Effects of Eye Vergence and Accommodation on Merging an AR Magic Lens Display with its Surrounding Real Environment

Geert Lugtenberg

Abstract

Screen-based Augmented Reality (AR), such as on handheld devices, is a convenient and accessible way to enrich our environment with virtual imagery. Common limitations of such a display are that it presents a monocular view of the environment where the image plane is located on the display. Since the display is closer to the viewer, either it or the environment is not in focus. Stereoscopic displays allow each eye to have a different view and thus allow them to converge on a variable depth, however having a different distance for eye vergence and accommodation is known to cause discomfort (vergence-accommodation conflict). These limitations could make it more difficult to merge the AR content on the screen-based display with its surroundings, a significant problem when usage requires rapid shifts between the two (e.g. when validating augmented instructions before making incision, cutting the wire, general hand-eye coordinated tasks such as grasping for augmented objects, etc.). To investigate the relative influence of accommodation and vergence on merging AR content we run two user studies with 9 and 27 participants and found that when rapidly switching gaze between the display and the environment, minimising accommodation difference plays a key role, wheras when viewing the display and the environment as a single merged contex without switching gaze, vergence prevails. Furthermore vergence-accommodation conflict did not impact cognitive workload nor was it detected as an important factor for accurate merging of the AR conten. Based on this we propose design recommendations for scenarios that utilize a screen-based AR display.

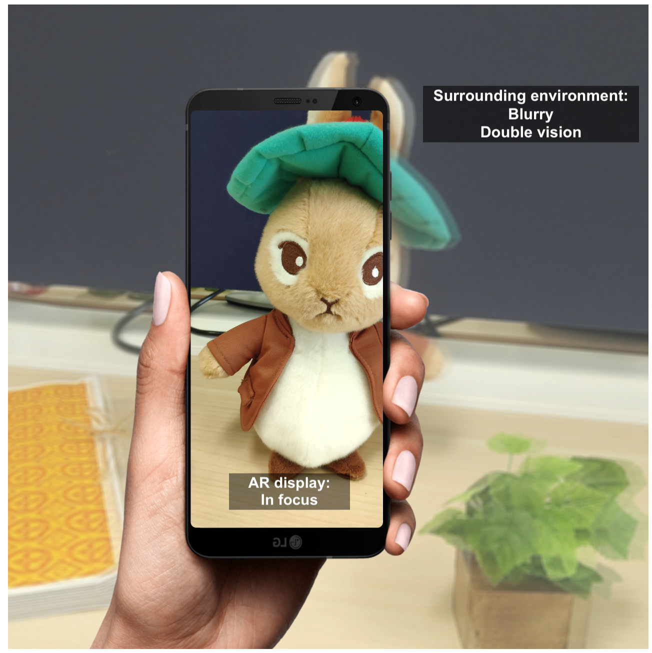

Figure 1: Display content as rendered from the perspective of the user. Focusing on the handheld display causes the surrounding environment to become blurred and double (diplopia) due to eye accommodation and vergence respectively.

1 Introduction

Augmented Reality (AR) has long been envisaged as a support system for both everyday and specialized tasks [3]. These amongst others include teaching [1] and learning [2]. Since smartphones equipped with dedicated graphical processing units, high quality cameras and displays became readily available, the world augmented by virtual imagery became easily accessible to the common consumer with minimum extra effort or costs. By utilizing the smartphone camera image, a user is able to view the physical world together with digital content as if the handheld device is a transparent screen or lens, sometimes called a Magic Lens (ML) display.

2 Background & Related Work

In order to explore accommodation and vergence influence on merging a screen with its surroundings we first need to explore how these eye phenomena affect our regular daily vision.

2.1 Accommodation and eye strain

In order to bend light diffusing from a surface so that it ends up in focus on your retina, the muscles in your eye contract the lens in your eye, making it more or less convex. When this accommodation process does not work well enough, usually with older age, objects near the eye (hyperopia) or in the distance (myopia) become blurry. Myopia is a common phenomenon occurring in about 23% of people , varying with age, ethnicity and lifestyle. Both conditions can be corrected with convex or concave lenses in spectacles or contact lenses, but left untreated cause eye fatigue and headaches in addition to impairment of activities. Some studies suggest that prolonged use of near-view displays such as computer monitors, tablets and smartphones also cause accommodation-related symptoms and subsequently eye discomfort. In mixed reality systems, due to virtual content always being displayed at fixed focal distance, the logical result is that there is often a discrepancy in accommodation distance between the virtual and the real, causing either to be out of focus. Related work in augmented reality systems using head-worn displays investigate ways to relieve this issue; through vari-focal technology where the focal point is mechanically changed or multiple focal planes exist. Near-eye light field displays tackle the accommodation issue by rendering the scene from many view angles resulting in different depths per view angle. There are techniques such as the Maxwellian view that project the virtual image onto a specific part of the eye retina, most commonly the fovea. This requires careful calibration taking into account the positional relationship between the eyes and display, and has been used in HWDs before. Interestingly, screen-based augmented reality, such as those using handheld devices or Magic Lenses, have the same accommodation issues (since the virtual content focal plane is fixed at arm's length) but is far less investigated than their HWD counterpart, partly motivating the proposed work here.

Table 1: Subjective grading of performance per condition and display type for User study B

Transparent	FAR	FAR	20	2	3	1	93
Varifocal	FAR	NEAR	2	7	10	7	56
Stereoscopic	NEAR	FAR	3	13	7	3	68
Conventional	NEAR	NEAR	1	4	6	15	43

References

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