Four Ways to Experience Augmented Reality at Museums

Jakob Ossmann, Kasra Seirafi, Carina Doppler

Abstract: Augmented reality (AR) is a prevalent topic in the museum space as it promises to bridge the gap between the physical exhibition space and digitised information. The present paper introduces a framework of four distinct experience-based categories that outline which kind of AR applications are possible inside the museum: 1) object annotation, 2) object visualisation, 3) guiding, and 4) data visualisation.

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1. Potential of Augmented Reality for museum mediation

During the last decade, Augmented Reality (AR) has been one of the most hyped technologies within and beyond the museum world. Recently AR has exited the prestigious Gartner Hype Cycle, a regularly updated graph that visualises the impact of the latest technology trends on their potential to solve business problems (Gartner 2021). The exit makes industry experts argue that the AR has reached maturity as an operational production tool (Herdina 2021).

AR, which can be defined as real-time interaction of real-world objects with digital 3D content (Azuma 1997), offers unprecedented possibilities especially for inspiring visitor experiences as well as cultural and science learning by bridging the divide between physical exhibitions and digital information. Where in the 1990s digital media and especially the Web were regarded as "parallel space," today this dichotomy does not hold true anymore. Current theoretical concepts instead highlight that the digital and physical space have become intertwined. Tim O'Reilly and John Battelle described the Internet that emerged from the dotcom crash as a decentralised "Web Squared" platform that is built on collective user interaction as opposed to being a one-way publishing tool (O'Reilly and Batelle 2009). More specifically, Eric Gordon and Adriana de Souza e Silva introduced the concept of "Net Locality" by arguing that new technology tools connect individuals to their surroundings and their community instead of creating detached parallel virtual worlds (Gordon and de Souza e Silva 2011). The physical and the digital museum should therefore also not be regarded as separated anymore but need to be designed and conceptualised as an integrated, holistic visitor and learning experience.

Research has already highlighted AR as a powerful tool to bridge the divide between physical and digital as it proves to be a reliable medium for learning due to its knowledge transfer capabilities by creating a state of immersion that makes individuals more accessible to new stimuli (Georgiou 2018). For example, while consuming learning content about a museum exhibit, it makes a difference if the learner uses informational media parallel vs. immersive to the exhibit. With the latter, the learning content is received directly "on the object" making the access more intuitive and direct. At visitor venues AR has furthermore been proven to improve mediation, by functioning as creative playgrounds (Scholz and Duffy 2018), as media of joy and engagement (Leue et al. 2014) or as source of inspiration (Rauschnabel, Felix and Hinsch 2019). Jung et al. highlighted the entertainment aspect of AR and proved that it leads to an improved perception of a visitor experience at the museum (Jung et al. 2016).

2. Four experience-based categories for AR at museums

However, those existing theoretical and empirical analyses of AR and museums do not provide an explicit framework that outlines the type of experiences that can be created with this technology nor do they give recommendations for practitioners on how to actually best integrate AR applications into the museum.

Mark Billinghurst, the co-author of ARToolkit (1999), the disruptive open source software that paved the way for mainstream AR adoption via image targeting, introduced two category frameworks for overall AR experiences. The first is based on four types of configurations depending on how the virtual view image is combined with the real-world view: (1) video based, (2) optical see-through, (3) projection onto a physical surface, and (4) eye multiplexed. (Billinghurst et al. 2015, 128)

Billinghurst's second AR experience categorisation is rooted in the input source: 1) Information Browsers: Interfaces for showing AR information on the real world; 2) 3D User Interfaces: Using 3D interaction techniques to manipulate content in space; 3) Tangible User Interfaces: Using real objects to interact with AR virtual content; 4) Natural User Interfaces: Using natural body input such as free hand gestures (Billinghurst et al. 2015, 165).

