Human-Computer Interaction Patterns for Head-Mounted-Device-based Augmented Reality in the Exhibition Domain

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Head-mounted-device (HMD) based augmented reality (AR) applications bring new opportunities to the exhibition domain. However, first-time users such as exhibition visitors are not familiar with the interaction method of the HMD, which also brings challenges to exhibition authors while implementing HMD-based AR technologies. This research project focuses on the accessibility of HMD-based AR applications in the exhibition domain. It explores potential interaction patterns based on the technical features of the HMD for exhibition-related use cases. Both information system research and design research methods are applied while exploring interaction solutions for human factor challenges. Several prototypes will be created and iteratively tested and evaluated at the exhibition for generalizing effective and accessible interaction patterns. As a result, we will achieve a pattern-based interaction system as an artifact with integrated design knowledge. This will support the future development of AR authoring tools.

Additional Key Words and Phrases: Human-Computer Interaction (HCI), augmented reality (AR), head mounted device (HMD), design research, spatial interface, interaction pattern, accessibility

1 INTRODUCTION

As head-mounted devices (HMDs) are still relatively new to the market, many developers such as media designers and authors need to face the challenges of augmented reality (AR) content creation. Also, museum visitors as end-users face obstacles when using unfamiliar user interfaces and interaction patterns for device operations. Current solutions for interface and interaction pattern design mainly focus on hand-held devices (HHD) as more HHD-based AR applications have been introduced to the public so far[5][6][19]. HMDs provide different technical solutions for showing and interacting with augmentations[4][7]. For example, the Microsoft HoloLens 2 offers a stereoscopic visual unit and hand tracking technology for augmentation manipulations.

3D objects provide effective visual affordances for supporting people to understand possible interactions [8], and understandable hand gestures have a positive impact on the use of HMD-based AR applications [15]. We assume that spatial interfaces with optimized visual affordances plus understandable hand gestures have great potential to facilitate the use of HMD-based AR applications. However, there are no widely established interaction patterns that casual users can easily adopt. Therefore, this PhD research aims at an integrated, evaluated system of interaction patterns with accessible and effective spatial interfaces plus novel interaction techniques (for example, with hand gestures) for HMD-based AR in a museum environment (see Fig. 1).

The main contribution of this research is to provide interactive solutions for HMD-based AR applications via exploring various combinations of spatial visual elements and specific hand gestures while applying this to exhibition-related use cases. As a result, this PhD work will provide a system of several operationalized exhibition-related use cases with evaluated interaction patterns to illustrate an interaction concept for HMD-based AR applications. This research directly affects the development of applied computer science from the perspective of augmented reality technology. It provides interaction solutions and suggestions for applying current computer science research to daily lives. Ultimately, interdisciplinary creative industries, including 3D design, spatial computer games, and spatial film can profit from this research.

IMX '22 - Doctoral Consortium, 2022, Portugal

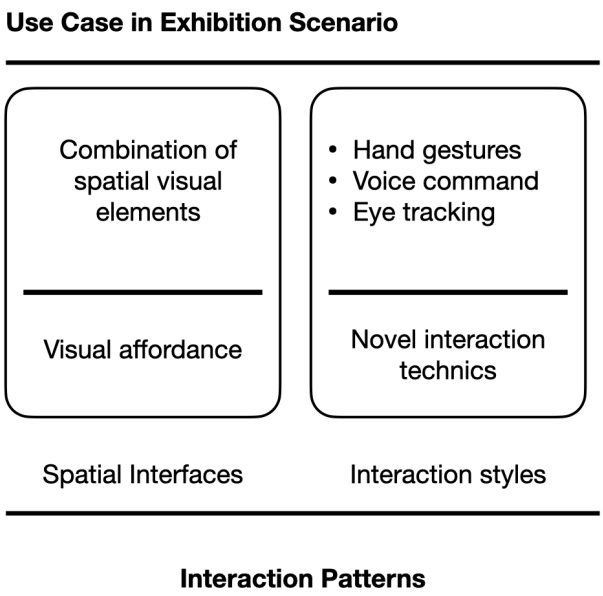

Fig. 1. Exploring combinations of spatial interfaces with novel interaction techniques (for example, with hand gestures) in a museum environment

