BokodeVision: Gaze-Activated Bokode Display for Smart Glass Interactions

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Motivation:

Smart glasses are emerging as an important disruptive technology poised to grow rapidly already at an estimated $1.93B market size in 2024 [1] and are seeing rapid adoption across industry and consumers. Current smart glasses primarily rely on voice commands, touch controls, and hand gestures, each with significant drawbacks:

1. Voice commands led to social awkwardness in public [2] and significantly dropped in accuracy in noisy environments.
2. Touch controls lead to slower task completion and discomfort from prolonged usage [3].
3. Hand gestures suffer from low accuracy and cause fatigue after short usage times [4].

This work aims to explore gaze as an alternative interaction mechanism for smart glasses in order to tackle some of the limitations discussed above.

Related Work

Gaze detection has been employed in smart-glasses to improve spatial localization for vision-language model queries on smart glasses [7], however, this requires eye-tracking over the entire field-of-view which requires expensive power-hungry camera-based eye tracking. [6] employs near-eye displays but these are always powered on which leads to higher energy consumption and can possibly cause eye-strain from prolonged usage.

Overview

The goal of this project is two-fold:
First, to build a near-eye display that can show the user simple icons and can be employed as an interface for gaze-based interactions.
Two, to build a light-weight gaze tracker that can detect when the user looks in the direction of the display to selectively activate it.

For the course project we focus on the first part while integrating it with an off-the-shelf eye tracker by Pupil Labs. This significantly reduces the complexity of the design so that we can focus on building the display alone.

The display: Bokodes [5] were introduced as a compact unobtrusive alternative to barcodes that are imperceptible to the human eye. However, we repurpose the Bokode to build a near-eye display following a similar optical design.
Our optical design utilizes the following components:
- Plano-convex lens (4mm diameter, 3mm focal length)
- LED (8x10mm, RGB)
- Tracing paper as a diffuser
- 35mm e6 transparency (with a variety of designs to test the display)

All of these components are housed in a 3D-printed housing and connected to an Arduino-ESP32 for control. The Arduino is going to be connected to the laptop via a USB cable for prototyping purposes only. Later on, we can move the power supply onto the glasses.

Eye-tracking: In the long-run the goal is to switch to infra-red and photodiode based gaze detection. However, due to safety concerns the current design utilizes a camera based gaze detection system from Pupil Labs which can be interfaced with using the open source Pupil Core SDK for python and can communicate with the arduino-ESP32 over bluetooth to give gaze-based commands. We use off the shelf gaze-detection modules built for the eye-tracker. The eye tracker connects to a laptop with a USB cable.

Final Goals

The objective is to have a 3D printed glass which contains both the eye-tracker and the Bokode-based display. The eye-tracker should first initiate a calibration sequence after which we can turn on the Bokode display by looking towards it. The display pattern can be set by replacing the transparency slide which should have a variety of patterns with common icons as well as chirp signals to test the frequency resolution of the display and printing technology codesign.

Milestones:

Week 1: Interface eye-tracker with laptop and design the 3D printed housing for the eye-tracker and Bokode components. Create and then order the transparency prints for the display designs.
Week 2: Assemble the Bokode components along with the transparency in the 3D housing and setup control with the Arduino. Interface the Pupil Labs eye tracker with the bluetooth module. Debug and iterate.

References:

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