While providing an interesting starting point on how to create AR experiences in general, the two established categorisation frameworks described above fail to address the museum mediation context. More specifically, existing literature has not addressed the question: which kind of AR experiences can be created at museums? To address this knowledge gap, the authors of the present paper will outline four specific categories which museum professionals can rely on to plan and create new AR-based exhibitions aligned to their mediation goals. The categories described below are derived from observation- and evaluation-activities from the research

and development (R&D) projects "HoloMuse"[1] and "Museum4Punk0"[2], as well as from in-depth industry knowledge gained by the authors who have been working as industry professionals and early adopters in the field. We analysed those use cases from R&D and industry projects along the dimensions of user experience and mediation goals (instead e.g. the dimension of technology used). Our findings suggest four "experience-based" categories for AR at museums:

1) object annotation,
2) object visualisation,
3) guiding and
4) data visualisation.

These are neither based on the configuration method nor the input devices suggested by Billinghurst et al. (2015) but are instead derived from the different possible types of experiences that can be achieved by placing new layers of digital information upon the physical space of the museum and are therefore ideally suited to create visitor experiences.

Our categorisation approach is *user-based* as opposed to *technology-based*. It refers to the form of interaction between curated museum content and visitors. Thus, it refers to the crucial mission of each museum, i.e. the curated transfer of cultural heritage knowledge via its exhibits. This perspective on AR-technology turns our framework into a tool for museum professionals which allows them to connect the process of curation with technology in order to achieve intended mediation goals.

In order to make those categories operational for museum experts as well as for museum researchers, we now will discuss them individually and, in the next section, apply them to specific use cases.

1 "HoloMuse" ("Holographic museum exhibition design and visitor system based on Augmented Reality enhanced wearables") was an R&D project funded by the "Wirtschaftsagentur Wien" (Grant P1721153), where different Mixed Reality approaches at museums where developed, analysed, piloted and evaluated (Seirafi and Wiencek 2017, Wiencek and Seirafi 2019, Wiencek 2020). Observation- and evaluation-methods were carried out via piloting events at Naturhistorisches Museum Wien (Vienna), Deutsches Museum (Munich), and the Stadtmuseum Tulln (Austria) as quantitative surveys, focus interviews and observational methods like "thinking aloud."

2 "Museum4Punkt0" ("Digitale Strategien für das Museum der Zukunft. Erproben und Evaluieren innovativer Einsatzmöglichkeiten digitaler Technologien") is a broad initiative of the German government to innovate the museum ecosystem (https://www.museum4punkt0.de/teilprojekt/perspektiven-dreidimensionaler-visualisierungen-in-der-musealen-vermittlung/). The authors participated in one project which developed new, gamified learning approaches with Augmented Reality (https://www.museum4punkt0.de/ergebnis/kosmos-kaffee-augmented-reality-anwendung-zur-sonderausstellung/). The developed solution was carried out in real world settings both at the museum (Deutsches Museum, Munich) and for remote use. Evaluation was carried out in partnership with the "HoloMuse" project and included museum experts and professionals.

The first category we would like to name is *object annotation*. This form of AR experience is created by placing a layer of digital information directly over the physical layer of exhibition objects. An often-prevalent form is *iconographic object annotation* which is similar to the painting style of classic iconography, where a two-dimensional artwork is enhanced by painting techniques that seemingly extend the canvas outwards in the direction of the viewer. Iconographic annotation opens up the possibility to not only present information about the artwork for the visitors to consume – as most digital mediation forms do – but to encourage and strengthen early phases of contemplating art. The AR device becomes a lens that visitors can use to frame and channel their subjective experience of an artwork. This form of *on-object-mediation* is best suited to provide additional information or show hidden information on static physical objects and to continue a story told within the work of art.

The second proposed category is *object visualisation*. This category refers to the recreation of real-world objects as 3-dimensional digital objects in the space of the museum. This mediation category not only annotates existing objects (the first category) but provides object content itself which (at least not easily) can be shown in the physical exhibition space, e.g. rare or historically lost objects. Object visualisation can also add new object content to existing exhibits, e.g. to animate/visualise the internal workings of machines. This can also create learning experiences on the objects by revealing internals and what is "hidden" at the physical exhibit. Object visualisations make it possible to place new storytelling elements in the museum space. This enables mediation professionals to add novel content contributions to the overall experience.

