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Embodied Virtual Objects

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***Abstract*: The project "Embodied Virtual Objects" describes a strategy and technological setup to explore rare museum objects with the help of touch-enabled handheld devices. In a mini-exhibition that can be downloaded to a consumer device users can explore virtual representations of museum objects through an intuitive touch-interface. They can access additional information and examine the objects by turning them, zooming, and scrolling, allowing the users to become active and engaged museum visitors. The application is tested for its value in the preparation of a museum visit, as supportive material during the museum visit, and as a reference after the visit. The study assesses the technical setup, feasibility, and first user responses.**

***Keywords*:** Virtual museum, ubiquitous computing, mobile devices, mixed reality**.**

I. Introduction

A museum visit does not anymore consist simply of making a trip to the museum and exploring the exhibition. Today the majority of museum visitors first visits the website of the museum to find out about current shows, opening hours etc. It has become almost indispensable for a museum to feature their holdings on a website that offers rich content beyond the practical information about exhibition calendar, location, and hours. The web presence plays a big role in the preparation of the museum visit as well as in continuing the experience after the visit. It has been shown that online resources are widely used to plan the visit in a practical sense [1], [2] and in order to develop a personal interest in specific holdings [3]. The learning process centered on the museum visit does not end when the visitors leave the museum and visitors often continue to expand on their visit and draw conclusions from their experience well after the visit [4]. Off-site reference materials such as exhibition catalogues as well as online resources are important for this process. While the online availability of practical data is most important prior to the visit, visitors are more likely to access content related to the collections, additional images, and research materials after their visit. Providing high quality resources enabling both phases, before and after the visit, are a means for institutions to build an ongoing cyclical relationship with their visitors and result in more frequent visits [5].

In the described scenario the museum visit can be divided into two separate parts: The off-site component and the on-site component. Traditionally the main focus of museum institutions has been the latter component but in order to build a strong relationship with their visitors both components have to be taken into consideration equally and conceived to be mutually supportive. In particular for natural history museums the main drawing power came from the high quality and "life-likeness" of their objects. Well-made taxidermies were the main attraction giving the viewer the opportunity to see exotic animals in a highly realistic form. A considerable amount of the power of this attraction has disappeared with the availability of a multitude of nature films on television, which extend the possibility to see exotic species to the home screen. To maintain the power of attraction of the museum it has become important to offer new layers of content to the visitor. The aspect of exploratory engagement, allowing the visitors to examine objects in a self-guided way and giving them the possibility to be "explorers" by themselves, is an important component that films do not offer. In the more recent studies a perspective of the museum visitor as active interpreters has been fostered [4]. Building a strong information ecology that integrates both components, on-site and off- site, is a challenge for museums and goes in hand with a reconsideration of the role and function of the collection as the main asset of the museum [6].

The project "Embodied Virtual Objects" is the first part of a series of studies exploring different ways of constructing an information infrastructure that faces the challenges laid out above. The focus of the project is on natural history collections. It is a small scope pilot study intended to determine acceptance and feasibility of downloadable media content-units offered to museum visitors for self guided support of their visit. The recent popularity of tours that can be assembled by the visitors themselves using online resources such as podcasts or phone guiding systems such as the "Art on Call" series of the Walker Art Center in Minneapolis indicates a demand for highly customized experiences that go beyond the standard audio guide that is still the standard in most museums. The general acceptance of these offers by the audience is very high as Robin Dowden from the Walker Art Center states. This demand encouraged us to investigate possibilities to use popular entertainment devices to create an experience that integrates both the in depth programming of the guided tour with the possibility for self-guided exploration and the encounter with tangible museum objects.

