Handheld vs. Head-Mounted AR Interaction Patterns for Museums or Guided Tours

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Abstract. In recent years, Augmented Reality (AR) technology has been adopted in various fields. The development of handheld devices (HHD) such as smartphones and tablets gives people more chances to use AR technology in their daily lives. However, AR applications using head-mounted devices (HMD) such as Microsoft HoloLens or Magic Leap provide stronger presence experiences than HHD, so that users can immerse themselves better in AR scenarios. While currently there already exist prototypical examples of HMD in museum contexts, widely used interaction patterns are not yet well established, although they would play an important role for accessibility by large user groups. This paper explores existing and potential interaction patterns for guided tours in museums, led by the question how to reconcile AR interaction patterns on HHD and HMD. We use an existing museum showcase for handheld AR from the project "Spirit" to transfer its interaction patterns to an HMD, such as the MS HoloLens. Technical constraints and usability criteria regarding the potential overlaps and applicability have been analyzed in this paper.

Keywords: Augmented Reality · Handheld devices · Head-mounted devices · User interaction patterns · User experience design · Cultural heritage

1 Introduction

In recent years, smart technologies have changed not only working environments, but also private use of gadgets for living and entertainment. For example, the emergence of Augmented Reality (AR) technology evoked higher expectations for visit experiences in museums and exhibitions. However, while people benefit from new technologies, they are also under pressure to use them properly. Therefore, providing reasonable and understandable interfaces and interaction patterns to enhance the usability of AR devices is important, especially for laypersons.

For tour guide applications and storytelling in a cultural heritage context, such as in a museum, AR applications have been researched for decades and recently already produced for the App market. Most of these applications are developed for handheld devices (HHD) like smartphones or tablets, which are available off-the-shelf. However, head-mounted devices (HMD) such as Microsoft HoloLens or Magic Leap provide a much stronger immersive presence experience than handheld AR, while more directly

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exploring the digitally enhanced natural environments, making use of more integrated sensors, including gesture and speech input. Thus, although HMD-AR so far has been successfully applied mainly to hands-free maintenance and assembly support applications, there is only little established common-sense regarding interaction patterns for guided tours. There is a gap between existing scenarios of handheld AR for laypersons and head-mounted AR for professional work, which still needs further investigation.

Our applied research goal in the long run is to develop AR content that can be shared between HHD and HMD. The contribution in this paper is to first identify possible interaction patterns for both HHD and HMD by analyzing their interaction styles and technical affordances based on cultural heritage related use cases. Further, we use an existing museum showcase for handheld AR to discuss the possibility and challenge of transferring its interaction patterns to a head-mounted AR device like the HoloLens. We analyze technical constraints regarding their potential overlaps and applicability and identify gaps for further research.

2 State of the Art

AR technology has been investigated by various industries in the past decades. Marker-based AR technology is widely used on handheld devices; its technical solutions of mixing the digital content with the real world are successfully explored in entertainment [1], production [2] and cultural heritage context [3]. One step in the development of AR applications is interaction design. Pattern approaches have been taken by many software developers and designers to identify and solve problems in the development phase [4–6]. For AR based guided tour applications, many researchers explored the potential possibilities of AR technology in the cultural heritage context with HHD [7]. However, HMD interaction design approaches are not yet sufficiently explored in this application area. While it is often postulated that HMD-based AR enriches user experience by engaging and motivating their imagination through interactive storytelling, gaming and learning [8], there are not many prototypes nor design guidelines that can be used if a new project starts. The technology potential of HMD for cultural heritage recently just gains interest in avant-garde artistic research projects [9, 10], while general interaction patterns are not discussed yet in these.

This paper is concerned with comparing interaction patterns used in exhibitions, museums, or cultural heritage learning, exploiting the possibilities of the HoloLens. In Sect. 3, we compare interaction styles and technical solutions of both HHD and HMD based on cultural heritage related use cases. In Sect. 4, we use an existing showcase from the “Spirit” project [11] to analyze the possibilities of transferring its digital content from HHD to HMD.

2.1 Interaction Patterns

Although many researchers believe that so-called natural user interfaces can ease difficulties to use a new product, people often still must learn basic interaction methods when facing a new interface. [12] Thus, as HHD-based AR applications become more and more popular in daily life, providing understandable interfaces and more widely-used interaction patterns for laymen has become an important topic for development teams.