A third application category of AR in museum mediation could be roughly described as *guiding*. The user may be provided with directions through the exhibition spaces by digital static objects like arrows and clues. In a more immersive form of this category, the user is guided by avatars in the form of fictional or real-life characters. Those *AR avatars* make it possible to introduce elements of dialogue-based storytelling into the overall museum experience by directly addressing the visitor. Avatars can be applied to provide additional context to the exhibition or on specific objects in the exhibition space.

As fourth category we propose *data visualisation* where sources of complex quantitative data are visualised in relation to the physical exhibits. Museum objects are often underpinned by complex network relations between human interactions, history events, geospatial transitions, provenance and so forth. For example, an antique artefact at a western museum will have its own historical context but will also have travelled through many centuries, countries and owners before arriving at its location of display where it is embedded into the story of the present exhibi-

tion. This context information often is available as complex data sets which are unsuitable for visitor mediation. Proper visualisation modes could make this valuable background knowledge available to museum visitors. Objects could e.g. be connected to artist biographies and therefore made tangible via digital visualisations. This creates connections between objects, biographies and other relevant information, thereby telling holistic stories that span vast time spans and connect various different disciplines. Such interconnected mediation is difficult to achieve in traditional museum mediation formats.

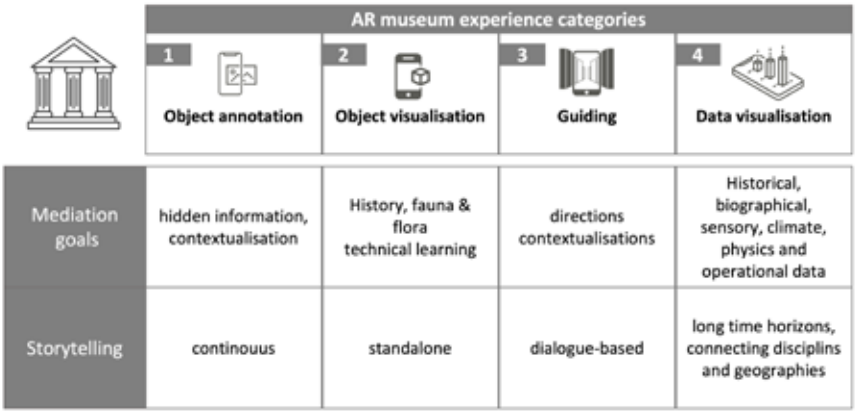

Figure 1. AR Museum Experience Categories. Table: © Fluxguide.

3. Categories applied to museum practices

The four categories outlined above will now be applied to multiple museum practices and mediation goals. The authors will connect the categorial system with modes of museum knowledge transfer and underpin them with best practice use cases from international museum projects.

3.1. Object annotations

AR object annotations make it possible to show details or invisible elements of an exhibited object that otherwise remain hidden: for example, versions of a painting can be revealed through overlays of infrared, MRI or X-ray images which are augmented over the original painting. Including them in moving-image augmentations allows the museum to tell a story about the painting technique of an artist and the change of an artwork over time during the process of its creation. Object annotation is the most common category of AR museum mediation to date and has been adopted by renowned institutions like the Albertina Museum in Vienna to tell the

story of the artwork in a playful way through animations and added sound[3] or the Belvedere Museum[4] in Vienna as well as the Louvre to reveal the story behind famous paintings[5].

Another project that uses object annotations is "HoloMuse" at the Kunsthistorisches Museum in Vienna: an application for Microsoft Hololense was developed to enhance the visitor experience in front of Pieter Bruegel's "Children's Games."[6] Specific areas of the painting were highlighted by AR annotations (see Figure 3) which was paralleled by audio narration. Moreover, the narration also connected different areas of the complex painting which then were highlighted by AR. This example shows how narrated storytelling can be extended and deepened by AR-based annotation strategies. Thus, visitors' eyes were guided to details of the painting and paired with

Figure 2. Participants at the piloting event at the Kunsthistorisches Museum Vienna, trying out the HoloLens application for Bruegel's "Kinderspiele." Photo: © Fluxguide.

