Project Esky: Enabling High Fidelity Augmented Reality on an Open Source Platform

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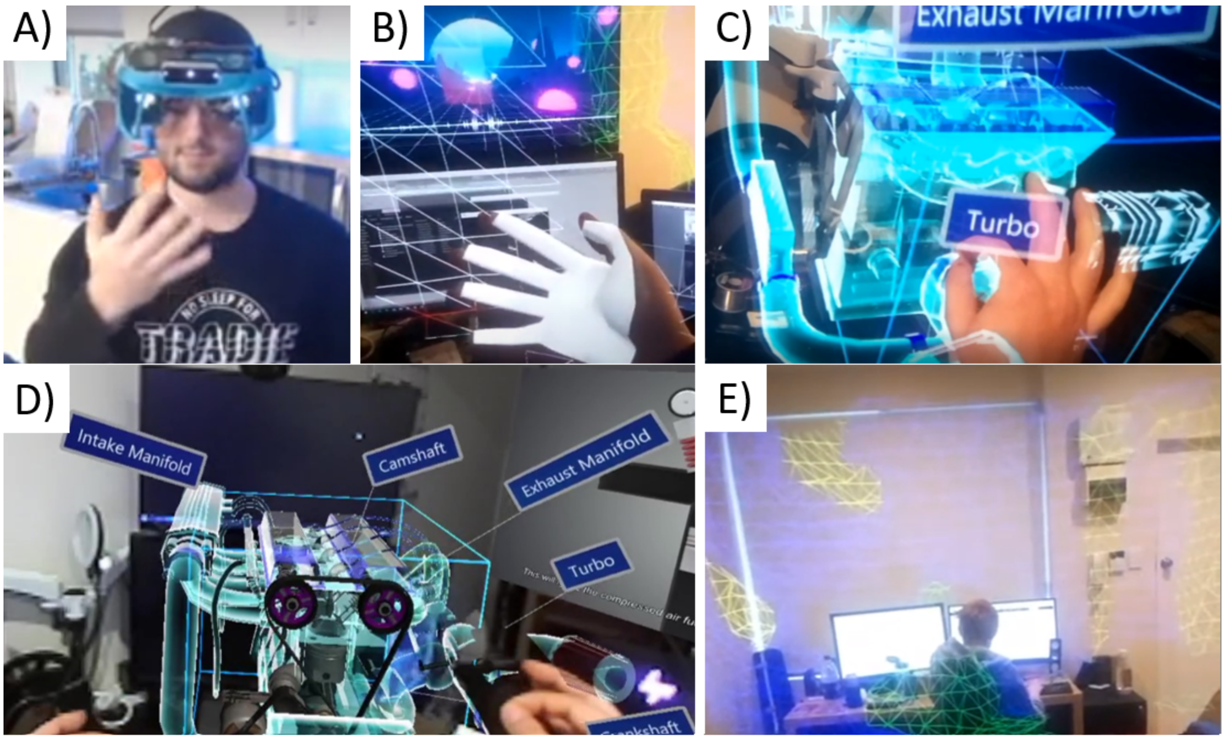

Figure 1: We present Project Esky, A complete Open Source Augmented Reality (AR) modular platform capable of high fidelity AR. A) A user wearing Project Esky. B) A photo from the user's view showcasing the hand tracking capabilities. C) An example integration with Microsoft's Mixed Reality Toolkit, providing natural hand gesture interactions. D) A preview captured from the integrated 6DOF Tracker. E) A second photo from the user's view showcasing the spatial reconstruction capabilities.

Abstract

This demonstration showcases a complete Open-Source Augmented Reality (AR) modular platform capable of high fidelity natural hand-interactions with virtual content, high field of view, and spatial mapping for environment interactions. We do this via several live desktop demonstrations. Finally, included in this demonstration is a completed open source schematic, allowing anyone interested in utilizing our proposed platform to engage with high fidelity AR. It is our hope that the work described in this demo will be a stepping stone towards bringing high-fidelity AR content to researchers and commodity users alike.

Keywords: Augmented Reality, High Fidelity, Collaborative Augmented Reality, Open Source Platforms

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1 Introduction

Recent years saw an explosion in Augmented Reality (AR) experiences for consumers, typically deployed on commodity Optical See-Through devices such as the Microsoft Hololens 2 [4], Magic Leap [2] and Project NorthStar [8]. These devices enable end-users to engage with AR content via Hand Interactions or a 6DOF controller, and are capable of high fidelity immersive experiences. However, each device has limitations varying from low graphics capabilities due to a mobile deployed system, limited field of view, delayed hand tracking, or in the case of Project North Star, a lack of built in 6DOF head tracking.

Other DIY AR systems exist [5, 6] albeit with lower-fidelity capabilities due to the method used to track the user, and the tools used to interact with virtual objects. It is indeed a challenge to deploy a mobile AR system capable of high fidelity AR, [1, 7]. This is further compounded by the entry level market place cost vs fidelity properties, isolating hobbyists from the field. This sparked the need for an alternative, open source solution that allows for high fidelity AR interactions.

In this demo, we present a complete open source DIY AR modular platform capable of High Fidelity AR and hand based gesture interactions with virtual content. We do this via several live desktop demonstrations and a collaborative AR game specifically designed for our platform. We also present the schematic and source code of our system, allowing other researchers to build our proposed platform themselves, and engage with high quality AR development and research.