II. The museum of the 21. century

In the competition with a broad variety of offerings in the field of information as well as entertainment media, the museum has to revise its approaches to stay "contemporary" and keep its experience attractive. In an attempt to introduce more flexible and holistic ideas into the museum work, Eva M. Reussner argues in her paper Strategic management for visitor-oriented museums that museums should move towards a strategic management approach. "Strategic museum management consists of organising, planning, leading, and monitoring all areas of museum work, such as collections, research, exhibitions, public programs, administration, and marketing in the view of the museum's primary goals." [7] In line with this notion several museums are experimenting with integrating their offerings and creating new programs and activities for the potential museum audience. Programs in this vein range from attempts to turn the museum visitor into a curator who arranges his visit with the help of online resources that give him highly customized and individualized access to the holdings [8], as well as to personalized museum tours with iPhone or iPod devices [9].

The described project "Embodied Virtual Objects" was developed with a similar aim and to address three different aspects of what can be seen as a larger strategic program for museum work that makes use of a range of media technologies to support the actual on-site experience. The first goal was to allow for a personalized access to the museum according to areas of interest that have been identified before the visit with the help of the museum online resources and that filter into a customized self-curated tour; second we are aiming for an integration of the on-site and off-site experiences. Within the off-site experience we distinguish the pre-visit phase dedicated to the process of getting acquainted with the holdings and identifying areas of interest and the post-visit phase where parts of the experience are reviewed in a customized record of the visit that reflects the stations visited; and third we are aiming to create a tool that augments the on- site experience and fosters a process of active learning.

III. Playful interaction with virtual objects

"Embodied Virtual Objects" is an interactive virtual mini-exhibit that can be downloaded and explored at leisure with a handheld touch-enabled device. Through an intuitive interface users can examine virtual representations of the museum objects in a tangible way as if they were "holding them in their hands", they can turn them around, look at them from all angles, zoom in to look closely etc. This exploration can happen in preparation before a visit to the real museum, it can happen during the museum visit providing additional information and perspectives that are not possible in connection with a real object, and after the visit as a way of reviewing and revisiting the experience with the real objects. The hypothesis we are investigating in this project is that the use of popular handheld touch screen devices allows to create an experience that bridges the gap between on-site and off-site resources for a museum visit and combines the benefits of popular devices such as mp3 players in the preparation of customized museum visits with the experience of encountering and exploring real tangible objects. Our notion is that this kind of experience can foster a new form of heightened accessibility of the objects and that it can have great benefit for the creation of an ongoing relationship between the visitor and the museum collection. In later stages the scope of this first experiment can be widened and integrated with extensive web-resources that can provide a wide range of options for customization and the identification of areas of interest priors to the visit of the museum and potentially as a motivation for such a visit.

A. Enabling the museum visitor

The motivation that brings visitors to a museum is the possibility to the see original objects in reality. In the case of natural history museums this power came from the possibility to see real animals from all parts of the world brought together in one place. The majority of natural history collections was amassed in the 19th and early 20th century, which was a time where museum politics changed fundamentally. During this time we see the emergence of public museums with an educational purpose and accessibility for a general public [10]. The educational value of the contemplation of real objects was considered very high. With this opening to the public, though, the objects themselves became increasingly inaccessible. While in the early collections it was normal practice that the scholars take objects out of their cases and turn them in their hands to examine them and make their own observations, this practice was not possible in the public museum anymore. In the public museum objects were only presented in display cases and out of the reach of the visitors as mere objects of contemplation rather than examination.

Modern museum concepts treat the visitors as more autonomous subjects and provide more openness in the didactic approach. Nevertheless, the direct tangible access has rarely been re-established. One way of remedying the distance to the objects can be seen for example in the Natural History Museum in Paris where the high quality fragile taxidermies were replaced by simplified models placed in the exhibition without any sheltering case around them. The accessibility here compromises the amount of detail and fidelity that the viewer can access. Since detail is important in a science that relies exactly on this detail in order to establish the subtle differences between species, we were searching for another approach in our project. Our attempt to implement tangible access to the artefacts uses virtual representations of the objects that visitors can examine through a touch interface. In order to provide tangibility and preserve the detail of the original we are using a virtual model of the object that is based on a large set of high quality photographic images.

