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User-Centered Design of Immersive Research Applications for Understanding Written Artefacts

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Abstract

Writing is an essential cultural technique that shaped our world's societies and is an important cultural heritage. The Cluster of Excellence 'Understanding Written Artefacts' is an interdisciplinary and cross-cultural long-term project dedicated to studying so-called 'Written Artefacts (WA)', which include all sorts of objects on which visual signs are applied by hand. Through our work, the research field of human-computer interaction is represented in the Cluster for the first time.
This paper introduces our interdisciplinary research on immersive applications for understanding WA. We motivate the usage of virtual reality (VR) technologies for the novel field of WA research, in which we explore new immersive ways of studying WA. Currently, only fieldwork provides the spatial context to the WA in the inscribed spaces. Immersive applications could provide researchers with virtual access to the spatial and even temporal context at any time, but so far, VR has not been used in academia for this use case. We developed two immersive VR systems with a user-centred design approach in close cooperation with academic experts from ancient history, classical archaeology, and theology, among other fields. Our VR systems visualize WA with their temporal and spatial context and provide additional content such as reconstructions, hidden layers, and meta information. Our tool was developed for two different application scenarios, (1) a large outdoor scenario of the ancient Roman theatre of Miletus, and (2) an interior scenario of the church at the Rittergut Lucklum.

CCS Concepts

• ***Human-centered computing*** → ***Human computer interaction (HCI);*** *Interactive systems and tools; User centered design; Virtual reality;*

1. Introduction

Writing is an essential cultural technique that shaped our world's societies. 'Written artefacts (WA)' is a concept being developed at the Cluster of Excellence 'Understanding Written Artefacts (UWA)' at Universität Hamburg. It is a cover term for *all* objects produced by human beings on which visual signs are applied by hand. Due to the importance of WA as cultural heritage, increasing efforts are made to catalogue, digitize, and provide access to the vast quantities of WA from all regions of the world [Bau, SR19, Liu19].

The Cluster is an interdisciplinary and cross-cultural long-term project for investigating the impact of WA on human societies and cultures. Our work introduces the field of HCI to the Cluster for the first time. We investigate how immersive technology can benefit WA research. So far, virtual reality (VR) technology has not been used in academia for analysing and understanding WA with a focus on the spatial and temporal context. Currently, researchers from the humanities only have access to the 3D spatial context of the WA in the inscribed space while doing field work. Otherwise, the researchers rely on 2D documentation such as notes and photos for their work. We apply a user-centred design (UCD) approach to develop immersive research applications which provide spatial context for researching WA outside of the actual inscribed space. Moreover, these applications allow us to add temporal context through the visualization of former structures and layers.

This paper is an introductory work which outlines our UCD approach and initial development process and serves as a basis for our future investigations on immersive WA. In collaboration with academic experts from the humanities, two VR applications were developed based on the following scenarios involving inscribed spaces:

1. A large-scale outdoor scenario of the ancient theatre of Miletus in Asia Minor, and
2. the interior of the church at the Rittergut Lucklum in Germany.

2. Related work

Virtual reality technologies have been used in research for more than 25 years. Due to the technological advancements and increased availability of head-mounted displays (HMDs) in the last

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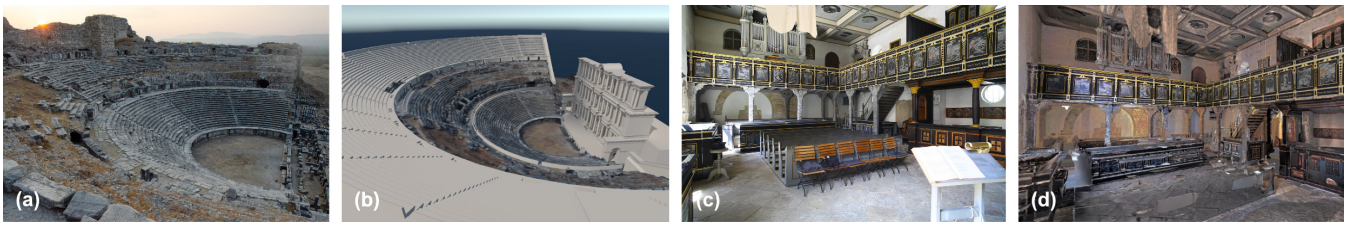

