Minimizing Latency for Augmented Reality Displays: Frames Considered Harmful

Feng Zheng¹, Turner Whitted¹², Anselmo Lastra¹, Peter Lincoln¹, Andrei State¹³, Andrew Maimone¹, and Henry Fuchs¹
¹University of North Carolina at Chapel Hill ²Twi Research ³InnerOptic Technology Inc.

Abstract: In Optical See-Through Augmented Reality (OST-AR) systems, latency accumulates throughout all stages, from tracking, to application, to image generation, scanout, and display. In this work, we present initial results from a new image generation approach for low-latency displays such as those needed in head-worn AR devices (e.g. Google Glass, Epson Moverio BT-200).

Proposed low-latency binary image generation method (Figure 1):

Question 1: Assuming that the Desired Image (grayscale) and the User Perceived Image (grayscale) are known, how to compute the Binary Projector Image?

Answer 1: Compare them pixel by pixel → turn on the binary pixel if needs more light → turn off the binary pixel otherwise

Question 2: How to compute the User Perceived Image?

Answer 2: Integrate over a window of 64 (≈3 ms) most recently projected binary images.

Figure 1: End-to-end low-latency OST-AR pipeline. While the whole prototype comprises many stages, each operating faster than the prior stage, our current prototype implements only the stages in the red rectangle for binary image generation and display.

Figure 2: Experimental setup. The conventional projector is DLP Lightcrafter ( @ 60 Hz color ). The experimental projector is TI Discovery 4100 Development Kit ( @ 22,727 Hz binary; @ 291 Hz grayscale) using conventional pulse width modulation (PWM) to achieve various levels of light intensity; @ 97 Hz color (hardware upgrade required, i.e., not natively supported). The recording camera is 120 Hz.

QR Code for Results Video:

Conclusion: Our approach produces visually pleasing results. Rapid updates decrease or eliminate the “swimming” artifacts induced by latency, and the imagery shown by our proposed display is more natural and resembles motion blur, which is more acceptable to viewers.

Future Work: (1) Efficient FPGA implementation of the proposed algorithm; (2) High-speed image scanout from GPU; (3) Extension to color images; (4) Explore the effects of eye movements.