Augmented Reality
the new frontier for UI design

Research report
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Introduction

Technological advancements have made it possible to create an enhanced reality by overlapping virtual elements onto the environment, called Augmented Reality (AR). Augmented Reality, together with Virtual Reality (VR) and Mixed Reality (MR), are becoming part of a larger trend. Some of the largest tech-companies as Google, Microsoft and Apple are currently developing devices to experience Augmented Reality, called head-mounted displays (HMDs).

Problem

Interface designers and developers (UI/UX) should recognize the career opportunities in the near future. As it stands, many and developers designers might find Augmented Reality too unknown or futuristic. The UI/UX designers or students currently studying or specializing in media and design, this research is for them to give insight on how UI design in Augmented Reality is currently visualized and how Augmented Reality can offer a new playing field for creative work.

Goal

The goal of this research is to gain an understanding on how user interfaces in Augmented Reality are currently visualized. In order to do so, UI theory and design will be compared and evaluated.

Approach

The approach for this study is a mixed methodology based on desk research (available online literature) and analysis of online images/video that illustrate user interface design elements in Augmented Reality. The focus of the research will be Augmented Reality (AR) interface design on head-mounted displays.

Research questions

How is user interface design currently developing in Augmented Reality?

To answer this question, the following sub-questions need to be answered first:
- What are the capabilities of head-mounted displays for Augmented Reality?
- How do interface designs compare with each other in Augmented Reality?
What are the capabilities of head-mounted displays for Augmented Reality?

**Augmented Reality**
Head-mounted displays enable the user to blend the reality of his surroundings with virtual content. Augmented Reality is a new platform for interactive information, media, virtual objects and design. AR has the potential to become a medium to get things done more efficiently by integrating virtual content and information in the user's environment. The difference with Virtual Reality (VR) is that Augmented Reality enhances real-life surroundings with an overlap of virtual content while VR completely immerses the user into a virtually simulated world. Mixed Reality (MR) uses a more advanced technology that enables virtual content to coincide with the actual environment.

Users will interact with virtual content integrated on to their surroundings instead of through a screen. With head-mounted displays, users will experience projections of interactive holographic objects. Interface designers that are used to the established design principles of Graphical User Interfaces (GUI), will require a shift of thinking on how to approach interaction with holographic interfaces.

Users wear head-mounted displays like a pair of glasses (or helmet). The features of the head-mounted display's hardware and software are purposefully added to accommodate the user's needs. The capability of an head-mounted display to display Augmented Reality is determined by technical features, such as hardware and software, as well as the different ways users are able to interact with virtual content. The two types of displays used in HMDs are video see-through and optical see-through. The two displays are briefly explained below:

**Video see-through**
Video see-through displays use cameras to capture the environment. Those digital images are then projected onto the environment and the combination is displayed on digital LCD or OLED screens. Using digital images allows for better registration of head movement tracking. According to Poelman and Van Krevelen (2010), the disadvantages of this technique is a low resolution display, a limited field-of-view and a possible offset due to the difference between the positioning of the camera and eyes of the user.

**Optical see-through**
Semi-reflective and semi-transparent optical elements, that are similar to mirrors, allow light from the environment to pass through for the users to see. Virtual images are projected onto the holographic optical elements, which are then subsequently reflected/projected onto the display. This technique requires other input devices (cameras) for registration and user interaction. Optical see-through displays are preferred among head-mounted display manufacturers.

**Field-of-view (FOV)**
The field-of-view (FOV) is one of the key features for head-mounted displays, allowing the user to view Augmented Reality through the display. The field-of-view is measured in degrees. The average field-of-view of the human eye is 120° horizontally and 135° vertically. According to Meta (2017), the average field-of-view on head-mounted displays is 33°, which has only been achieved recently. The technical capabilities will improve gradually, including the field-of-view which allows a more immersive Augmented Reality experience.
The user experience is different with each head-mounted display. Virtual content is projected onto the user’s environment (either by optical or video display). The technological capabilities of the head-mounted displays, especially the field-of-view (FOV) and according resolution, influence the immersive experience of Augmented Reality. HMDs are currently in production for different target audiences to suit the preferred amount of virtual content in the FOV and for which purposes they will be used.

The virtual content of Augmented Reality is often visualised as see-through projections appearing in the environment, ranging from a non-intrusive interface with Google Glass to life-sized ‘holograms’ with Microsoft HoloLens. However, each head-mounted display augments the user’s reality in a different way with a variety of virtual content able to disrupt many markets and industries such as education, healthcare, retail, engineering, entertainment and the military. Access to information and interaction with multimedia content in Augmented Reality has been made easier by using head-mounted displays.