Figure 1: *Real and virtual versions: (a) theatre of Miletus (©A. L. Osthof, C. Berns), (b) 3D model of theatre with reconstructions, (c) interior of the church in Lucklum (©J. A. Steiger), and (d) 3D model of the church's interior.*

few years, VR has been increasingly attracting new target groups of users, which created novel use cases with specific requirements [Ste16]. Cipresso et al. [CGRR18] conducted a literature analysis in 2018 and found over 21,000 scientific articles on VR: While most publications still come from the field of computer science, an increase in VR related publications in other, previously not represented fields was observed in recent years. The latest projects in the field of digital heritage include the ongoing Ganjali-Khan research initiative that will use 3D scanning and VR technologies for documenting large historical landmarks [BLK20]. Research in digital preservation and production of virtual heritage spaces [HLH21, WWC19, WWYC18] explores how to digitally preserve and expand access to cultural heritage sites with immersive technologies. There is also the emerging research area of digital epigraphy, which explores the digitalization of inscriptions and the development of appropriate digital tools, practices, and new methodologies, including the application of virtual and augmented reality [SR19, BB17, Bar13].

'The VR Book - Human-Centred Design for Virtual Reality' by Jason Jerald [Jer15] describes how the VR community started to turn toward human-centred design in the 2000s. In order to understand the user's needs and get user feedback, well-established UCD methods in the field of HCI such as focus groups, interviews, and empirical usability evaluations can also be applied to VR development [Jer15]. In the context of VR preservation and heritage tourism, there are first projects which apply a user-centred design approach [BBM17, PVM*20].

To summarize, immersive technologies have come a long way in the domain of cultural heritage and archaeology and have recently also been used in the digital epigraphy community. To date, however, there are no available VR applications that focus on the spatial and temporal context in an interactive immersive environment for Written Artefact research, which have been developed with a UCD approach.

3. Understanding Written Artefacts

The Cluster of Excellence 'Understanding Written Artefacts: Material, Interaction and Transmission in Manuscript Cultures (UWA)' is part of the 'Centre for the Study of Manuscript Cultures (CSMC)' at the Universität Hamburg. Established in 2019, the cluster is dedicated to investigating so-called 'Written Artefacts (WA)', which is a cover term for *all* objects produced by human beings on which visual signs are applied by hand, such as manuscripts from shopping lists to copies of literary works (see definition [LBB*15]) and inscriptions ranging from kingly dedications to anonymous graffiti. The Cluster follows a holistic and interdisciplinary approach with close collaboration of more than 120 academic experts from across the humanities, natural sciences, and computer science.

The Cluster is structured into five research fields. We are part of two interdisciplinary projects within the research field *Inscribing Spaces*, in which we investigate how immersive technology can be used in Written Artefacts research and how researchers interact and process information in immersive research environments. With our work, the field of HCI is represented in the Cluster for the first time.

4. Scenarios

4.1. Inscriptions and Construction of Social Spaces in Miletus

This large-scale outdoor scenario focuses on inscriptions in the ancient theatre of Miletus (Asia Minor) (Figure 1(a)) from the Greco-Roman period, which range from hastily engraved graffiti to carefully carved letters. The particular text, formal design, material, and location of these inscriptions reveal the spatial construction of the public space. This project involves perspectives and methods from classical archaeology, epigraphy, ancient history, and HCI. Over 300 inscriptions and other incised signs of usage will be comprehensively recorded, digitized and made available in VR for the first time.