3 Object annotation at Albertina, concept and implementation by Artivive: https://www.youtube.com/watch?v=WeEw_DaFQx8.

4 "Egon Schiele in Augmented Reality", Belvedere Museum Vienna, concept and implementation by Artivive: https://youtu.be/jEv6jZcRgrU.

5 "Mona Lisa beyond the Glass", created by HTC VIVE Arts and Emissive: https://www.youtube.com/watch?v=Au_UpzhzHwk.

6 "HoloMuse", Kunsthistorisches Museum Vienna, lead, concept and implementation by Fluxguide: https://youtu.be/XcKBAdEYMpY.

contextual information to trigger engagement with the work and ultimately support learning, contextualisation and understanding of cultural exhibits.

Figure 3. View through the HoloLens showing a highlighted and zoomed image detail. Photo: © Fluxguide.

3.2. Object visualisation

AR object visualisations make it possible to place life-size three-dimensional objects in the physical space. This can be used e.g. to recreate historical objects and put them in context. The mobile App project "Ovilava – Heroes of the Roman Age" (city of Wels in Austria) offers multiple AR experiences with reconstructed digital Roman assets, like e.g. Roman warriors. Based on complex 3D modelling with strong historical and archaeological precision this enabled authentic and astonishing access to Roman history and culture – directly at the specific historic relevant spots in the city.[7] In this case, AR visualisations also connected to elements of "gamification": the interactive exploration of the AR scenes was followed by interactive challenges and questions about the respective content and triggered scores (coins) and rewards (cards). The new object therefore made it possible to introduce a whole new direction of storytelling connected to the Roman soldiers' appearance into the overall visitor experience.

7 "Ovilava - Heroes of the Roman Age", City of Wels, lead, concept and implementation by Fluxguide: https://youtu.be/dNsH4wvGVyg.

Figure 4. AR visualisations for "Ovilava – Heroes of the Roman Age." Image: © Fluxguide.

Individual objects of flora or fauna can also be visualised inside the museum as AR objects, e.g. in order to reanimate extinct dinosaurs (Rieland 2012). Another good example for object visualisation of biological topics was demonstrated by the German Museum in Munich at its "Kosmos Kaffee" exhibition: an AR application offered a "gamified" simulation which enabled users to grow their own coffee plant and to observe the influence of the climate on growth and harvest. At a certain point in the game the user influences the climate conditions – rain and temperature – and gets feedback on how that affects the plant and crop. This turns the interactive game into a virtual experiment and the exhibition into a *digital laboratory*. It follows the paradigm of "show, don't tell," i.e. the user learns by observing, doing and experiencing, not just by being given information.[8]

The category of object visualisation is furthermore suited to showcase principles for complex technical objects with stand-alone three-dimensional animations such as engines.[9] This makes it possible to create holistic learning experiences that add completely new storytelling elements to the museum which would not be possible without AR.

8 "Kosmos Kaffe", Deutsches Museum, lead, concept and implementation by Fluxguide: https://youtu.be/l1_wsFFy_3U.