**Types of Interaction**

Augmented Reality offers new types of interaction by implementing depth in the user’s environment, instead of touchscreens or the conventional mouse and keyboard. The addition of depth is one of the new factors that changes the way UI designers should think about interaction and interface design.

Users wearing HMDs are able to freely move their heads freely and look around, which is called ‘Six degrees of freedom’ (6DoF). Users can look forward, backward, up, down, left, right and rotate their head which is ‘pitch, yaw and roll’. By tracking the head movement with those degrees and camera input for environmental mapping, HMDs are able to track 2D and 3D surfaces, such as walls and tables. Additionally, the virtual content in the room keeps locked in place when the user moves his head.

So how do users interact in Augmented Reality with virtual content that’s displayed as holographic projections? An overview on the different ways users can interact in Augmented Reality:

**Hand-tracking & Gesture-based**

Head-mounted displays have implemented hand-tracking (and finger-tracking) technologies that enable users to interact with virtual contents and interfaces using their hands. These are virtually calibrated by measuring fingertip positions relative to each other and the fingertips are detected based on the contours of the hand. Hand gestures are being recognized and are used to interact with virtual content by pointing, pinching, swiping, tapping, hold and much more. Interaction with virtual objects, scaling or rotating for example requires both hands sometimes. Selecting multiple objects by tapping, grouping objects by tapping multiple or drawing a ‘lasso’ around the selection is also possible.

Gesture-based interaction methods use the front-end camera’s of head-mounted displays for hand-tracking. Examples of these HMDs are Microsoft’s HoloLens and Meta’s Meta 2, where users are able to directly manipulate virtual objects using their hands.
**Tangible User Interface (TUI) & Psychical Controllers**

Using psychical objects to interact with virtual content is called Tangible User Interface (TUI). According to Billinghurst, Grasset and Looser (2005) the basic principles include the support for spatial 3D interaction techniques and support of multiple controllers being used simultaneously. A tangible user interface is very intuitive to use, psychical controllers are mapped to virtual objects such as the computer mouse and cursor for example. Microsoft's HoloLens has a ‘clicker’, a hand-held controller for interacting with the holographic projections (select, scroll, move, and resize) in Augmented Reality instead of hand gestures. The Recon Jet Pro and Google Glass have a touchpad on the side of the HMD where users interact with user interfaces.

**Eye-tracking & Gaze Based**

Some head-mounted displays are capable of monitoring the user's head- and eye motions (eye-tracking) and enables the user to interact with UI elements using a cursor when voice command or gesture-based interaction is not possible. The design of eye-based input control is delicate, as it can quickly become tedious and distracting if not implemented well in such manner that it doesn't interfere with the user's behaviour. Head-mounted displays that utilize gaze-based interaction is the DAQRI Smart Helmet and Microsoft’s HoloLens for example. Their tracking technology recognizes where the user is looking at and displays context-aware information or interacts with UI elements.

**Voice-recognition & Speech-based Interaction**

Speech-based interaction as one of the most used type of interaction in Augmented Reality as an alternative to gesture- or gaze-based interaction. Examples of speech-based interaction used today in smart devices are Apple's Siri, Microsoft's Cortana and Amazon's Echo. Users can 'wake up' Google Glass with the phrase “Ok Glass”. While perhaps easy to use indoors, there are possible drawbacks that speech recognition can prove difficult to use in high-noise environments.

Head-mounted displays display Augmented Reality and enable users to interact with the virtual objects (UI elements) by implementing the latest technological developments. Optical displays are able to display Augmented Reality more immersive than video displays. The technical capability of displaying Augmented Reality with the field-of-view (FOV) is very important and makes a big difference for the immersive experience. Interestingly, the most technologically capable head-mounted displays, such as Microsoft’s HoloLens and Meta’s Meta 2, gravitate towards Mixed Reality.

Users are able to interact with virtual content in Augmented Reality in a variety of ways. The type of interaction with buttons, swiping touchpads and voice-input are already familiar and doesn’t push any boundaries. The use of controllers, tangible user interface, is an alternative but familiar way to interact with virtual content in Augmented Reality. Head-mounted displays that implement innovative ways of interaction that really complement the Augmented Reality experience is gesture-based interaction and the use of eye-tracking.
How do interface designs compare with each other in Augmented Reality?