The first pattern theory was introduced by Christopher Alexander in the 1970s. The purpose of his pattern language was to provide laypersons with a vocabulary to explain their ideas and designs, and to communicate with professionals in the architecture domain [13]. Baltzer et al. adopted the pattern theory from Alexander for their interaction pattern analysis. They point out that patterns are approved solution strategies to repeat known problems and describe the core of the solutions in a way that can be used repeatedly in our daily life [4]. Thus, from the conclusion of Baltzer et al., creating an interaction pattern requires application designers to identify repeatable problems and solutions from a certain task.

In general, the user manipulates the interface with certain interaction styles such as click, swipe, pinch, etc., and it often requires a sequence of repeatable manipulations to finish a specific task. As a pattern offers a vocabulary to explain the problem and solution, an understandable interaction pattern can for example offer a meaningful metaphor that helps users to remember multiple complex manipulations [14].

Understanding use cases can also help designers and software developers to invent new interaction patterns. Constantine [15] points out that from the view of software developers, use cases guide the design of communicating objects to satisfy functional requirements, and use cases provide a straightforward and logical means for modeling workflow. Rumbaugh [16] also indicates that a use case is a sequence of actions, including variant sequences and error sequences. Therefore, we conclude that interaction patterns offer meaningful metaphors to explain the actions within use cases.

In AR application design, actions within use cases are mainly formulated by physical interaction styles and technical solutions. For instance, users need to understand whether they should tap on a screen or move their device to finish a certain task, and, if they will use marker recognition or location detection to activate the digital content. Thus, to create a meaningful metaphor for an interaction pattern, related interaction styles and technical solutions of both HHD and HMD must be explained at the beginning.

3 Comparing Interaction Styles and Technical Solutions of HHD and HMD with Cultural Heritage Use Cases

Research results from Constantine [15] and Rumbaugh [16] suggest that workflows of use cases are often differentiated by different technical solutions. Besides, interaction styles are another important factor that influence the workflow [15]. Therefore, interaction styles and technical solutions from both HHD and HMD will be discussed in the following.

3.1 General Interaction Styles of HHD and HMD

Since smartphones become popular in our daily life, screen-based interactions have been investigated by many researchers. For the handheld device, the user interacts with digital content mainly via press (touch), swipe, pinch, etc. The HMD (such as the HoloLens) offers new interaction styles to manipulate 3D content. According to the Microsoft Mixed Reality design guideline [17], three interaction models have been proposed for developers: hands and motion controllers, hands-free, and gaze and commit. The user interacts with the digital content via various gesture controls such as “air tap”, “tap and hold” or with voice input like saying “select” or “back”. Yet the different interaction styles from HHD and HMD may share similar manipulation actions in the same task. For example, while the user manipulates digital content on a tablet by "touch" and select, on HoloLens the user will use “air tap” for selection instead. Other important hardware aspects are that the HoloLens and tablet (depending on its configuration) may indeed share some of their internal equipment and sensors, such as a display, sound in/output, camera, and movement tracking/gyroscope. Each platform has specific hardware solutions and restrictions that influence the potential implementations of interaction styles (see Fig. 1).

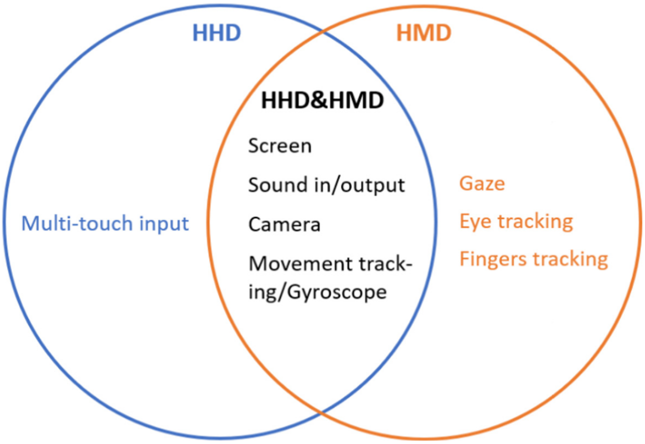

Fig. 1. Overlaps and differences in hardware design relevant for interaction.

Although the HoloLens provides different interaction styles such air tapping and air scrolling, these interaction styles share similar logical input methods with those from a tablet. Thus, it should be possible to adopt at least some use cases from a tablet for a HoloLens. However, the HoloLens also offers new input methods, for example “Gaze and Dwell” by analyzing head position and gaze direction. For a specific use case such as selecting an object in 3D space, the HoloLens then provides more options to manipulate digital content.

