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Dark/Light Mode Adaptation for Graphical User Interfaces on Near-Eye Displays

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Abstract

In the fields of augmented reality (AR) and virtual reality (VR), many applications involve user interfaces (UIs) to display various types of information to users. Such UIs are an important component that influences user experience and human factors in AR/VR because the users are directly facing and interacting with them to absorb the visualized information and manipulate the content. While consumer's interests in different forms of near-eye displays, such as AR/VR head-mounted displays (HMDs), are increasing, research on the design standard for AR/VR UIs and human factors becomes more and more interesting and timely important. Although UI configurations, such as dark mode and light mode, have increased in popularity on other display types over the last several years, they have yet to make their way into AR/VR devices as built in features. This demo showcases several use cases of dark mode and light mode UIs on AR/VR HMDs, and provides general guidelines for when they should be used to provide perceptual benefits to the user.

CCS Concepts

• ***Human-centered computing*** → ***Mixed / augmented reality; Virtual reality; User interface design;***

1. Introduction

Dark mode and light mode style user interfaces (UIs) have increased in popularity over the last several years, and are now built in features of many different operating systems. In general, dark mode UIs involve light-colored text (typically white) overlaid on dark-colored backgrounds (typically black), and light mode UIs involve the opposite with dark-colored text overlaid on light colored backgrounds (see Figures 1 and 2). There has been a wealth of research into these types of UIs for traditional displays; however, the work is still in its infancy for augmented/virtual reality (AR/VR) devices [EKBW20a].

Since WYSIWYG—What You See Is What You Get—UI paradigm became the norm in editing software, light mode UIs on electronic displays, which can mimic the appearance of finished product like ink on paper, have been dominantly used and showed some benefits in user experience, such as increased visual acuity and task performance in reading [PMMB13, PMB14, BMB09]. However, while different types of displays are adopted in various use cases and circumstances in our modern lives, the need for context-adaptive UIs is increasing while taking user experience and human factors into account, e.g., *night mode* visualization in modern in-car displays and smartphones for improving visual acuity and reducing visual fatigue. Near-eye AR/VR devices, such as

Figure 1: *An example of how light mode UIs (left) and dark mode UIs (right) appear on virtual reality displays.*

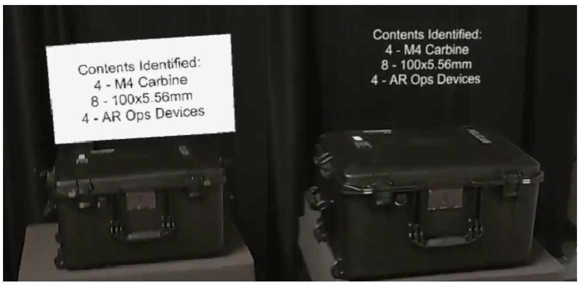

Figure 2: *An example of how light mode UIs (left) and dark mode UIs (right) appear on optical see-through head mounted displays.*

head-mounted displays (HMDs), are unique in the fact of the close proximity of the display to the user's eyes. Because of this, it is possible that user's eyes will react differently to content shown on an AR/VR device than they will if viewing the same content on a flat

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panel display. Our research has shown that there is typically an optimal choice between dark mode and light mode displays, which is dependent on the type of display technology being used and factors related to the user's environment. This optimal choice normally adheres to traditional guidelines for UI design for VR and video-see through AR (VST-AR) devices, whereas it breaks from the guidelines for optical see-through AR (OST-AR) device.

In this demo, we will outline the benefits that can be gained from choosing one UI style over the other, and showcase the types of conditions that influence the optimal UI choice.

2. Implementation

Despite the researcher's choice of development environment, the implementation of a dark mode or light mode style UI can be straightforward. For example, a simple dark mode UI can be set up by creating white-colored text, and then creating a rectangular background primitive in a dark color, which is displayed slightly behind the text. The choice of color for the background primitive will depend on the AR/VR device being considered, and should be black for VR or VST-AR devices to provide maximum contrast in a dark mode (see Figure 1). However, since RGB pixel values of black at (0, 0, 0) become completely transparent on OST-AR devices (see Figure 2), if this pixel value is chosen, then the contrast of the UI between foreground and background is heavily influenced by the illuminance of the user's physical environment, where a bright environment will offer less visual contrast than a dark environment [EKBW20c]. For instance, the black background in a dark mode style UI is transparent while the black text in a light mode style UI is transparent showing the physical objects behind the virtual content in the environment. In this case, the optimal choice of the text and background color for legibility depends on the appearance and lighting condition of the user's physical environment, and must be considered carefully if using OST-AR displays.

3. Demonstration

Our demo presents both dark mode and light mode style UIs on different near-eye displays, such as Microsoft HoloLens 1/2 and Oculus VR HMD. The dark/light mode style UIs were implemented in the above mentioned manner, with color choices being pixel values of black at (0, 0, 0) and white at (255, 255, 255). These UIs were made using the Unity 3D game engine and were rendered using standard unlit shaders, so that their appearance is not impacted by the presence/absence of virtual lighting. Our UIs take into account the distance between itself and the user in order to scale their size such that the visual angle of the text size remains constant, despite changes in distance.

In addition to several demonstration UIs in both light mode and dark mode styles, we have included a virtual visual acuity chart that is also shown in both styles. These charts are shown using randomly rotated Landolt C characters of varying sizes, and allow the user to determine how easily readable text is between the two UI styles.

Our previous research has shown that there are usually differences in the size of the smallest readable text between the two styles of UIs [KEL*19, EKBW20b]. These studies indicate dark mode

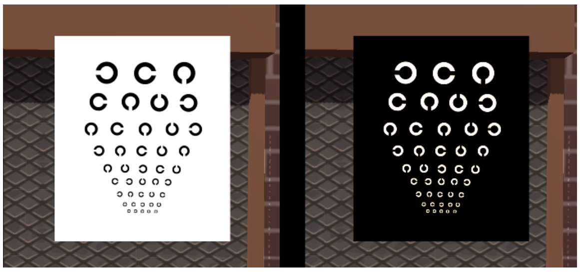

Figure 3: *The Landolt C visual acuity charts shown in a virtual reality head-mounted display. The charts are displayed in light mode (left) and dark mode (right).*

style UIs typically result in better visual acuity performance and overall less visual fatigue on OST-AR displays. For VR/VST-AR devices, dark mode UIs still typically result in less visual fatigue, however the optimal UI choice adheres to traditional UI guidelines and is dependent on virtual lighting, where light mode results in better performance for bright environment and dark mode for dim environments. Because of this, the VR/VST-AR mode of the demo has two duplicate scenes in which the only difference is the virtual lighting levels present in the virtual environment. This allows the user to experience how lighting may impact their performance in reading from the visual acuity charts and their preference of UI style.

Acknowledgments

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