This part of the research is dedicated to the user interface design used in Google Glass, Recon Jet Pro, DAQRI’s Smart Helmet, Meta 2 and Microsoft’s HoloLens. These HMD’s all have different approaches for user interface design in Augmented Reality. Insights for UI/UX developers can be obtained by comparing the existing design of the user interface and how they are implemented in head-mounted displays.

3D canvas

Interaction in Augmented Reality has become three-dimensional with the addition of depth (z-depth). Virtual content in Augmented Reality is displayed in a spatial context, projected onto the user’s environment. The area where content can be projected is limited: the HMDs’ field-of-view and capability of displaying content in depth to a certain extent, the peripheral view of the human eye and a comfortable range for user’s head rotation. Restrictions of these variables determine the dimensions of the ‘3D canvas’ - the suitable range for interface design in Augmented Reality.

Figure 2 shows what developers at Microsoft (2017) established an optimal depth for hologram placement between 1,25 and 5 meters. Considering visibility and avoiding cluttering of the environment, interface design elements should be placed between 1,25 and 2 meters.

The near peripheral vision of the human eye and the average range for people to comfortable rotate their head are quite similar. Chu (2014) conducted the ‘Comfort Range Test’ to test the average comfort range of head rotation. He found that users are more comfortable looking left and right rather than looking up and down. Chu distinguished head rotation ranges between comfortable and maximum. By comparing these variables, UI elements could be placed around the edges of the user’s comfortable range of view: 30° to the right/left side, 20° up and 12° down in combination with a depth of 1,25 to 2 meters.
**Types of User Interface (UI)**

In 2009, Fagerholt and Lorentzon found that there are four types of interfaces while exploring theories of game UI design. These four types of interfaces are: Diegetic, Spatial, Meta and Non-Diegetic. The terms were introduced for different types of UI depending on how they were used for narrative and game geometry, as shown in figure 6. Diegetic and Meta UI are characterized by being part of the virtual (game) environment, which is not possible Augmented Reality nor does it fit the purpose. The Meta UI is suitable for a more virtual experience that gravitates towards Mixed Reality and Virtual Reality. The two types of UI that are suitable for Augmented Reality are Spatial UI and Non-diegetic UI.

**Spatial UI**

Components of spatial UI are virtual objects or designs, in the form of projections, placed in the 3D space with added depth, light, focus and size to fit like other objects in the environment. The less realistic, the better the user can understand it’s an virtual object to be interacted with. The use of spatial UI elements is effective for providing information to the user in the environment, as shown in figure 7. If UI elements make use of the geometry of the environment (surface-tracking), the interface is more part of the environment and creates a more immersive user experience. Information of the Spatial UI should be context-aware and reactive to the user’s environment. A suitable style can contrast the environment and enhance what the user is seeing.

**Non-Diegetic UI**

A Non-Diegetic UI is what’s often associated with a Heads-Up Display (HUD) in videogames, an overlay on top of the environment, as shown in figure 8. Typically two-dimensional, without depth and fixed in place. The UI is not part of the environment. Non-Diegetic UIs can adopt their own visual treatment, though often share the same art-direction of the (game) environment. The UI displays information, for example health and ammo in videogames with first-person and/or third-person perspectives and reactions based on the actions of the player/user in the environment. Utilizing 2D or HUD elements can create a clear contrast between the UI and the actual environment and show information clearly, but can also prevent users of an immersive experience with too much visuals fixed in place.

The two head-mounted displays that implement Non-Diegetic UI is Google Glass and Recon Jet Pro. Recon Jet Pro’s video display doesn’t blend with the environment and creates a non-immersive augmented reality experience. Google Glass and Recon Jet Pro’s approach to Augmented Reality UI design is simplistic for displaying instructional information. Optical displays on the other hand often implement Spatial UI, creating an immersive mix of virtual elements and the user’s environment. HMDs utilizing Spatial UI enable innovative ways to interact with UI elements especially with the combination of hand-gestures and surface-tracking.
**Comparison of Non-Diegetic UI design (Glass, Recon Jet Pro)**

Google Glass has an adjustable optical display with a relative small field-of-view (14°) and a resolution of 640 x 360 pixels. Glass has a minimalistic and straightforward Non-Diegetic interface design. The Operating System (OS) of Google Glass is called Glassware, based on Android. Glassware's menu is called 'timeline' and consists of a horizontal row of 'cards', as shown in figure 9. Glass can display data or information such as time, temperature, messages, but also photos and videos in a overview in front of the user. Users can scroll through different sections of the timeline, revealing cards that show information. The home card and most recent items are shown first when users ‘wake up’ Glass. It’s interface is easy to display/hide so the user can continue his daily routine without being too much distracted.