Re-establishing the possibility to "touch" the artefacts and examine them at will constitutes a significant change in museum practice. It breaks the barrier of an authoritative display without compromising in the needs of preservation and protection of the objects. Of course it is impossible to

replace the power of originality through any kind of mediated form of display but according to the reports from our test audience the pleasure of being able to manipulate the artifacts is great and recreates a certain amount of the immediacy of the real object.

B. Delivering historic context

In the past years an increasing awareness of the contextual information around museum objects and collecting practices has developed. While in the traditional approach exhibits in natural history museums were meant to display the objects primarily as objects of a scientific interest and theory. To give an example, a taxidermy was intended to give an impression of the species in regards to appearance, anatomy etc., secondary messages communicated through this taxidermy might be an exemplification of behavioral aspects of the animal, such as the bird-flight, or evolutionary aspects of how this species may have developed, how different stages of age look etc. In more recently developed approaches museum objects are also interpreted beyond their primary role in the natural sciences for example as witnesses of collecting practices and as historically contextualized objects. This perspective has been formulated by historians and museum specialists [11], [12] and has slowly found its way into the curating practice of natural history objects [13]. Part of this curatorial shift is also the notion to present objects together with their original collection furniture, the cabinets that were used to store them and that still preserve a historic significance. While often the furniture is only considered a practical protective housing for the objects and therefore not attributed a lot of attention besides the usage value, the notion of a cabinet as a knowledge tool that plays a role in the scientific knowledge constitution and thus is part of a science- historical curatorial practice has been formulated [14] and has become part of exhibition concepts, as instantiated among others by the exhibition “Klasse, Ordnung, Art” in the Natural History Museum in Berlin, Germany. The approach proposed in this chapter supports the realization of this curatorial concept, which was part of the development intention. The objects on display can remain in a specifically curated historical setting, i.e. enclosure or situation, while still being accessible for detailed examination and exploration by the user. In this scenario the presentation of virtual representations of museum objects next to the original objects becomes a compelling experience as it provides several layers of information that could not be achieved with solely one of the presentations.

IV. Technological basis

We decided explore the usability of virtual objects since earlier studies have shown that virtual environments and computer simulation can provide significant learning benefits and create a quasi-tangible experience quality [15]. The applicability for museum installations has been investigated with various examples [16]. Also the recent (2007) experience made in the Natural History Museum in Berlin showed a significant increase in visitors after the opening of re-designed parts of the exhibition employing a range of media installations such as the “Jurascope”, which overlays simulation images from dinosaurs onto their skeletons in the exhibition. Compared to our project the “Jurascope” has the downside that it is limited to the on-site experience and cannot be taken home or accessed remotely. Technologies such as Augmented Reality displays or virtual environments were so far not available in a mobile setting. In the recent past, though, small handheld devices have entered the consumer market, which have sufficient graphics computation power to run interactive simulations and small-scalevirtual environments. The use of small mobile devices in the context of immersive museum experiences is rather recent. Projects like the “Aixplorer” and the “Corona”-experience in the “Aixplorer” framework explore the use of mobile technology in this context [17]. In most cases, though, dedicated hardware is used that has to be provided by the museum (in the case of the “Aixplorer” an off-the-shelf cellphone is used with custom-made location tracking hardware) and therefore requires a considerable hardware investment by the museum, equipment tracking and most importantly allows only for an on-site experience and does not support the phases before and after the museum visit.