3.2 Technical Solutions of Mixing Virtual Objects with the Real World

Augmented Reality is able to integrate the perception of interactive 3D virtual objects within the impression of users’ real surrounding environments in real-time [18]. Marker recognition is just one solution to trigger and position AR content within the physical world. To get an overview of the existing market solutions of mixing digital content with the physical world for HHDs, we recently compared and tested 80 popular AR applications with several kinds of categories from App stores.

The result shows the following: Out of 80 applications, 29 used visual marker recognition to trigger content; for example the OTE Museum AR application shows further information about an artefact when the marker is triggered by the camera. 4 applications used face recognition to show AR content; for instance, Instagram uses face recognition to overlay virtual effects once a face is identified. 36 applications used surface detection to let users place AR content by tapping on the screen, while the camera is directed at (mostly) horizontal planes; one example is IKEA Place that requires user to identify a suitable surface to place digital furniture augmenting their home. 11 applications used location detection; such as Car Finder AR that shows a 3D icon to guide the user to the parking place. Table 1 provides an overview.

Table 1. Four technical solutions to apply AR content on HHD

Technical solution	Steps	Example application
Marker recognition	1. Activate the camera 2. The camera focuses on the target marker (or Image) 3. Showing related digital content	OTE Museum AR [19] (Showing virtual object in the real world)
Face recognition	1. Activate the camera 2. The camera focuses on a face 3. Add digital content on the face	Instagram [20] (Add filters or masks on the face)
Surface detection	1. Activate the camera 2. The camera focuses on a flat surface 3. Confirm the flat surface 4. Showing the digital content	IKEA [21] (Select an efficient surface to place the digital content)
Location detection	1. Activate the GPS sensor 2. Detect and calculate the distance 3. Towards the target destination 4. Showing the related digital content	Car Finder AR (Navigation system)

The table above shows four principles of activating and placing AR content on the HHD. With surface detection, the application requires the user to pick up a relatively empty surface to place AR content. Mostly no other specific sensor is required for this solution, as users will place digital content manually. With marker recognition, when image recognition software recognizes a pictorial marker through the camera, the system activates digital content staying registered to that marker. Face recognition works similar, in that once a face pattern is recognized, digital content will be overlayed on the detected face. Locative applications work with distance and location sensors, such as GPS, WiFi or beacons, triggering content when the user gets close to a specific hot spot created during an authoring process.

The HoloLens shares many of these technical solutions for activating and registering AR content, documented in the Microsoft Mixed Reality design guideline [17]. However, the HoloLens does for example not offer GPS in its hardware unit, which means, it is comparably difficult to implement outdoor location detection on the HoloLens as easily as on HHD. Therefore, developers may need to use other technical solutions to implement location detection related use cases. Besides, for placing AR content on a horizontal surface, the HoloLens provides different (and better) solutions than most HHD. The HoloLens uses SLAM technology including room scanning, scene understanding, spatial anchors, spatial mapping, etc. to integrate digital content with the physical world [17]. For instance, the camera sensors on the HoloLens scan the environment consistently and convert the acquired spatial data to an updated digital 3D environment. Based on its unique spatial mapping algorithm, digital content can be automatically anchored to this newly created digital 3D environment.

To sum up, compared with HHD solutions, the HoloLens provides different options, such as spatial mapping algorithms and hand gesture tracking, to allow users operating the AR content. Thus, creating an understandable and reasonable interaction pattern on HoloLens, developers need to combine the advantages of its specific interaction styles and AR-specific technology.

3.3 Identifying General Repeatable Use Cases in a Museum Visit

One goal of this paper is to explore shared potential interaction patterns for both HHD and HMD in a cultural heritage context. To start, we identified typical repeatable use cases from general museum visits.

Visiting processes and user behaviors in museums have been focused on by many researchers. Litvak proposed two states for their interface design based on the visitors' guiding process (compare Fig. 2). When visitors position themselves within the boundaries of a point of interest (POI), all relevant information concerning this POI will be presented within the visitors' view. When attendees leave one POI and return to the main path, the system will change to a navigation state [3]. In general, the digital content of a guided tour includes multiple locations and information about various artefacts. In a tour, visitors may explore artefacts in a certain sequence or by searching for certain POIs to get through an exhibition. We identified an overall visiting pattern with two alternating use cases, based on the exploring behavior in museums which can be further investigated for potential use cases in the cultural heritage context.