The Recon Jet Pro is developed by Recon Instruments. The Recon Jet Pro's OS is called ReconOS, also based on Android. It’s specifically developed for workers in certain industries such as field service, manufacturing and logistics. Workers are able to access information/ instructions 'on-the-go', enhancing work productivity. The Recon Jet Pro has a Non-Diegetic video display with small field-of-view (10°) and small resolution of 420 x 248 pixels. The UI is fixed in place in the bottom-right of user’s view. Recon Jet Pro's UI displays mostly information against a black background, shown in figure 10. The ReconOS has three types of menus (horizontal, vertical and static - based on the list of items to be displayed).

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**Menu design of Google Glass (Glassware)**

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**Menu design of Recon Jet Pro (ReconOS)**

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Fig. 9 Adapted from Design - User Interface (2015), by Google Developers. Copyright 2015 by Creative Commons. Retrieved from https://developers.google.com/glass/design/ui

Fig. 10 Adapted from Design guidelines for Recon Jet (2016), by Peter N. Copyright 2017 by Intel. Retrieved from https://software.intel.com/en-us/articles/design-guidelines-for-recon-jet
Glassware's Non-diegetic UI is not very innovative with the use of cards but the focus of Google Glass seems to be displaying additional relevant information with an easy-to-use timeline. The AR display with Glass can be placed above the user's line of sight or adjusted to a central position. The UI design requires an solid black background in the cards as information in white and bright colors is projected over the environment using an optical display. Google Glass applies the Glass theme to the Glassware to ensure consistency with the rest of the UI. The typeface used is Roboto.

Interaction with Glass is somewhat limited in options. Users are able to use voice-command and/or swiping the head-mounted display's touchpad. Glassware is based off Android, making it accessible for designers and developers with experience.

The interface of ReconOS is supposed to be as uncluttered as possible, as it's designed to be glanced at. Using more than enough padding is encouraged. The font used is Open Sans (Regular/ Semibold). Recon Jet Pro's display is also designed to be worn during the day, so light text and objects are used against a black background for maximum visibility. The video display of Recon Jet Pro prevents that UI elements are combined in the user's environment, as opposed to optical displays. The standard colors in ReconOS are white (text), orange (highlighted menu items), gray (non-highlighted menu items) and black.

The Recon Jet Pro share similarities with Google Glass because both HMDs have a small field-of-view and resolution, using the Non-Diegetic UI as a heads-up display mostly for relevant information. Both HMDs also feature interaction through a touchpad on the side of the device, though the Recon Jet Pro has a extra button to interact with the UI. ReconOS implements horizontal and vertical lay-out for menus to improve on visibillity. The location of the display is fixed however, as the video display is integrated in the head-mounted display.

The Recon Jet Pro is designed to improve productivity on work sites where workers receive up-to-date information or instructions. ReconOS's UI elements is understandably simplistic, consisting mostly out of text and icons to enhance the workplace environment instead of being distracting for the user.
Comparison of Spatial UI design (Smart Helmet, HoloLens, Meta 2)

Head-mounted displays with optical displays such as Meta’s Meta 2, Microsoft’s HoloLens and DAQRI’s Smart Helmet utilize Spatial UI for holographic projections in Augmented Reality. Spatial UI’s provide a more immersive experience, when viewed through a large field-of-view and supporting resolution, that visualize projections of interactive holographic objects onto the environment for different purposes. For instance, Microsoft’s HoloLens projects realistic 3D ‘holograms’ into the user’s environment using spatial mapping. HoloLens’ OS is Holographic, incorporated in Windows 10. Interaction with HoloLens’s holographic interface is by gestures, gaze or voice recognition (GGV).

DAQRI’s Smart Helmet can map the environment, virtually reconstruct entire workspaces and recognize and track industrial objects such as gauges, for example. DAQRI’s Smart Helmet also has thermal vision to see through objects to identify and prevent system overload. It’s purposefully built for workers to make their jobs easier, safer and more productive in the (industrial) workplace.

The Meta 2 headset has a more intuitive approach for interaction with hand-gestures. Pens and paint brushes can also be tracked as though painting in three-dimensional space. With the widest field-of-view (90) and advanced interaction through natural hand gestures, the Meta 2 allows a very immersive Augmented Reality experience for the user.
The start menu's of DAQRI’s Smart Helmet (‘Launcher’) and the HoloLens both feature flat interface design - falling back on familiar GUI design such as the Windows 10 tile menu style. The display of time, battery level and Wi-Fi signal with icons is nothing new but easy to understand and recognizable.