For “Embodied Virtual Objects” we decided to use a popular off-the-shelf handheld device which has a rather wide distribution and decided to develop it as an App for the iPhone and iPod touch from Apple Inc. People who own such a device can download a small application that delivers the interactive mini-exhibit to their device and makes it thus available for exploration in all three phases of the museum visit. This architecture allows for a custom-made interface using the built-in touch sensitivity of the device. Through this interface it is possible to explore objects in the palm of the hand in a quasi-tangible way. The footprint of the application is kept rather small in order to accommodate for the limited storage capacity of the handheld devices. Additional materials were acquired through an online connection and downloaded through the application from a dedicated server. In order to provide as fast as possible data traffic an openly accessible wireless network access was provided.

The project uses a large set of photographically generated images. A series of high quality photos has been taken covering the objects of the project-exhibit from all angles in a 360-degree coverage in 10-degree steps. For each of the objects on display this results in 540 images (Figure 1).

Figure 1. Grid of different perspectives of a glass model

In order to optimize the production of these images, which also serve the purpose of the ongoing digitizing project of the museum holdings, we used a specialized motion control camera (Figure 2).

Figure 2. Motion-Control-Camera setup with object on turntable

This setup automatically positions objects and camera for all necessary shots, and allows to reduce manual interventions to the initial positioning and removing of the object on the shooting turntable, virtually automating the entire capture process. To allow for good photographic quality the objects have been brought into a light tent with more or less standardized lighting. The arrangement of lighting was the most time intense part of the capture process since the objects had highly reflective surfaces. With the highly reflective surfaces of the object it was important to avoid excessive highlights as well as confusing reflections. It is important to make sure that the different perspectives of the objects fuse together to give a coherent and immersive impression of the photographed object. The same applies to the photography across different objects, which has to be consistent and objective to establish a notion of coherence across the entire experience. As Singh, Zaveri, and Raghuwanshi state [18] imbalances in illumination can have a strong effect on the recognizability of images and it is important to account for possible differences in the lighting situation.

While the process overall can still be optimized we were able to produce the imagery for the project in three days. For the use with the handheld device the photos had to be scaled down to a size of 1024 by 1024 pixels and additionally retouching and masking of the individual images was applied. For the implementation of the virtual environment we used the commercially available real- time 3D-engine Unity 3D. This game engine provides a very convenient user interface that makes the authoring process feasible also for non-programmers. We developed a number of workflow-tools that will allow us to hand the production process of applications like the “Embodied Virtual Objects” off to some trained people from the museum-communication staff.

The photographic images are used as texture maps on billboard-objects that are navigated by the user. Depending on the perspective the user chooses the corresponding image is shown. The photographic approach is able to preserve the high detail and visual quality of the original objects that would normally get lost in a purely computer generated approach. Besides the general shape of the artefact all imperfections and irregularities are equally translated into the virtual object. Through the touch screen of the device the objects are available for close examination, the users can turn them around, zoom in and access additional information on the objects.

V. Spinning jellyfish

The set of objects that was chosen for the project “Embodied Virtual Objects” is a series of historic glass models of deep-sea creatures. The models represent different species of jellyfish and other deep-sea creatures. It is an irony in itself that for the implementation of our virtual objects we chose objects, which were themselves “virtual versions” of deep-sea creatures made in the 19th century. Since jellyfish are consisting 99% of water and live in the high-pressure regions of the sea it was almost impossible to preserve these animals

with the technologies of the 19th century. The model-makers Leopold and Rudolph Blaschka in Dresden managed to develop a technique that allowed them to build very intricate models of these creatures in glass [19]. The 40 glass models of the Museum for Natural History are highly detailed and extremely fragile and more sensitive to vibration than most other taxidermies. Therefore these objects are very rarely shown and can only be displayed in solid glass display cases, which makes it impossible for the viewers to closely examine the complex three- dimensional structure of the jellyfish. With the described technological setup it becomes possible to explore the objects in depth and spin them, turn them, zoom into them to closely examine their structure. Small labels that can be interactive activated are used to identify elements of the jellyfish.