3.4 Current Interaction Patterns in a Cultural Heritage Context

Most guided tour applications have focused on the two modes shown above, whereas recently, especially those in the state of current AR research prototypes, may only offer the "exploring" mode. This may be because most research publications are still concerned more with the technical functioning of the AR-related prototype (like tackling the problems of tracking accuracy) than with the overall end-user experience. For example, Chiu et al. [22] proposed an AR guiding system on HHD to guide visitors to walk through the Baoan Temple. The prototype uses marker recognition for showing a virtual object. The visitor first focuses on a mural art piece with the camera. Once the system recognizes the content, more detailed information about the art piece will be triggered and be shown to the visitor. However, the system does not include a navigation function, therefore the visitor must tap on the smartphone screen to operate further visit flows.

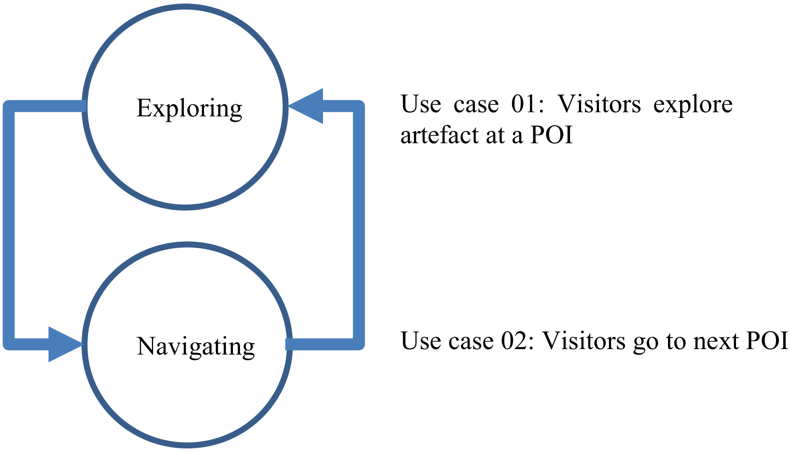

Fig. 2. Visiting pattern of a general museum visit.

Hammady et al. [8] introduced a system loop in the prototype for their museum guidance system "Museum Eye" to test and evaluate the design integrity. The prototype works with a HoloLens and it consists of three stations and other nine stops in the tour. Once the visitor triggers one station, a scene will be generated and mapped on top of the physical environment. Visitors will explore different scenarios without a predefined specific order, so that they receive an authority to control and jump from one scene to another.

Unlike the above, Litvak [3] proposed a guiding system for smart glasses based on location-dependent interactions. Once the user arrives at one POI, related information will be triggered and shown to the user. The system includes both a wearable and a handheld device. The user will follow AR navigation marks (e.g. arrows) popping up in the view to find the way between POIs. When the user arrives at a POI spot, an audio alert will be triggered on arrival. Further, additional information regarding each POI will be presented to the user.

For many "real" cases found in app stores for specific museums that are designed for smartphones, QR markers or similar signs are positioned in the physical environment. Users have then the task to find and move towards the sign, as well as point their camera at it, to access further information. Since we can expect a broader user community to easily get familiar with this pattern, it is often repeated. However, not only technical functioning and interaction patterns affect the visiting experience, as the thematic background of exhibitions and use cases from storylines may also influence the expectations of visitors.

There are only a few experimental projects yet on usable/end-user tested HMD guided tour or museum applications, although some of the very first seminal research endeavors in AR combined HMD and cultural heritage, such as Touring Machine [23] and Archeoguide [24]. However, because of their feature for hands-free interaction, in the following HMD have preferably been developed towards professional industrial applications, mainly in the fields of maintenance or assembly. Currently, the penetration of consumer markets with smartphones and tablets is another reason to use these in museums, which is a matter of accessibility. However, users more and more are fascinated by the experience of immersion and presence that new hardware products like the Microsoft HoloLens or Magic Leap can offer.

Brancati et al. [25] performed a usability study with end-users in a Naples city tour with an HMD, while Hammady et al. [8], who designed a tour with the HoloLens, pointed out that the current lack of existing knowledge in spatial UX made effective usability design a challenge.