2 RELATED WORK

As we use HoloLens 2 in this research, the technical features and functions of HMD mentioned below are analysed and discussed with HoloLens 2 as an example. The pattern theory was firstly introduced by Christopher Alexander in the 1970s[1]. Nowadays, the term of interaction pattern is frequently used in the computer science domain. Finishing a specific task often requires repeatable sequences of certain manipulations, following a pattern. For example, Spierling et al [18] introduced the interaction pattern of searching for the outline of the building (called "stencils") to trigger the augmentation with the marker recognition technology. As the HMD offers novel technologies and there are several repeatable sequences of manipulations while visiting an exhibition, it is necessary to explore various interaction patterns based on the technical features of HMDs. Besides, the specific input method of HMDs still needs further exploration[2][11][13]. Museum applications are usually different from other training or education-related applications. Museums are places that people visit without any preparation, only occasionally or even once in a lifetime[17]. Visitors usually do not expect to do tutorials or read long menus or join any training classes. The requirement of exhibition-related applications is to easy and fun to use, rather than asking people to do a job. Thus, creating interfaces and interaction patterns for museum applications should consider the characteristic of museum visitors, especially, that they should be user-friendly for beginners. There are already projects that provided 3D interfaces and interaction methods of HMD-based AR for business industries such as surgery-supporting in medicine, training and education, and factory-related commercial productions [3][10][12][16][21]. However, there are only few projects that especially focus on head-mounted AR devices for exhibition-related scenarios[7]. To sum up, there is neither useful design guidance nor example systems of interaction patterns as models for supporting the implementation of accessible HMD-based applications in the exhibition domain. This PhD research will address this gap through three main research questions described in the next section.

3 RESEARCH QUESTIONS

This research aims at developing a system of evaluated and classified interaction patterns for HMD-based AR applications in the exhibition domain. The resulting classification with implemented examples shall be helpful for potential AR developers. The following research questions will be investigated and answered.

3.1 Research question 1

What are the potential chances and limitations of head-mounted AR glasses' interaction paradigms for accessible end-user interaction design in museums and exhibitions?

- What are the first impressions of first-time users when they engage with an augmentation via the 3D vision unit? What are their general expectations and reactions in a museum context?
- Based on the reaction and expectation of first-time users, what information is potentially missing from interfaces that constrains the end-user adoption of head-mounted displays and impedes user interactions at a point of interest (PoI)?
- What specific interaction-design problem do we identify based on the missing information?

3.2 Research question 2

Benefiting the functionality of the head-mounted AR device and based on the exhibition-related use cases, what accessible and effective interaction patterns can be generalized for an interaction system used in the exhibition domain?

- Based on features of the exhibition series, which user interaction tasks shall we focus on in the exhibition-related use cases?
- Based on the interaction techniques of the HMD and established design principles concerning accessibility, how can visual elements and specific hand gestures be optimized, so that the end-user can complete user interaction tasks without extra external help?
- What can be generalized from the explored case study towards other cases of exhibitions?

3.3 Research question 3

How can the generalized interaction patterns be organized so that computer developers can build the interaction system into an authoring tool?

- Which functions, parameters and guidelines must be included in a future tool-set so that exhibition authors can complete the authoring tasks effectively?
- What are the mission, structure, and dependencies of the interaction system?
- How shall the integrated patterns and knowledge be documented to be usable by future developers?

4 METHODS AND PRELIMINARY RESULTS

Because this research focuses on human factor challenges and provides interaction solutions for human beings, we use both information system research and design research methods for answering addressed questions [9][14]. We follow the design science research process-model from Vaishanavi and Kuechler[20]. A central element of this is the building of prototypes. All prototypes with various interaction patterns will be created and implemented with Unity3D. The following steps will be taken to answer the addressed research, (see Fig. 2).