Figure 3. Glass models inside the cabinet in the context of other historic documents and objects

In the small test-exhibit we presented the glass models in a historic cabinet which used to serve as the storage for these objects (Figure 3). In former times the objects were part of a teaching collection and used to demonstrate anatomic specificities of the different kinds of jellyfish. For this purpose they were only shown to select groups of students, but they were not part of the publicly accessible collection. Presenting the models now in their historical context with explanations about the model makers, the time of their creation, which falls into the time when around the turn of the 19th to the 20th century the aquarium movement originated, and specific explanations about the different animals.

VI. Evaluation

Focusing so far on only one display case the mini-exhibit makes a small excerpt of the large holdings accessible for individual exploration in all three phases of the museum visit as described above. The objects remain available for reference and the user can turn to them to revisit what he has seen in the museum. It is a bit more complex to correctly assess the role of the “embodied Virtual Objects”-application during the museum visit. Given the fact that the application provides only photographic representation it is not as stunning as the real original. The added value is that the application functions like a visualization tool, it allows to view the objects from perspectives that are not available in the real exhibition due to protection constraints. Furthermore it adds contextualized labels that are placed in precisely the location they refer to for example to describe a light organ of a deep-sea creature. This is an easy task in the virtual object where these labels can be turned on and off, but it is difficult to fix labels to the real object without obstructing the view. Another quality, which is difficult to quantify, is the pleasure

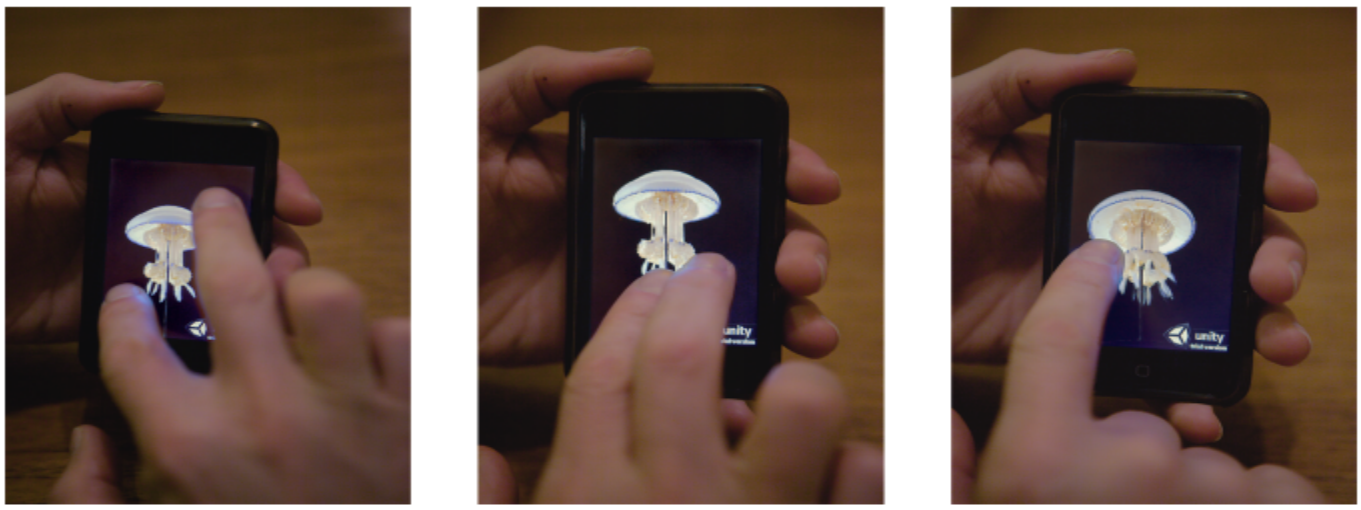

Figure 4: Touch screen interactions with a virtual object:

1. Pinch two fingers to zoom in and out (left image)
2. Swipe two fingers to scroll the enlarged image (middle image)
3. Swipe with one finger for rotation around the x- and y-axes (right image)

that our test audience derived out of the pleasure of manipulating the objects with simple finger gestures. The interface of the application implements a set of established gestures to navigate the objects as shown in figure 4.