In summary, there are too few projects with HMD in museums to already be able to see end-user interaction patterns emerge that can be reused widely. Therefore, our goal is to design and research potential suitable interaction patterns. Further, since handheld AR in museums will most certainly not be replaced by HMDs, we see the necessity to develop guided tour content only once and use it on both kinds of devices. Resulting interaction patterns would need to be reconcilable across both platforms.

4 Transferring Digital Content from Tablet to HoloLens 2

As a start, in order to explore the applicability of existing content designed for tablets and smartphones towards experiencing it on the HoloLens 2, we use a showcase built within the project "Spirit" [11]. The goal of this showcase was once described to achieve a feeling of "presence" [26] at a historical place, in this case a Roman Fort. However, the requirement was to use HHD target platforms (tablets) that were available off-the-shelf in 2016. The AR app placed re-enacted historical scenes of Roman village inhabitants between the mural remains that are still visible.

Although the HoloLens hardware is not optimized to be used in outdoor scenarios, we want to transfer this project to this HMD because of several reasons. First, we estimate a greater experience of "presence" for the encounter with the ghost-like impressions of the "spirits", and want to explore the chances and limitations of placing video characters into the real environment. Further, we estimate that future HMD may have enhanced features (e.g., GPS) and we use this experiment as a step into the future. Finally, we already have access to all the content and authoring elements of this previous project. The scenario is complete in the sense of providing a guided tour and providing suitable content (both general museum use cases of Navigation and Exploration), which allows us to experiment with all the necessary situations for users and explore limitations.

4.1 Example: Interaction Pattern in the Spirit Project

The showcase application from the "Spirit" project was designed to follow a metaphor of "magic equipment" in that interaction design and interactive narrative design were strongly intertwined [27]. The user had to track down the "spirits" of people that once lived by the Roman Fort, represented by filmed actors in historical costumes. While a fictional story built the backbone of the whole interaction, also factual knowledge in form of readable text should be made accessible. The user metaphorically had to find places that the main character of the story, Aurelia, remembered. In the meta-dialogue with Aurelia, she showed blurry memory outlines of buildings that the user had to go to in the following (called “stencils”). That way, several locations could be visited. The app used GPS and image recognition to trigger parts of the story, once the user has found the right position at the “next” location. Additionally, at each position, the user was urged to look around and experience the real environment, such as meaningful geographic directions or relationships to other places around. Using the gyro sensor of the tablet, the device tracked the user’s turning movement and thus triggered more “spirits” appearances to the left and to the right, which in total resulted in a pseudo 3-dimensional stage around the user. Because of the intended impression of “presence” of historical figures in the real environment, we assume that using a head-mounted device such as the HoloLens 2 would increase that feeling.

Figure 3 and Fig. 4 show example scenes of the Spirit application. While the app follows the main general visiting pattern explained in Sect. 3.3, it is structured into three modes. Only one of these provides the actual AR experience of an encounter with spirits. Apart from the navigation mode “Search”, there is also non-AR content displaying facts as readable text (mode “Read”). Thus, the Spirit concept separates re-enacted, partially fictional historical drama, which is the main AR content, from explanatory text that can be more conveniently read based on the users’ demand.

Figure 3 illustrates the three modes in the project “Spirit”:

1. Search (Fig. 3, left and middle)
2. Encounter (Fig. 4)
3. Read (Fig. 3, right)

Fig. 3. Spirit example showcase. Left and middle: “Search” mode with map and stencil (“memory image”). Right: “Read/Touch” mode to be used at the user’s convenience in between (non-AR content) [11].

4.2 Options for Transferring the Interaction Pattern from HHD to HMD

As mentioned in Sect. 2.1, to create a meaningful metaphor for an interaction pattern, it is necessary to evaluate both interaction styles and technical solutions in the Spirit

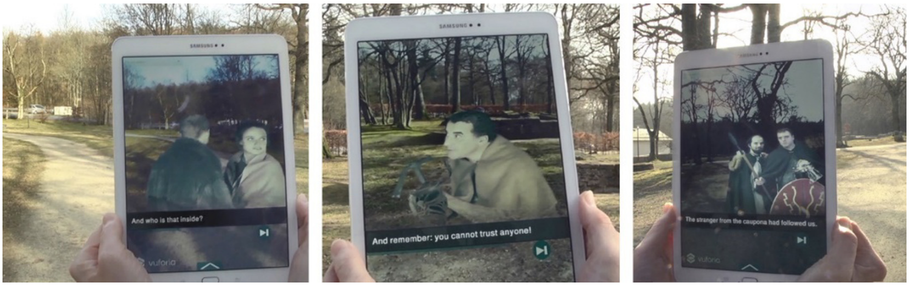

Fig. 4. Spirit example showcase. "Encounter" mode: One location with different characters to the left, front and right. GPS plus image markers trigger the first video of a scene. Users need to pan the tablet (turn around 90 degrees) between dialogue pieces to experience the whole scene. The gyro sensor triggers and starts further videos [11].

