oonagh/Villaespesa, Elena et al. (2020/2022). THE MUSEUMS + AI NETWORK. A Museum Planning Toolkit, London. Available online at https://themuseumsai.network/toolkit/.

My, Ha (2018). Vietnamese museum goes hi-tech with 'smart museum' app. Tuoi Tre News, 3 November 2018. Available online at https://tuoitrenews.vn/news/lifestyle/20181103/vietnamese-museum-goes-hitech-with-smart-museum-app/47533.html.

N.d.-a (2019). The First Smart Museum in Central Asia opens in Samarkand. UZDaily, 15 April 2019. Available online at http://www.uzdaily.com/en/post/49185.

N.d.-b (2022). Feature: China-aided science museum wins hearts of science-enthusiast Ethiopians. Xinhuanet.com, 19 November 2022. Available online at http://english.news.cn/20221119/20306acce7ce4d0a90aed208c65311b3/c.html.

Nocetti, Julien (2020). The Outsider: Russia in the Race for Artificial Intelligence. Etudes de l'Ifri 34. Available online at https://www.ifri.org/sites/default/files/atoms/files/nocetti_russia_artificial_intelligence_2020.pdf.

Onofri, Elia/Corbetta, Alessandro (2022). RSSi-Based Visitor Tracking in Museums via Cascaded AI Classifiers and Coloured Graph Representations. Collective Dynamics 6, 1–17. https://doi.org/10.17815/CD.2021.131.

Petrella, Stephanie/Miller, Chris et al. (2021). Russia's Artificial Intelligence Strategy: The Role of State-Owned Firms. Orbis 65 (1), 75–100. https://doi.org/10.1016/j.orbis.2020.11.004.

Puarungroj, Wichai/Boonsirisumpun, Narong et al. (2020). Using Deep Learning to Recognize Handwritten Thai Noi Characters in Ancient Palm Leaf Manuscripts. In: Digital Libraries at Times of Massive Societal Transition: 22nd International Conference on Asia-Pacific Digital Libraries, ICADL 2020, Kyoto, Japan, 30 November–1 December 2020, Proceedings. Berlin, Heidelberg, Springer-Verlag, 232–239. https://doi.org/10.1007/978-3-030-64452-9_20.

Read, Charles (2017). Thailand launches major 'smart museum' initiative to put nation's historic collections online. Blooloop, 6 October 2017. Available online at https://blooloop.com/museum/news/bangkok-smart-museum/.

Tattoli, Chantel (2023). A High-Tech Heist at the British Museum. The New Yorker, 17 April 2023. Available online at https://www.newyorker.com/magazine/2023/04/24/a-high-tech-heist-at-the-british-museum.

Tejada-Mesias, Alejandro/Dongo, Irvin et al. (2021). ODROM: Object Detection and Recognition Supported by Ontologies and Applied to Museums. 2021 XLVII Latin American Computing Conference (CLEI), October 2021, Cartago, Costa Rica, 1–10. https://doi.org/10.1109/CLEI53233.2021.9639989.

Thrun, Sebastian/Beetz, Michael et al. (2000). Probabilistic Algorithms and the Interactive Museum Tour-Guide Robot Minerva. Journal of Robotics Research 19, 972–99. https://doi.org/10.1177/02783640022067922.

Tyagi, Riya (2021). The Landscape of AI & Robotic Guides in Museums & Cultural Places. Aldebaran: United Robotics Group, 31 May 2021. Available online at https://www.aldebaran.com/en/blog/news-trends/landscape-ai-robotic-guides-museums-cultural-places.

Ukomadu, Angela/Shirbon, Estelle (2022). 'Looty' Project Launches Digital Art Heists to Reclaim African Artifacts. Reuters, 24 May 2022. Available online at https://www.reuters.com/world/africa/looty-project-launches-digital-art-heists-reclaim-african-artifacts-2022-05-24/.

Wang, Siyi/Duan, Yong et al. (2023). 'Smart Museum' in China: From Technology Labs to Sustainable Knowledgescapes. Digital Scholarship in the Humanities. https://doi.org/10.1093/llc/fqac097.

Xu, Yuhan/Guo, Qing et al. (2021). Multi-Objective Route Planning of Museum Guide Based on an Improved NSGA-II Algorithm. Journal of Physics. Conference Series 1828 (1), 12051. https://doi.org/10.1088/1742-6596/1828/1/012051.