In order to get a first feeling for audience responses we made our project available to a small test audience consisting of 30 people (male and female). The participants were provided an iPod touch with the exhibit installed. Since the software was provided pre-installed the assessment of the ease of the installation process as well as its relationship to the context of the website were not part of our study. For the installation we used the normal process, which is the same for all Apps on these devices and users are generally familiar with this process. The assessment of audience responses was done in interviews right after the visit and again 1 week after the visit to assess how often people returned to the application and how it influenced their thinking about the content of the exhibit. The responses were generally positive, though 7 out of the 30 participants did not re- access the exhibit on their devices again prior to the second interview. As they stated they did not feel a necessity to revisit the content. We also have to account for a novelty-effect making the participants more inclined to access the application, which might wear off are more exhaustive deployment. We noticed an unexpected benefit in the satisfaction that the free gift of an App that was generally perceived as “pleasurable” and “entertaining” created. Users felt they get something to take home.

It seems that the pleasure of interacting with the objects counterbalances some of the drawbacks of the mediated representation. Further reports stated that the status of the virtual objects changed before and after the encounter with the real object. While before the real object was seen the exploration of the virtual object has the character of revealing something unknown and stimulating the curiosity for the beauty of the real object, the same experience after the visit was re-contextualized and enhanced by the experience of the real objects. It was regarded as a good reference to keep the memory fresh and to go back to. This suggests that the real display and the virtual display are mutually supportive. Having the object-representation at hand does not discourage people from going to the museum to see the original and on the other hand neither does the application become obsolete after having seen the original objects, nor do the original objects loose their power as an original and real object.

VI. Conclusion

Our experience with the project “Embodied Virtual Objects” indicates that the proposed type of application can make a valuable contribution to the museum visit and is valuable in the preparation phase of the visit, during the visit and afterwards. It allows the users to become explorers at their own discretion and thus constitutes an empowerment of the museum visitor making him an active interpreter. At the same time it does not discredit or devalue the curatorial voice of the museum exhibition or the power of the presence of the real objects. The proposed application opens up a realm for personal discovery in the sense that visual inspection at a distance as it is classically happening in a museum is different and in some respects less strong than the feeling of “being given the object in hand”. This results in increased accessibility of the museum collection without any drawback in terms of object preservation.

Mobile devices and broadband internet connection have become very well established and broadly available as Henry and Sankaranarayanan found [20]. This means that users can access the content of applications build according to our model from virtually anywhere. This aspect makes it possible for such an application to extend the reach of the museum well beyond the walls of the actual museum building and reach more potential visitors as well as it allows visitors to stay connected to the experience they had in the museum and access it again in many different situations such as at home or in other moment of leisure.

Our study also indicated that after a certain amount of initial investment into software and hardware infrastructure (e.g. for digitizing and image preparation) this type of experience can be generated in a rather flexible way. Given the production time for capturing and the creation of a surrounding space to contextualize the objects as well as the scientific curating and proofing of the content will make the creation of a project like “Embodied Virtual Objects” only feasible for select objects and exhibitions that have a longer display time so that the investment can be justified. It is clear, though,that the real benefit of this approach is only fully realized, when multiple parts of the holdings are treated in the described way and made available to the audience. Otherwise the options for individual customization are too limited to invite the users to engage into this explorative activity.

Other drawbacks of the proposed application are clearly in the small screen real estate of the device that was used (480 x 320 pixels) as well as the limited processing power and memory capacity of the device. By scaling the images to a size that is comfortably manageable by the device we loose a considerable amount of detail of the high-resolution images that were initially produced. While the limited storage capacity of the device and the ease for flexible updating of the experience would make it desirable to provide the content through a wireless network connection, the limited bandwidth of the device makes it necessary to store a certain amount of the content locally on the device in order to ensure smooth and fast interaction. It seems highly probable that these technical drawbacks will be resolved with future generations of the devices. The newest existing generations already have a significant increase in processing power as well as storage than the devices used in our study. Faster network connections are likely to be available soon. Upcoming generations also promise larger screen sizes, which will open the room for more detail as well as potentially more immersive presentations suing stereoscopic displays.