Table 2. Interaction styles and technical solutions in the Spirit project

Interaction styles	1. Touching on the screen to operate the application 2. Turning the tablet to left and right to trigger further hidden digital information
Technical solutions	1. GPS units for tracking real time location coordinates 2. Marker recognition for triggering digital information 3. Gyro sensor for triggering further digital information at the same location

application to analyze the possibility of transferring its interaction patterns from the tablet to a HoloLens 2 (see Table 2).

The Spirit concept involves several interaction styles and specific technical solutions of a HHD for its interaction patterns, which are not easily transferred to a Hololens. In the "Search" mode, it uses GPS for map navigation feedback as users know it from usual navigation tasks with a handheld. The second mode "Encounter" employs image recognition and events from the Gyro sensor to trigger film scenes with virtual characters surrounding the user (see Fig. 5). In the third mode "Read", the application runs by a familiar touch interaction to scroll text and operate a menu. Users hold the tablet horizontally, while they can also make a short break and sit down for reading.

The HoloLens provides different interaction styles compared to a tablet, although there are at least overlaps in the hardware configuration (see Fig. 1). Therefore, it is partly impossible or unsuitable to transfer the complete designed interaction pattern from the tablet to the HoloLens 2. For example, in the Read mode, it is technically possible to transfer the facts text from the tablet to the HoloLens, but not resulting in a familiar or convenient reading experience.

Further, the HoloLens has no built-in GPS, which means, the "Searching on the map" interaction pattern must be skipped or redesigned to adapt to other technical solutions. Instead of GPS navigation, the HoloLens uses SLAM technology to track the nearby environment consistently. This is acknowledged to work well for indoor activities, but

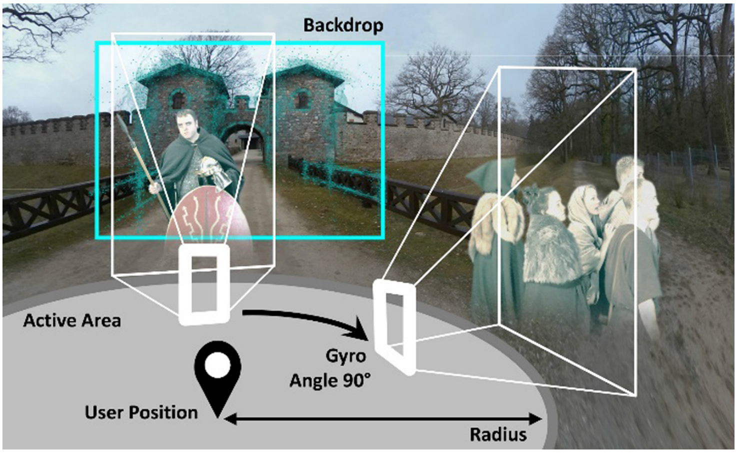

Fig. 5. Spirit triggers for the Encounter mode on the tablet (GPS, backdrop marker recognition, gyro sensor). [28]

only with limitations for outdoors, especially in unstructured environments without walls and for far distances. For the “Encounter” mode that needs recognition of a "backdrop" for a scene and changes in the users gaze direction, the HoloLens is also equipped with a RGBD-camera and gyroscope to support almost the same metaphors as on the tablet. Panning with the tablet to the left and right can be transformed so that users just turn their heads. However, if this is combined with triggering the starting videos, it feels unnatural and may cause physical inconvenience due to the repetition. It is also questionable whether this action is as intuitive as pointing a camera device explicitly into a certain direction for scanning. Currently, the implementation is ongoing work, while we also explore the limitations of so-called natural interfaces [12].