4.1 Methods in research question 1

We use qualitative evaluation in this research question. The first draft prototype from the exhibition domain will be created, tested, and evaluated iteratively with a group of first-time users. This research aims to understand

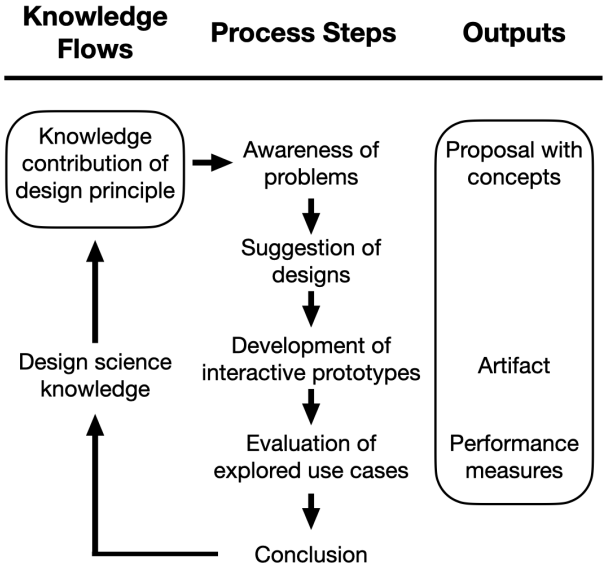

Fig. 2. Design Science Research Process Model (DSR Cycle)[20]

what prevents first-time users from further interaction with the first draft prototype. The prototype will be tested iteratively in a simulated exhibition environment, and it will be separated into three phases:

- Phase 1: Iteratively test the first draft prototype with and without interactive instructions. General initial reactions and expectations of first-time users are collected from both test types
- Phase 2: Compare expectations and reactions from test results to identify missing information in the interface
- Phase 3: Visualize specific interaction design problems by categorizing the missing information based on the exhibition visiting flow

4.2 Methods in research question 2

We will create and evaluate at least two prototypes (compare Fig. 3) to answer this research question following the design research method. Based on the identified interaction design problems in research question 1, we will create and evaluate various combinations of visual elements and hand gestures at an exhibition. To create generalizable interaction patterns for similar exhibitions, we will create a second prototype for another similar exhibition based on the identified interaction patterns. We will apply the following steps in this research method:

- To identify suitable use cases, we will investigate exhibition features and the user behavior during a visit to the first exhibition
- Iteratively test/modify the newly created interaction patterns at the first exhibition and identify further design criteria
- Apply the newly created interaction patterns at another similar exhibition. Iteratively test/modify them
- Collect and compare the final test results of both prototypes from various exhibitions
- Generalize the interaction patterns to an example interaction system by identifying the similarities and differences

Fig. 3. Illustration of one of the first prototypes for a navigation pattern

4.3 Methods in research question 3

The aim of research question 3 is to communicate the identified interaction pattern concept to a computer science developer with specific functions and its associated parameters. Based on the created example interaction system in research question 2, the following steps will be applied:

- Visualize the functionality and the workflow of the example interaction system
- Identify and document the design criteria with parameters from each interaction pattern
- Implement each interaction pattern in Unity3D as a prototype for communicating the concept to computer science developers

4.4 Preliminary results

We have made our first test with a group of students as first-time users, (see Fig. 3). Results show that all participants require at least basic instructions to start, such as how the interface will look like and with which hand gestures they can interact. More than half of the participants felt overwhelmed and surprised when they accessed immersive vision for the first time. Then they started trying to touch or grab objects in the scene, forgetting what they learned from the introduction. It also showed that with accessing the hand menu function, some participants accidentally entered the homepage instead of opening the in-app menu. Besides, it is also necessary to remind participants to put their hands properly in front of the device sensors. These evaluation results will be taken into account when alternative design solutions will be created in the next iteration.

5 INNOVATION AND VALUE

The PhD research provides two main contributions. First, we contribute interactive prototypical solutions for HMD-based AR applications in the exhibition domain. Second, we identify criteria for implementing authoring tools for similar types of exhibitions. Further, these artifacts also give suggestions to exhibition authors to build effective augmentation possibilities for various exhibits. It not only addresses one single design task in the exhibition, but also provides a more general design method when similar design tasks for related types of content occur in a series of exhibits.

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