9 Riga Motor Museum: https://www.youtube.com/watch?v=qjS6GIVGWgA.

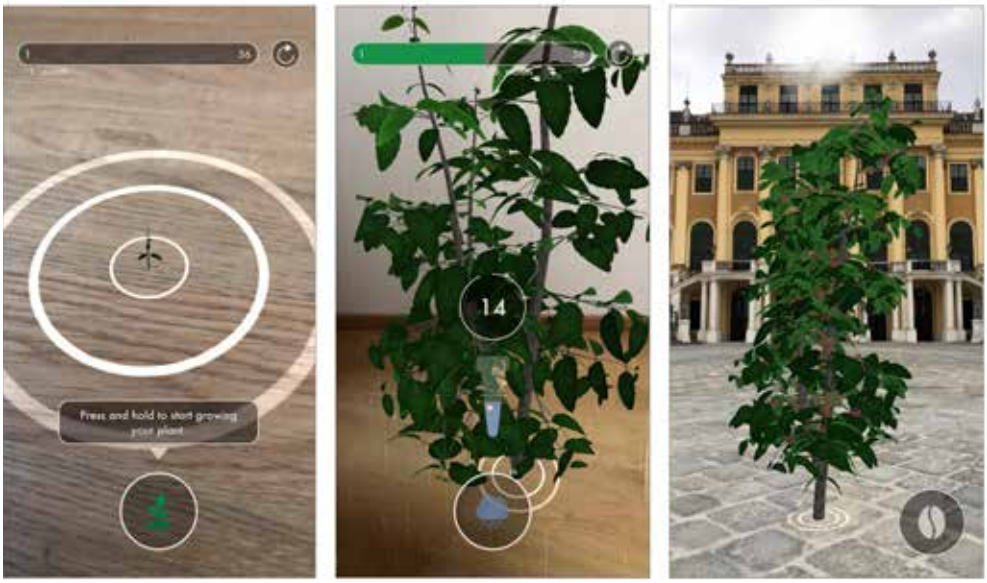

Figure 5. Prototype of the Cosmos Coffee AR-application used off-site. Image: © Fluxguide.

3.3. Guiding

Augmented reality is suited to guiding visitors through venues with digital information. This can be done for example via AR arrows or signposts. At the Landesmuseum Württemberg a mobile app offers interactive wayfinding and storytelling during the whole visit experience. At predefined locations visitors have the option to open the camera lens of their device which is augmented with dynamically animated arrows that point in the direction of the next tour stop.[10] With this kind of immersive guiding spatially separated tour stops can be connected and potential breaking points in story experiences bridged.

Figure 6. AR Arrows help visitors navigate through the museum: © Fluxguide.

In an even more immersive version of this AR category, visitors can be guided by *AR avatars*, i.e. real narrators appear on the spot and provide personal guiding. This can be done via so called Alpha-Channel-

10 "Wayfinding at the LMW", lead, concept and implementation by Fluxguide: https://youtu.be/TZqqyQuCbZw.

Videos[11] with real persons which then are added into the AR view, so that the video-recorded persons directly appear in front of the user. You could e.g. record comments of the museum's director to different exhibits and then let the director pop up in front of those exhibits.

Avatars often narrate about exhibits from the specific perspectives and points of view. This can, for example, be an artist's very own perspective or insights from the viewpoint of a historic witness[12]. At the Celtic Museum Hallein for example, a Celtic warrior appears to interact with the visitor at certain exhibits. Avatars can even be personified *narrating objects*, as in the exhibition "Sprechende Knochen" at the Centre Charlemagne where bones come alive and act as first person narrators about which knowledge can be derived from their findings and burial contexts.[13]

Figure 7. AR Avatar Ranger at Nationalpark Hunsrück-Hochwald. Image: © Fluxguide.

In addition to animated avatars, actual human tour guides can be featured at on-site AR experiences: the national park Hunsrück-Hochwald (Germany) let their real rangers appear as virtual guides within an AR-powered mobile app.[14] This significantly extends mere audio-only mediation, because the narrator can be experienced as human actor that directly addresses the visitor. It also extends usual video playback, because the human actor is not *besides the scene* (*on* the mobile) but *on the scene* (*through/via* the mobile). This adds a more immersive and personalised component to the guiding and storytelling experience through AR augmentation into the field of view of the user.

11 This type of video captures the recorded object (person) only and makes the background transparent. This then enables the insertion of the video into any other background.

12 E.g. this speaking Celtic at the Keltenmuseum Hallein: https://www.youtube.com/watch?v=_DDXc04Ru3A&t=57s.

13 "Sprechende Knochen", Centre Charlemagne, concept by Domeniceau: https://www.designmadeingermany.de/2015/81262.

14 "AR Ranger", Nationalpark Hunsrück-Hochwald, lead, concept and implementation by Fluxguide: https://youtu.be/0A2R7i9fmi8.

3.4. Data visualisation

AR is being used in industry to visualise complex information and to facilitate data driven processes, as it makes it possible to analyse correlations in three dimensions and to place different data outputs next to physical reference objects (Marr 2021). Museums, however, are only beginning to exploit this potential. AR creates the possibility of linking complex data on real objects in museum spaces via augmented visualisation. This offers new ways to create connections between objects, artist biographies, human interactions, historical events and other relevant information which is difficult to present in museum spaces.