This study aimed at exploring the possibility of transferring interaction patterns from HHD to HMD. After analyzing the specific interaction patterns used within the Spirit project, we see the potential of implementing the same metaphor on the HoloLens in principle. It may save time and money to adopt existing video data from the tablet platform. However, the HoloLens offers more options, as it could offer an even stronger presence experience in that virtual characters could be shown in 3D. Visitors could be able to experience more immersive scenes with spirits, for example viewing a ghost who accompanies them flying through the building while communicating with the users. In contrast, in the Spirit project, all characters were realized as pre-recorded videos, as this was sufficient for the target platform, a 2D screen. The existing 2D videos could still be placed in the 3D environment at a decent distance to the viewer to have a similar “ghost” experience as in the Spirit project. However, one disappointing effect could be that visitors will think of it as “Fake” experiences, as there is no stereo effect and there is greater awareness of the two-dimensionality.

Therefore, in order to optimize the usability and user experience, based on interaction styles and the technical solutions of the HoloLens, novel interaction patterns should be designed when transferring the general concept from the tablet to HoloLens. This would also lead to the necessity to create new content, as it reduces reusability. New interaction patterns making use of gestural input need to be further explored, for example, “waving arms” or “snapping fingers” could remind at a wizard who is casting a spell. Further, because the HoloLens performs poorly for outdoor activities, conceiving outdoor use cases could be limited to a confined radius. Thus, the entire concept of the Spirit application would have to be adapted for optimum fit with the HoloLens.

5 Conclusion

In this paper, we lay the ground for our further research targeted at designing interaction patterns for HMDs like the HoloLens to be used in museum contexts or in guided tours, and which need to be compatible with interactions possible with current handheld AR devices. While we expect that users will experience much stronger feelings of "presence" with an HMD concerning visual AR overlays, some other requirements of museum tours, such as acquiring plain text information and map navigation, may need to be adjusted in specially designed interfaces.

While related work often focuses on solving mainly still challenging technical issues of AR, and there are too few HMD related projects with the focus on meaningful interaction patterns in the cultural heritage context, the state of the art is not ready yet to illustrate efficient interaction patterns for both HHD and HMD. However, from analyzing interaction styles and technical solutions of HHD and HMD, we conclude that although it is possible to transfer the interactive AR content from HHD to HMD, the interaction style of HMD like the HoloLens offers different input methods such as air tapping or air scrolling to manipulate the digital content. It is necessary to redesign new interaction patterns for HMD like HoloLens 2. For cultural heritage content, because of the lacking GPS sensor on HoloLens 2, outdoor-based use cases may not fit the HoloLens 2 well, or, this may require developers and designers to find other technical solutions such as using marker recognition for outdoor tracking.

In the future, museums and exhibitions may be visited with different devices at the same time. Therefore, future work is needed on reconciling the different worlds of HHD and HMD to design one content for several possible devices.

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References

1. Itzstein, S., Thomas, B., Smith, R.: Augmented reality entertainment: taking gaming out of the box. In: Lee, N. (ed.) Encyclopaedia of Computer Graphics and Games. Springer, Heidelberg (2017). https://doi.org/10.1007/978-3-319-08234-9_81-1
2. Zhang, Y., Kwok, T.: Design and interaction interface using augmented reality for smart manufacturing. Procedia Manuf. **26**, 1278–1286 (2018)