The Meta 2, Smart Helmet and the HoloLens have all implemented some form gaze-based interaction. Tracking position and rotation of the head enables the user to target objects/ UI elements with a cursor positioned in the center of the user’s field of view. The cursor, in the shape of a dot, aligns with surfaces of the environment, creating spatial awareness when the user is not interacting with virtual objects.

Gesture-based interaction is one of the most exciting aspects of interacting with holographic projections with the HoloLens and Meta 2. Gesture input allows users to interact with objects naturally using their hands. The two HMDs have developed two different ways of approaching gesture-based interaction. HoloLens users interact by using the air-tap gesture (‘press and release’) and bloom gesture (opening of the hand with the palm up). Holding, manipulating or navigating objects/ UI elements is possible with the combination of press and release gestures. Users look around (gaze-based interaction) and interact with virtual objects in a ‘point-and-click’ manner with an air-tap gesture, similar to using a mouse.

The Meta 2 has implemented a more natural approach to gesture-based interaction. With key principles as ‘You are the OS’, Meta wants to remove complexity from interacting with virtual objects. Instead, the direct interaction with virtual objects through natural gestures is more easy to understand and use.

Interestingly enough, this direct approach of using hands and gestures to interact with virtual objects requires no additional user interface design elements (except appropriate responses from the object), as shown in Appendix D. The virtual objects are becoming the buttons. Using tools to interact with virtual elements is no longer necessary with gaze-tracking and gesture input. It’s foreseeable that tutorials or information might be shown additionally to inform the user of the interaction possibilities. Head-mounted displays with the latest technologies implemented are able to combine user interfaces to distinguish interacting with the virtual objects and UI design. Spatial UI, in combination with gestures, makes a powerful innovative combination of interaction in Augmented Reality.
In conclusion, the developments in Augmented Reality and their devices are transforming the way how UI/UX designers and developers should approach user interface design. The type of UI (Non-Diegetic or Spatial UI) makes a big difference in terms of design and interaction. Non-Diegetic UI is mostly used for displaying instructions or information to the user. UI design is simplistic and minimalistic so not to distract the user while he’s ‘on the go’. Designers that want to create sleek UI design similar to heads-up displays in video games, look no further.

Spatial UI in Augmented Reality, on the other hand, beholds great potential for innovative entertainment with holographic projections in the user's environment. The immersive experience is enhanced by using your hands to interact with virtual elements.

As interaction development for Augmented Reality is becoming more advanced, interface design is evolving to the point of being obsolete. Head-mounted displays with capabilities such as optical displays, Spatial UI and interaction through hand gestures are leading the way of a paradigm shift by eliminating the need for UI elements.
Reference list


DAQRI. (2016, November 15). DAQRI Smart Helmet Case Study Mortenson and Autodesk [Video file]. Retrieved from https://www.youtube.com/watch?v=U9t6Osl1Lbc


Head-mounted Display: Glass
Developed by Google

Fig. 16 Adapted from Google Glass (2013, April 30). How to use Google Glass [video file]. Retrieved from https://www.youtube.com/watch?v=4EvNxWhskf8

Appendix A: Glass

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Appendix B: Recon Jet Pro

Head-mounted Display: Recon Jet Pro
Developed by Recon Instruments

Fig. 17 Adapted from Recon Instruments (2016, September 13).
Intel’s Recon Jet Pro - Smart glasses for the connected workforce [videofile]
Retrieved from https://www.youtube.com/watch?v=BhBtuNe_8is

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Appendix C: Smart Helmet

Head-mounted Display: Smart Helmet
Developed by DAQRI

Fig. 18 Adapted from DAQRI (2016, November 15).
DAQRI Smart Helmet Case Study Mortenson and Autodesk [videofile]
Retrieved from https://www.youtube.com/watch?v=Uqt6OsIzLbc

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Appendix D: Meta 2

Head-mounted Display: Meta 2
Developed by Meta

Fig. 19 Adapted from Meta (2016, September 15).
Meta 2 - Build Groundbreaking AR Tools & Experiences [videofile]
Retrieved from https://www.youtube.com/watch?v=x6XcZOP-PKU

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Appendix E: HoloLens

Head-mounted Display: HoloLens
Developed by Microsoft

Fig. 20 Adapted from Imaargo Com (2016, Juli 15).
Microsoft Hololens Demo [video file]
Retrieved from https://www.youtube.com/watch?v=cAu3h9RxqE