4.2. The Interior of the Church in Lucklum

The church in Lucklum (Germany) houses a collection of 209 Latin inscriptions and 156 emblematic paintings from the early eighteenth century (Figure 1(c)), collected and published by Steiger et. al [SSA20]. This indoor scenario is dedicated to documenting and historically contextualizing the inscriptions and paintings. Moreover, earlier, hidden layers in these artefacts will be scanned and uncovered for the first time. The church's interior will be digitized and the WAs, including the uncovered layers, will be made accessible in VR. The project examines constellations of the WAs and how they structure the church's interior as a space of meditation and prayer. It involves researchers from the fields of theology, literature, art history, materials science, and HCI.

5. User-Centred Design Approach

Following a UCD approach was essential in both projects since none of the mentioned scholars had previous experience with VR,

gaming or using game controllers and thus, had little to no experience with 3D input, navigation and interaction techniques. This approach allowed us to analyse and understand the scholar's needs, define requirements for an immersive research focused application, and actively involve our end-users. We worked closely with them in each phase of the design and development process and held weekly to bi-weekly as well as larger monthly meetings. Due to the COVID-19 pandemic and the contact restrictions, the meetings could only be held digitally in the video conferencing tool Zoom. After our first six months of development, our current iterative approach and the resulting implementations are outlined below.

5.1. Requirements Analysis

We conducted a task analysis in order to understand current workflows in WA research, where we made observations on site and conducted expert interviews with academic experts from both projects. Current research methods are mainly analogue and involve work on-site, referencing existing literature, doing archival work, and recording information digitally as notes and photos. The scholars reported that although their work on-site happens within a spatial 3D context, everything else happens in 2D. Since there are no dedicated tools for digitizing, visualizing and analysing the recorded data, software such as Microsoft Excel, PowerPoint or Adobe Illustrator are used to create 2D representations and document the WA information. The only method for documenting 3D properties of the inscriptions themselves is to create reverse copies with paper, so-called squeezes. However, there are no tools for spatially visualizing the inscriptions with their position and arrangements in their inscribed space. By using VR technologies, the researchers expect to gain spatial access for analysing their data when they are not working on-site. Based on the analysis, we identified requirements and potential features for the VR application, with a focus on providing spatial access for viewing and analysing the WA. The most important requirements for an immersive application include the realistic representation of both spaces, the correct localization of the WA, and the display of meta-information in 3D space, such as translations, categorization and descriptions. Furthermore, overlays for visualizing the hidden layers of the emblematic paintings in Lucklum and 3D reconstructions of former structures in the theatre of Miletus were requested, which would provide additional temporal context for the WA.

For each scenario, we provided Oculus Quest 2 HMDs with our pre-installed applications to a part of the involved scholars 2. This enabled them to experience VR and gain a basic understanding of the advantages and potential of this immersive technology. In subsequent brainstorming sessions, we defined new requirements such as filtering, highlighting and comparison functions for the Written Artefacts.

5.2. Conceptual Design

Since there are no established patterns for designing interactions in research applications for analysing Written Artefacts in VR, we based our first prototype on common patterns and techniques found in VR games and applications [Jer15]. While the theatre in Miletus is a large and open outdoor space, the church's interior is a relatively small, enclosed space. The contrasting properties of both

Figure 2: *Written Artefacts researcher using the Oculus Quest 2*

spaces bring different challenges for designing VR interactions, which resulted in adaptive solutions for the interaction range and the display of information.

We chose to use a ray-based pointing pattern for selection interactions since it also performs well for selections beyond personal space [Jer15, Bow99]. As this pattern is based on the laser pointer metaphor, we assumed that even users with no prior VR experience would be able to derive the corresponding mental model [Jer15, Nor13] for this selection technique.

For locomotion, we chose two patterns: (1) The 'Walking Pattern' based on real, physical walking with room-scale tracking [Jer15, SVCL13] for moving across small to medium distances and ensuring presence and ease of navigation in the virtual environment [UAW*99]. (2) The raycast-based 'Automated Pattern' for covering large distances via teleportation, which is combined with a screen fade to soften the instant relocation [Jer15]. Later on, we added specific teleportation spots for point of interests based on user feedback. The interaction range is adjusted according to the size of the respective virtual space.