The study we conducted in the scope of the “Embodied Virtual Objects” project operated with a small exhibition with only seven objects and a limited test audience. While it waits to be seen how such an application will perform in a

larger setting the feedback we were able to gather so far indicates that the interaction with the embodied virtual objects is pleasurable and intuitive and constitutes a new asset in the museum communication. In a larger study in the future we will be able to gather more substantial user feedback. Equally we are aiming to solidify our approach and study new generations of devices and more immersive display technologies. We anticipate that future handheld devices will deliver improved screen quality and potentially even three dimensional display possibilities. First attachments are already on the market [21]. Another aspect to study in a future setup will be the use of a 3D scanner that will allow us to digitize the objects as three-dimensional objects that can be textured with our high-quality photos arrays. This approach could combine the quality and relative ease of use of photography and the benefit of 3d- models.

Further studies will also have to assess a growing number of thematic areas realized in the way as the described one in order to build towards a real customizable experience.

The aim of this study is to verify whether the creation of this kind of resource provides the expected benefit, whether it is technically and economically feasible, and to assess the resonance of a test audience.

References

[1] Ockuly, J., "What Clicks? An Interim Report on Audience Research", Museums and the Web, ed. Bearman, D. and Trant, J., Toronto: Archives & Museum Informatics, 2003. http://www.archimuse.com/mw2003/papers/ockuly/ockuly.html (retrieved March 29, 2010).

[2] Goldman, H., K. and Schaller, D., "Exploring motivational factors and visitor satisfaction in on-line museum visits", Museums and the Web, edited by Bearman, D. and Trant, J., 2004, pp. 223-235.

[3] Bowen, J., "Time for Renovations: A Survey of Museum Web Sites", In Museums and the Web, Selected Papers from Museums and the Web, ed. Bearman, D. and Trant, J., Archives & Museum Informatics., Pittsburgh, 1999. http://www.archimuse.com/mw99/papers/bowen/bowen.html (retrieved March 29, 2010).

[4] Taxén, G. and Frécon, E., "The extended museum visit: Documenting and exhibitingpost-visit experiences", Museums and the Web, edited by Bearman, D. and Trant. J., Toronto, Archives and Museum Informatics, 2005. http://www.archimuse.com/mw2005/papers/taxen/taxen.html (retrieved March 29, 2010).

[5] Marty, P., "Museum Websites and Museum Visitors: Before and After the Museum Visit", Museum Management and Curatorship, Volume 22, Issue 4, 2007, pp. 337 – 360.

[6] Hertzum, M., "A Review of Museum Web Sites: In Search of User-Centred Design", Archives and Museum Informatics 12, 1999, pp. 127–138.

[7] Reussen, E. M., "Strategic Management for Visitor-Oriented Museums – A change of focus", Museum Management and Marketing, edited by Sandell, R., Janes, R., R., Routledge, Abingdon, 2007. pp. 148-162

[8] Wang, Y., et al., "Be Your Own Curator with the CHIP Tour Wizard", Museums and the Web, edited by Trant, J. and D. Bearman, Archives & Museum Informatics, 2008. http://www.archimuse.com/mw2008/papers/wang/wang.html (retrieved February 21, 2011).

[9] Maurizio, M., Cefalù, V., del Monte, M.: Building own's guided tour in a conremporary art guide. In: 3rd International Workshop on Personalized Access to Cultural Heritage, PATCH 2011, forthcoming.

[10] Benett, T., The Birth of the Museum, Routledge, London, 1995.