One pioneer in this category is the American Natural History Museum that is working on a data visualisation platform which interlinks data from their scientific departments and their archives to create engaging visitor experiences in AR.[15]

A number of research and development projects address the question on how widely dispersed cultural data can be made more accessible. One of them is "InTaVia – In/Tangible European Heritage Visual Analysis, Curation & Communication," a H2020 research and innovation action funded by the European Commission within the Call DT-TRANSFORMATIONS-12-2018-2020 "Curation of digital assets and advanced digitisation." The project deals with the complex possibilities of visualising cultural data for researchers as well as for the general public. The project team will develop a new platform to access, analyse, curate and communicate cultural data of object collections and historical texts, especially artist biographies. "InTaVia" aims to utilise AR in order to integrate objects and biography data with the experience of the physical world around the users. One goal of the project is to enable museum educators to enrich their own collections with foreign cultural data. In other words, diverse datasets can be implemented into the visitor experience via AR to tell stories in the exhibition space.[16]

4. Conclusion and outlook

This paper attempted to bridge the knowledge gap between the benefits of Augmented Reality and the museum mediation practice. Existing research proved that AR at the museum can improve mediation by functioning as creative playgrounds (Scholz and Duffy 2018) or by improving perception of the overall experience (Jung et al. 2016). However, existing literature does not address what kind of visitor expe-

15 American Natural History Museum data visualisation platform: https://immerse.news/how-are-museums-experimenting-with-immersive-technology-f52612504e2.

16 This project has received funding from the European Union H2020 research and innovation program under grant agreement No. 101004825. More Information on InTaVia: https://intavia.eu/.

riences can actually be created at museums by using Augmented Reality to achieve specific mediation goals.

In order to address this knowledge gap, four experience-based categories for understanding and designing AR at museums were developed: 1) object annotation, 2) guiding, 3) object visualisation, and 4) data visualisation. Those categories for AR in museums are based on user experience settings in museums. They are meant for museum professionals as guiding concepts for their practice in order to achieve their educational and storytelling goals. The paper applied those four theoretical categories to real-world use cases and examples which demonstrated their applicability and validity for the museum context. Furthermore, the application made demonstrable the suitability of each category for specific storytelling goals: 1) object annotation – continuous, 2) object visualisation – standalone, 3) guiding – dialogue-based, and 4) data visualisation – connective.

The categories presented, along with the practical examples, may be used and further developed by both academics of the field and museum practitioners. The technology behind AR is constantly evolving and improving. Since the authors' approach is built on mediation goals rather than technical features, it is likely that the four categories will hold true even if the technology landscape changes for example with a mass rollout of reliable AR glass wear.

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Jakob Ossmann – MSc., an expert for digitisation management and has successfully shipped applications containing AR features at prestigious museums. Ossmann graduated from Maastricht University's School of Business and Economics with a paper describing the positive effects of XR experiences on ethical consumption behaviour.
e-mail: jakob[at]fluxguide.com

Kasra Seirafi – PhD from University of Vienna (Austria) and Stanford University (USA), M.A. from University of Vienna (Austria), B.Sc. from University of Derby (UK). As professional in leading positions, Dr. Kasra Seirafi contributed to the field of knowledge management systems, E-Learning, mobile innovations, cultural heritage technologies, and other related topics. Currently he works as founder and managing director at the technology SME Fluxguide. He has 20+ years of experience in

industry and research projects worldwide as well as a researcher and lecturer at international universities.
e-mail: kasra[at]fluxguide.com

Carina Doppler – in her studies at the University of Vienna, Mag. Carina Doppler dealt with theoretical and analytical questions related to theatre, film and media. As a project and communication manager, she has several years of experience in the conception, implementation and communication of interdisciplinary projects in the cultural and media sector. She managed augmented reality mediation projects for international institutions, clients and partners.
e-mail: carina[at]fluxguide.com