3. Litvak, E., Kuflik, T.: Enhancing cultural heritage outdoor experience with augmented-reality smart glasses. Pers. Ubiquit. Comput. **24**(6), 873–886 (2020). https://doi.org/10.1007/s00779-020-01366-7
4. Baltzer, M.C.A., López, D., Flemisch, F.: Towards an interaction pattern language for human machine cooperation and cooperative movement. Cogn. Technol. Work **21**(4), 593–606 (2019). https://doi.org/10.1007/s10111-019-00561-8
5. Fogli, D., Parasiliti Provenza, L., Bernareggi, C.: A universal design resource for rich Internet applications based on design patterns. Univ. Access Inf. Soc. **13**(2), 205–226 (2013). https://doi.org/10.1007/s10209-013-0291-6
6. Yuan, S.-T., Hsu, S.-T.: Enhancing service system design: an entity interaction pattern approach. Inf. Syst. Front. **19**(3), 481–507 (2015). https://doi.org/10.1007/s10796-015-9604-z
7. Bekele, M., Pierdicca, R., Frontoni, E., Malinverni, E., Gain, J.: A survey of augmented, virtual, and mixed reality for cultural heritage. ACM, J. Comput. Cultural Heritage (2018)
8. Hammady, R., Ma, M., Strathern, C., Mohamad, M.: Design and development of a spatial mixed reality touring guide to the Egyptian museum. Multimedia Tools Appl. **79**(5–6), 3465–3494 (2019). https://doi.org/10.1007/s11042-019-08026-w
9. Dixon, S.: Nomad project webpage. https://sophie-dixon.com/project/nomad. Accessed 11 Dec 2020
10. Woodbridge, P.: Immersive Storytelling Experiences, Research Symposium, https://www.curiousmagic.co.uk/immersive-storytelling-experiences. Accessed 11 Dec 2020
11. Spierling, U., Winzer, P., Massarczyk, E.: Experiencing the presence of historical stories with location-based augmented reality. In: Nunes, N., Oakley, I., Nisi, V. (eds.) ICIDS 2017. LNCS, vol. 10690, pp. 49–62. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-71027-3_5
12. Norman, D.A.: Natural User Interfaces Are Not Natural. Northwestern University, KAIST Industrial Design, Nielsen Norman Group (2010)
13. Alexander, C.: The Timeless Way of Building. Oxford University Press (1979)
14. Hey, J., Linsey, J., Agogino, A.M., Wood, K.L.: Analogies and metaphors in creative design. Int. J. Eng. Educ. **24**(2), 283–294 (2008)
15. Constantine, L.L., Lockwood, L.A.: Structure and Style in Use Cases for User Interface Design. Object-Modeling and User Interface Design: Designing Interactive Systems, pp. 245–279. Addison-Wesley (2001)
16. Rumbaugh, J., Jacobson, I., Booch, G.: The Unified Modeling Language Reference Manual. Chapter 5: Use Case View, pp. 63–64. Addison Wesley (1999)
17. Microsoft Design Guideline. https://docs.microsoft.com/en-us/windows/mixed-reality/interaction-fundamentals. Accessed 11 Dec 2020
18. Liarokapis, F.: An augmented reality interface for visualizing and interacting with virtual content. Virtual Reality **11**, 23–43 (2007)
19. Müller, M., Brunotte, J.: Augmented Reality im Museum. Culture To Go Agency Blogpost (in German). https://culture-to-go.com/mediathek/augmented-reality-im-museum. Accessed 11 Dec 2020
20. Priadana, A., Habibi, M.: Face detection using Haar cascades to filter selfie face image on Instagram. In: Proceedings of International Conference of Artificial Intelligence and Information Technology (ICAIIT), pp. 6–9. IEEE (2019)
21. Stumpp, S., Knopf, T., Michelis, D.: User experience design with augmented reality (AR). In: Proceedings of the ECIE 2019 14th European Conference on Innovation and Entrepreneurship (2019)
22. Chiu, C., Wei, W., Lee, L., Lu, J.: Augmented reality system for tourism using image-based recognition. Microsystem Technol. (2019)

23. Feiner, S., MacIntyre, B., Höllerer, T., Webster, A.: A touring machine: prototyping 3D mobile augmented reality systems for exploring the urban environment. In: Proceedings of the First International Symposium on Wearable Computers (ISWC 97), pp. 74–81. Cambridge, Massachusetts, USA (1997)
24. Vlahakis, V., et al.: Archeoguide: first results of an augmented reality mobile computing system in cultural heritage sites. In: Proceedings of International Symposium on Virtual Reality, Archaeology and Cultural Heritage, VAST 2001, pp. 131–139. Glyfada, Greece (2001)
25. Brancati, N., Caggianese, G., Pietro, G., Frucci, M., Gallo, L., Neroni, P.: Usability Evaluation of a wearable augmented reality system for the enjoyment of the cultural heritage. In: Proceedings of 11th International Conference on Signal-Image Technology & Internet-Based Systems (SITIS). IEEE (2015)
26. MacIntyre, B., Bolter, J., Gandy, M.: Presence and the aura of meaningful places. Presence: Teleoperators Virtual Environ. **6**(2), 197–206 (2004)
27. Spierling, U., Kampa, A., Stöbener, K.: Magic equipment: integrating digital narrative and interaction design in an augmented reality quest. In: Proceedings of International Conference on Culture & Computer Science ICCCS 2016, pp. 56–61. Windhoek, Namibia (2016)
28. Spierling, U., Kampa, A.: An extensible system and its design constraints for location-based serious games with augmented reality. In: Alcañiz, M. et al. (eds.) Serious Games, Proceedings, JCSG 2017. LNCS, vol. 10622, pp. 60–72. Springer, Cham (2017)