Information on the WA are visualized with 2D panels based on the 'Widgets and Panels Pattern', which uses common 2D desktop widgets and metaphors and provide a good content structure [Jer15, LKM*17]. The panels contain a photo gallery, numbering, translations, and categories, among other information. In later iteration cycles, the main text area was changed into a collapsible component to make them more compact. The readability and user experience was improved by adding an adaptive billboarding behaviour to the panels. The panel's tilt and rotation changes according to the user's position, distance, and height. Together with the users, two different visualizations were chosen to mark the positions of the WA. They are also used as selectable elements for opening the information panels. As displayed in Figure 3, 3D pins shaped like the commonly known Google Maps pins are used in the theatre, while 2D markers resembling labelling used in museums are used in the church. Both visualizations were chosen to fit the users' mental model for marking locations and labelling objects in different types of environments.

5.3. Prototyping and Implementation

The applications are developed with the Unity engine, LTS Version 2019.4 and are built for the Oculus Quest 2, since the portable

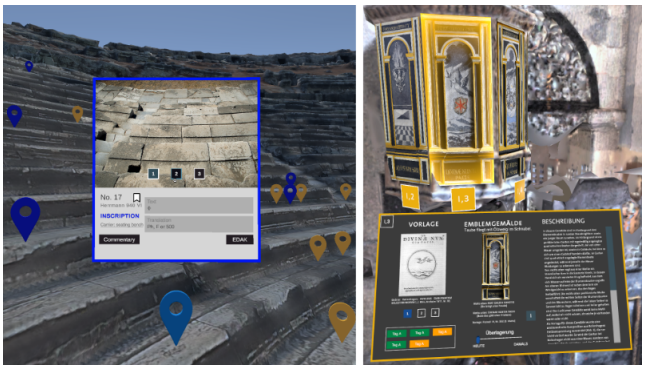

Figure 3: *left: 3D pins and infopanel on stairs of theatre, right: 2D markers at church's pulpit and infopanel with improved billboarding feature. (©photos A. L. Osthof & J. A. Steiger)*

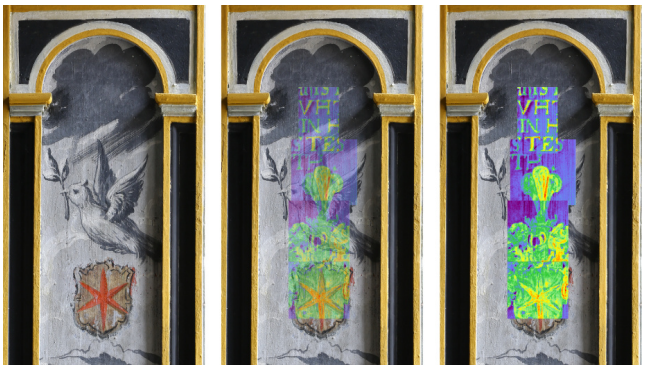

Figure 4: *Intensity images (©S. Bosch) of hidden layers overlayed on top of painting (©J. A. Steiger). left: no overlay, middle: 50% opacity, right: full opacity overlay*

and lightweight standalone HMD is an ideal entry-level VR device. Since it does not require additional hardware or complex setups to run, this allowed us to send out the HMDs to provide the academic experts with the VR experience during the pandemic.

The interactions and locomotion are implemented using Microsoft's Mixed Reality Toolkit (MRTK), so the apps can be easily ported to other HMDs in the future. The 3D models were created from data provided by our cooperation partners. The theatre in Miletus was created with photogrammetry based on drone images (see 1(b)), while point cloud data was used for the church in Lucklum (see 1(d)). Post-processing of the 3D data as well as meshing and texturing of both 3D models were done in the software Agisoft Metashape. The 3D reconstructions of former structures in Miletus were created in the software Blender and include the stage, the entire third tier, and the last rows in the first and second tier (see 1(b)). Small objects like the 3D pins were created in Blender as well. For the 2D markers and the information panels, world space canvases were used. The hidden layers in the emblematic paintings are implemented as sprite overlays in the information panels and on the paintings in the virtual environment itself. Their opacity can be freely adjusted by the user, as shown in Figure 4.