2 System Design and Implementation

The following section describes the design and implementation schematics for Project Esky. Our work required the usage of an Optical See-Through Head Mounted Display (OST-HMD) with high field of view. It also requires a means of capturing 3D environment information so that we can facilitate interactions between the virtual objects and the physical environment. Finally we require a means of interacting with virtual objects in order to bridge the physical gap between the real and virtual worlds. Figure **??** contains a basic high level overview of a schematic derived from these requirements, based on fitting the design space for high fidelity AR experiences [7] since it is the end target of our system.

At the high level, Project Esky is designed to be a modular system, with components that are easily substituted, allowing for better hardware or cheaper solutions as per user specific requirements.

Based on these schematics, we built our variation of Project Esky using the following hardware:

- PC: HP Z VR G2 Backpack PC. 2.6 GHz Intel Core i7-8850H, 32 GB RAM, GTX 2080
- Display: Project Northstar [8]
- Hand Tracking: Ultraleap Leap motion device
- 6DOF tracking: StereoLabs ZED 2

For software, we utilize the Unity Game Engine along side several c++ plugins to handle native level undistortion, rendering, and tracking. Our software also integrates Microsoft's Mixed Reality Toolkit (MRTK) to provide hand-gesture interactions with virtual content.

Before the system can be used, several calibration steps need to be taken to calculate the optical distortion of the headset, and the positional offsets of all trackers from the origin of the HMD viewport. The next sub sections describes the details behind the calibrations.

Calibrating the Optics: Performed once after the hardware is setup, by calibrating the optics of the North Star headset, we ensure that the re-projection of a virtual image is presented to the user undistorted. This results in all virtual lines appearing parallel/straight, and the virtual image appearing to be correctly registered to it's physical location in 3D space. Utilizing the calibration stand from [8], a stereo camera is placed on the stand and calibrated with a checkerboard marker. The North Star HMD rests on top, so that the stereo camera captures the viewport through the HMD.

We then utilize binary-coded structured light homography [3] to compute the depth of each pixel displayed on the north star lens, in order to collect a series of undistortion points. These points are utilized to create a look up table, resolving a 3rd-order 2D polynomial from the 2D screen space to the corresponding point on the now undistorted virtual viewport. While this calibration method is faster to perform compared to previous undistortion mapping algorithms [8], it is not perfect, and exhibits distortion at the extreme edges of the display (See Figure 1). However, the displayed image is acceptable for the majority of the central viewport of the display and is therefore acceptable for augmentations. To render images on the display, we utilize a secondary OpenGL instance created at runtime within the running Unity Engine. Two render textures (one for each virtual eye camera) are shared with the OpenGL instance, rendering them to the display with the polynomial shader. The resulting rendering is shown in Figure 1C.

Between Sensor Calibration Before the 6DOF and hand tracking can be utilized with our now-calibrated HMD, their offsets from the user's viewport need to be calculated. For this we offer two approaches.

Online Hand-based Alignment: A user holds their hand in front of the leap motion tracker, which shows the virtual hand with some offset, then the user presses a button, freezing the virtual hand in place, allowing the user to match the virtual hand's pose and orientation with their real hand. Doing this several times captures the corresponding points between the initial fingertip pose and orientation. While this method does work, and requires less hardware to perform, it can lead to errors due to misaligned user Input.

Offline Visual Marker Alignment: This process involves the usage of the calibration stand, with an ARuCO marker placed in the view of all sensors. The relative pose between each sensor is computed automatically by inferring from the transform between each sensor and the detected ARuCO marker. This technique involves the use of extra hardware, but allows for an automated calculation of the required pose offsets.

3 Demonstrating the Capabilities of Project Esky

As shown in the accompanying video, our completed open source platform is capable of high fidelity AR. We showcase several desktop demonstrations that have been quickly built using the combined software alongside the default demonstrations packaged with the integrated Mixed Reality Toolkit by Microsoft. The first is a virtual piano that has been connected to a realtime-generation of an synthesized organ using Virtual Studio Technology, showcasing the low-latency of the hand tracking. The second is an engine learning experience, where users are able to manipulate a virtual car engine, with full animations of the pistons, crankshaft, and all extra components. The hand menu allows users to turn the engine transparent (to show the internal engine components) and adjust the speed the engine rotates.

Viewer Participation: Since the conference will be held virtually, we intend to demonstrate Project Esky as a live online streamed demonstration. While we have a live actor demonstrating the system, viewers can preview the demo with through-the-lens and video see-through previews of the action occurring.

4 Conclusion and Future Work

Although there are several off-the-shelf OST AR solutions, Project Esky is the first open source modular DIY AR platform capable of high-fidelity. In this demo, we showcase some of the capabilities of Project Esky by presenting several high quality desktop AR experiences. As a bonus, we also present the blueprints for our platform including the hardware used, and the software steps required for a novice-user to build their own platform. It is our hope that attendees who view our demonstration, are inspired by the designs of our AR experience, and the open source platforms the demo is deployed on. This will hopefully encourage attendees to build their own variation of Project Esky based on the provided blueprints and software, bringing high fidelity AR to the masses.
Links to the related source code can be found here:
Unity Integration: https://github.com/HyperLethalVector/ProjectEsky-UnityIntegration/,
LLAPI: https://github.com/HyperLethalVector/ProjectEskyLLAPI

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