SUMMARY

Neli võimalust liitreaalsuse kogemiseks muuseumis

Jakob Ossmann, Kasra Seirafi, Carina Doppler

Võtmesõnad: liitreaalsus, rakendus, muuseumi vahendamine, tehnoloogia, muuseumi kommunikatsioon, külastajakogemus

Liitreaalsus (LR) on muuseumides levinud, kuna see lubab ületada lõhe füüsilise näituseruumi ja digiteeritud teabe vahel. Vastav tehnoloogia on nüüdseks küpsuse saavutanud ja muutunud tootmisvahendiks mitmetes tööstusharudes. Käesolevas artiklis vaadeldakse, millised on muuseumides rakendatavad konkreetsed kasutusviisid.

Muuseumides kasutatava LR-i põhjalikuks mõistmiseks on mitmeid teoreetilisi ja tehnoloogilisi lähenemisviise. Käesolev artikkel täiendab olemasolevat kirjandust, ühendades LR-i teoreetilisi kontseptsioone ja selle tegelikke rakendusi. Selleks võetakse kasutusele neli liitreaalsuse kategooriat, mis ei tulene mitte tehnilistest kirjeldustest, vaid hoopis kasutajakogemuse seadistustest muuseumides. Need kategooriad on 1) objekti annotatsioon, 2) objekti visualiseerimine, 3) vaataja suunamine (LR giid) ja 4) andmete visualiseerimine. Artiklis järgneb kategooriate lühikirjeldustele analüüs, milles vaadeldakse nende rakendamist eri riikide muuseumides.

Peale nende nelja kategooria rakendamist eri riikide muuseumide parimatele rakendustele väidame, et iga kategooria sobib ideaalselt konkreetsete narratiivsete eesmärkide saavutamiseks: 1) objekti annotatsioon – pidev, 2) objekti visualiseerimine – eraldiseisev, 3) vaataja suunamine – dialoogipõhine ja 4) andmete visualiseerimine – ühendav narrativiseerimine.

See parimate rakendustega seotud kategooriate kogum aitab muuseumispetsialistidel ja otsustajatel paremini mõista LR-i kasutusvõimalusi ning saavutada vahendamise ja narrativiseerimisega seotud soovitud eesmärke.

Jakob Ossmann, MSc. on digiteerimise haldamise ekspert, kes on edukalt toonud mainekatesse muuseumidesse LR-funktsioone sisaldavaid rakendusi. Ossmann on lõpetanud Maastrichti ülikooli ettevõtlus- ja majanduskolledži tööga, mis kirjeldab XR-kogemuste positiivset mõju eetilisele tarbimiskäitumisele.
e-post: jakob[at]fluxguide.com

Kasra Seirafi – PhD Viini Ülikoolist (Austria) ja Stanfordi Ülikoolist (USA), MA Viini Ülikoolist (Austria), B.Sc. Derby ülikoolist (Ühendkuningriik). Juhtivatel ametikohtadel töötanud professionaalina on dr Seirafi panustanud teadmusjuhtimissüsteemide, e-õppe, mobiiliuuenduste, kultuuripärandi tehnoloogiate ja muude sarnaste valdkondade arengusse. Praegu töötab ta tehnoloogiaettevõtte SME Fluxguide asutaja ja tegevdirektorina. Tal on pikem kui 20-aastane kogemus tööstuses ja rahvusvahelistes uurimisprojektides ning teadlase ja õppejõuna mitme riigi ülikoolides.
e-post: kasra[at]fluxguide.com

SUMMARY

Carina Doppler – Viini ülikoolis magistrantuuris õppides tegeles Doppler teatri, filmi ja meediaga seotud teoreetiliste ja analüütiliste küsimustega. Projekti- ja kommunikatsioonijuhina on tal mitmeaastane kogemus interdistsiplinaarsete projektide kontseptsiooni loomise, elluviimise ja kommunikatsiooni vallas kultuuri- ja meediasektoris. Ta on juhtinud liitreaalsuse vahendamise projekte rahvusvahelistele institutsioonidele, klientidele ja partneritele.
e-post: carina[at]fluxguide.com