The research results are documented as Excel spreadsheet which can be loaded into our internal Unity database. The data is used to automatically create and place information panels and fill them with the specified content for each inscription and emblematic painting.

6. Evaluation

Evaluation is a core element of the UCD approach, and we will continuously get user feedback and involve users in evaluations during the further development of the applications. We are currently preparing our upcoming user study. Initial feedback from a small sample of users has been positive regarding the spatial context of the WA in the VR applications.

7. Conclusion and Future Work

In this paper, we described our UCD approach for two interdisciplinary projects in which we worked with academic experts from the humanities to create immersive VR applications for the novel field of WA research. Close collaboration combined with the use of the Quest 2 HMD facilitated and encouraged user engagement and enabled users to view the WA in a spatial context. The researchers who could try out the applications in VR were open to give detailed feedback, make suggestions, and contribute further ideas. At the current stage of development, the applications already include 3D models of the inscribed spaces with examples of reconstructions and uncovered hidden layers, as well as first marked locations of the WA with information panels.

In the next step, we will conduct systematic user studies to validate whether VR has added value for WA research compared to non-VR applications and evaluate the usability and UX. Our current work and implementation serves as a foundation for our future investigations and allows us to collaboratively develop and test these research focused VR applications.

In future work, we will further explore the potential benefits of using immersive technologies in WA research and develop immersive research tools together with academic experts from the humanities. Furthermore, we will investigate and implement adaptive interaction and locomotion techniques such as distance- and size-independent object selection and redirected walking [SVCL13, Ste16, LLBS17] and work on responsive design for the interface. With our work, we hope to provide useful implications for future research-focused VR projects in novel fields.

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References

[Bar13] BARMPOUTIS A.: Digital epigraphy toolbox. *Humanities Commons* (28-Feb 2013), 11–Jan. doi:http://dx.doi.org/10.17613/M64W9R. 2

[Bau] BAUSI A.: Beta masaheft: Manuscripts of ethiopia and eritrea. Website. Hiob Ludolf Centre for Ethiopian Studies, Universität Hamburg. doi:10.25592/BetaMasaheft. 1

[BB17] BOZIA E., BARMPOUTIS A.: Augmented reality for epigraphy: How to bring holograms of inscriptions to your classrooms. *CIEGL17: 15th International Congress of Greek and Latin Epigraphy* (28-Aug 2017). 2

[BBM17] BARBIERI L., BRUNO F., MUZZUPAPPA M.: User-centered design of a virtual reality exhibit for archaeological museums. *International Journal on Interactive Design and Manufacturing (IJIDeM) 12* (2017), 561–571. doi:10.1007/s12008-017-0414-z. 2

[BLK20] BOZORGI K., LISCHER-KATZ Z.: Using 3d/vr for research and cultural heritage preservation: Project update on the virtual ganjali khan project. *Preservation, Digital Technology & Culture 49*, 2 (2020), 45–57. doi:10.1515/pdtc-2020-0017. 2

[Bow99] BOWMAN D. A.: *Interaction Techniques for Common Tasks in Immersive Virtual Environments*. PhD thesis, Georgia Institute of Technology, 1999. 3

[CGRR18] CIPRESSO P., GIGLIOLI I. A. C., RAYA M. A., RIVA G.: The past, present, and future of virtual and augmented reality research: A network and cluster analysis of the literature. *Frontiers in Psychology 9* (2018). doi:10.3389/fpsyg.2018.02086. 2

[HLH21] HONG Z., LEILEI W., HEQING Z.: The application of virtual reality technology in the digital preservation of cultural heritage. *Computer Science and Information Systems 2021 18*, 2 (2021), 535–551. doi:10.2298/CSIS200208009Z. 2

[Jer15] JERALD J.: *The VR Book: Human-Centered Design for Virtual Reality*. Association for Computing Machinery and Morgan & Claypool, 2015. doi:10.1145/2792790. 2, 3