[11] Pomian, K., Collectors and CuriositiesI, Polity Press, Cambridge, UK, 1990.

[12] Pearce, S., M. "Objects as meaning; or narrating the past", Interpreting Objects and Collections, Pearce, S., M. (ed.), Routledge, London, 1994, pp. 19-29.

[13] Bredekamp, H., Brüning, J., Weber, C., Theater der Natur und Kunst – Theatrum naturae et artis, Henschel, Berlin, 2001.

[14] te Heesen, A., "Vom Einräumen der Erkenntnis", auf\zu. Der Schrank in den Wissenschaften, edited by te Heesen, A., Akademie Verlag, Berlin, 2007.

[15] Lee, E. and Wong, K., "A Review of Using Virtual Reality for Learning", Transactions on Edutainment I, LNCS 5080, 2008, pp. 231-241.

[16] Cheok, A. et al., "Touch-Space: Mixed Reality Game Space Based on Ubiquitous, Tangible, and Social Computing", Personal and Ubiquitous Computing Issue 6, 2002, pp. 430–442.

[17] Heller, F., et al., "Multi-User Interaction in Virtual Audio Spaces", Spotlight on Works in Progress, Session 2, ACM CHI, 2009.

[18] Singh, K. R., Zaveri, M. A., Raghuwanshi, M. M., "Illumination and Pose Invariant Face Recognition: A Technical Review", International Journal of Computer Information Systems and Industrial Management Applications (IJCISIM), ISSN: 2150-7988 Vol.2 (2010), pp.029-038; http://www.mirlabs.org/ijcisim

[19] Hackethal, S., "The Blaschka models of the Humboldt University of Berlin and their historical context", Historical Biology, Volume 20, Issue 1, 2008, pages 19-28.

[20] Henry, L., Sankaranarayanan, S., "Intelligent Agent based Mobile Learning System", International Journal of Computer Information Systems and Industrial Management Applications (IJCISIM), ISSN: 2150-7988 Vol.2 (2010), pp.306-319, http://www.mirlabs.org/ijcisim

[21] Kratky, A., "Re-Viewing 3D – Implications of the Latest Developments in Stereoscopic Display Technology for a New Iteration of 3D Interfaces in Consumer Devices", Advances in New Technologies, Interactive Interfaces and Communicability ADNTIIC 2010, edited by Cipolla-Ficarra, F. et al. LNCS, Springer, Berlin, Heidelberg, 2011

Author Biographies

Andreas Kratky Born in Berlin, Germany, Andreas Kratky lives and works in Berlin and Los Angeles. He holds a BA and MFA degree in Visual Communication from the University of the Arts in Berlin. Andreas Kratky is a media artist and visiting assistant professor in the Interactive Media Division of the School for Cinematic Arts of the University of Southern California. His work comprises several award winning projects like the interactive installation and DVD "Bleeding Through – Layers of Los Angeles 1920-1986", the algorithmic cinema system "Soft Cinema", the interactive costume projection in the opera "The Jew of Malta" and the interactive installation and DVD "Vorstoß ins Innere".

Previously Andreas Kratky has worked in the ZKM | Center for Art and Media in Karlsruhe, Germany, where he was the head of the Multimedia Studio. He also worked as a member of the research initiative "Labyrinth Project", an organized research unit of the University of Southern California, where he designed the installation and interactive DVD "3 Winters in the Sun – Einstein in California". Working with the research initiative "Anarchive", an organized research unit of the University of Paris 1, Pantheon-Sorbonne, he designed the interactive DVD "Title TK" in collaboration with the French theorist and video artist Thierry Kuntzel.

Besides numerous works published as interactive media on DVD and in art catalogues, Kratky has published his research work in human computer interaction, interface design, and the didactic use of interactive media.

Kratky has won several awards for his work and held residencies in the ZKM in Karlsruhe, Germany, and the Baltic Center for Contemporary Arts, Gateshead, UK