[LBB*15] LORUSSO V., BAUSI A., BONDAREV D., BRITA A., BROCKMANN C., CIOTTI G., FRIEDRICH M., ISAACSON H., KAROLEWSKI J., QUENZER J. B., SAMSOM R., VALENTE S., WILDEN E., WIMMER H.: Searching for a definition of "manuscript". Occasional Paper, Mar. 2015. Universität Hamburg. URL: https://www.csmc.uni-hamburg.de/publications/occasional-papers/files/csmc-occasional-paper-1-lorusso-et-al.pdf. 2

[Liu19] LIUZZO P. M.: Eagle continued: Idea. the international digital epigraphy association. In *Crossing Experiences in Digital Epigraphy*, Santis A. D., Rossi I., (Eds.). De Gruyter Open Poland, 2019, ch. 17, pp. 216–230. doi:10.1515/9783110607208-018. 1

[LKM*17] LAVIOLA J. J., KRUIJFF E., MCMAHAN R. P., BOWMAN D. A., POUPYREV I.: System control. In *3D User Interfaces: Theory and Practice (Usability)*. Addison-Wesle, 2017, ch. 9, pp. 562–615. 3

[LLBS17] LANGBEHN E., LUBOS P., BRUDER G., STEINICKE F.: Application of redirected walking in room-scale vr. In *2017 IEEE Virtual Reality (VR)* (2017), pp. 449–450. doi:10.1109/VR.2017.7892373. 4

[Nor13] NORMAN D. A.: *The Design of Everyday Things: Revised and Expanded Edition*. New York: Basic Books., 2013. 3

[PVM*20] POUX F., VALEMBOIS Q., MATTES C., KOBBELT L., BILLEN R.: Initial user-centered design of a virtual reality heritage system: Applications for digital tourism. *Remote Sensing 12*, 16 (2020). doi:10.3390/rs12162583. 2

[SR19] SANTIS A. D., ROSSI I. (Eds.): *Crossing Experiences in Digital Epigraphy*. De Gruyter Open Poland, 2019. doi:10.1515/9783110607208. 1, 2

[SSA20] STEIGER J. A., SCHILLING M., AREND S.: *Sinnbilder im Sakralraum. Die Kirche in Lucklum – Ein Kompendium der geistlichen Emblematik der Frühen Neuzeit.* Schnell & Steiner, 2020. 2

[Ste16] STEINICKE F.: *Being Really Virtual - Immersive Natives and the Future of Virtual Reality*. Springer International Publishing, 2016. 2, 4

[SVCL13] STEINICKE F., VISELL Y., CAMPOS J., LÉCUYER A. (Eds.): *Human Walking in Virtual Environments - Perception, Technology, and Applications*. Springer, New York, NY, 2013. doi:10.1007/978-1-4419-8432-6. 3, 4

[UAW*99] USOH M., ARTHUR K., WHITTON M. C., BASTOS R., STEED A., SLATER M., BROOKS F. P.: Walking > walking-in-place > flying, in virtual environments. In *Proceedings of the 26th Annual Conference on Computer Graphics and Interactive Techniques* (1999), SIGGRAPH '99, p. 359–364. doi:10.1145/311535.311589. 3

[WWC19] WOOD Z. M., WILLIAM A., COPELAND A.: Virtual reality for preservation: Production of virtual reality heritage spaces in the classrooom. In *3D/VR in the Academic Library: Emerging Practices and Trends*. Council on Library and Information Resources, 2019, ch. 3, pp. 39–53. URL: http://hdl.handle.net/1805/23685. 2

[WWYC18] WOOD Z. M., WILLIAM A., YOON A., COPELAND A.: Virtual bethel: Preservation of indianapolis's oldest black church. Research Methods for the Digital Humanities. Cham Palgrave Macmillan, 2018, ch. Wood Z.M., William A., Yoon A., Copeland A., pp. 195–210. doi:10.1007/978-3-319-96713-4_11. 2