Exploring Edge Computing in Multi-Person Mixed Reality for Cooperative Perception

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Abstract

Traditional Mixed Reality(MR) and Augmented Reality(AR) devices support a wide gamut of sensors, but the limited computational resource onboard such devices make advanced tasks difficult. We introduce the use of Edge with MR devices to provide a cooperative perception capability to the MR device. We base our approach on the portability and low latency of the Edge. Through our prototype system, we demonstrate the potential of devices and evaluate the performance and feasibility through real world trials. Our evaluation proves that the system is capable of supporting cooperative perception tasks.

1 Introduction

Newer sensors as well as more sophisticated technologies are ushering in new ways of interaction with the world around us. The three different interactions that are most well known are Augmented Reality(AR), Virtual Reality(VR), and Mixed Reality(MR). However, these devices, such as the HoloLens, are limited by the hardware, especially when it comes to running intensive or non-native tasks [1–4,7,9]. In our application, we seek to utilize the HoloLens in both machine learning tasks such as object detection and recognition as well as communication tasks such as cooperation between multiple users.

2 MR-Edge Cooperative Perception System Design

Edge computing has seen a lot of research in recent years [5,6,8]. But, routing from the HoloLens to the cloud servers or other remote connections through the internet require a multi-hop process. However, bringing the Edge into the picture will reduce the number of hops between the device to the Edge down to one, making it the better choice for latency critical tasks. In our design, we utilized three separate channels of MR to Edge, Edge to Edge, and Edge to Cloud. With each channel facilitating its own connection, we have a separation of tasks that also allow for data management as well as filtering.

3 MR-Edge Cooperative Platform

In our proof of concept experiment, we used two HoloLens communicating through the nearest Pi device for our tests. In our tests, we were able to establish and measure the low latency communication channel between the two HoloLenses. As our system requires deep learning, and as our Edge Device is a Raspberry pi, we used the Movidius Compute Stick as our computer vision accelerator.

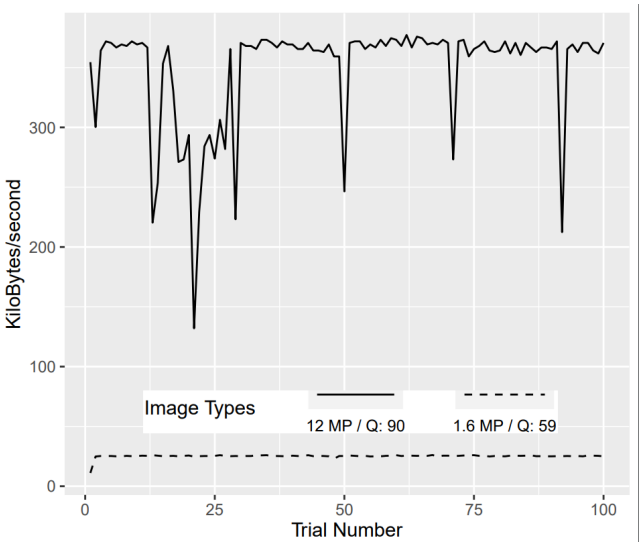

Figure 1: Throughput in KB/s of image upload and detection. High resolution 16MP JPEG image is 3000x4000 pixels at 90 quality while the low resolution is 1.6 MP JPEG 1080x1440 at 59 quality.

3.1 System Throughput

In Fig. 1 we showcase the two separate workloads performed by our system. Then, using the same image for both workloads, we scaled one to the native resolution of the HoloLens and kept the source resolution to test for system bandwidth. While the lower resolution shows a lower throughput averaging 25 Kilobytes per second and the higher resolution peaks at around 375 Kilobytes per second, our system only shows throttling in a few instances of the higher resolution.

4 Conclusion

In our evaluation, we find that while having Deep Learning does not impact the operating energy consumption, it does limit the speed. As seen in Fig. 1, the bandwidth is more than capable of handling the native resolution of our MR Device. We conclude that Edge Devices can vastly enhance the capabilities of MR and AR devices, and through our proof of concept system, we demonstrated the possibility of such systems.

Availability

All Source code for the prototype system can be found at: https://github.com/HaidiChen/Holo_Pi

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EXPLORING EDGE COMPUTING IN MULTI-PERSON MIXED REALITY FOR COOPERATIVE PERCEPTION

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★ Facilitate the use of MR onboard sensors towards a wider array of tasks through Edge.

★ Prototype system for an edge computing architecture using low power machine learning with a portable edge device.

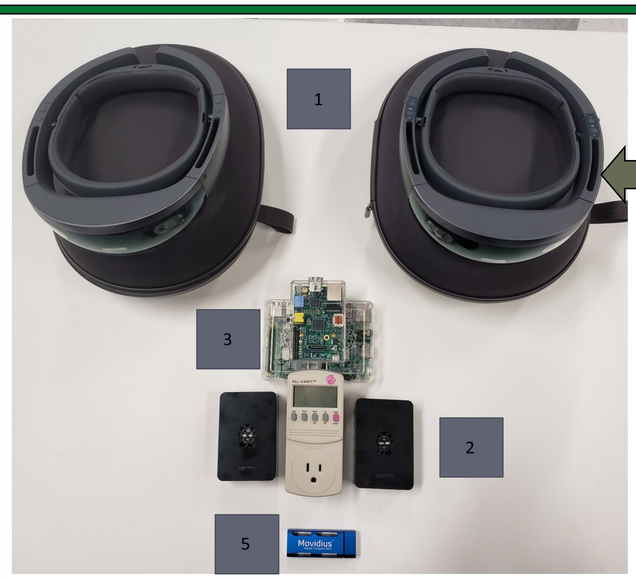
Background

Traditional Mixed Reality(MR) and Augmented Reality(AR) devices support a wide gamut of sensors, but the limited computational re-source onboard such devices make advanced tasks difficult.

We introduce the use of Edge with MR devices to provide a cooperative perception capability to the MR de-vice, basing our approach on the portability and low latency of the Edge. Through our prototype sys-tem, we demonstrate the potential of devices and evaluate the perfor-mance and feasibility through real world trials. Our evaluation proves that the system is capable of sup-porting cooperative perception tasks.

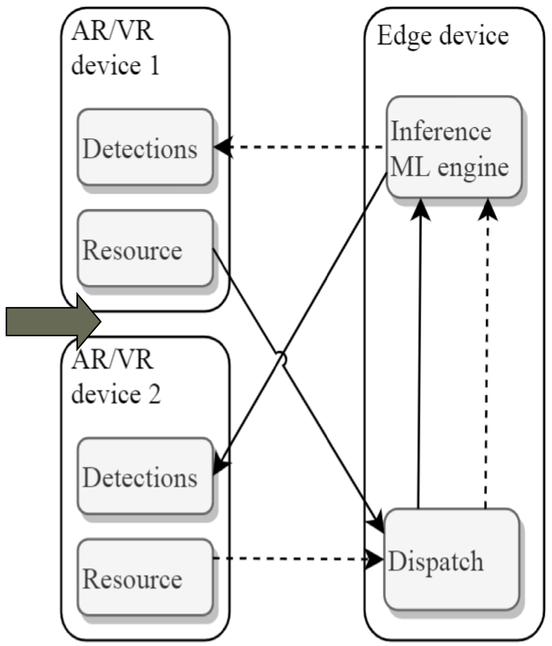
Potential Application

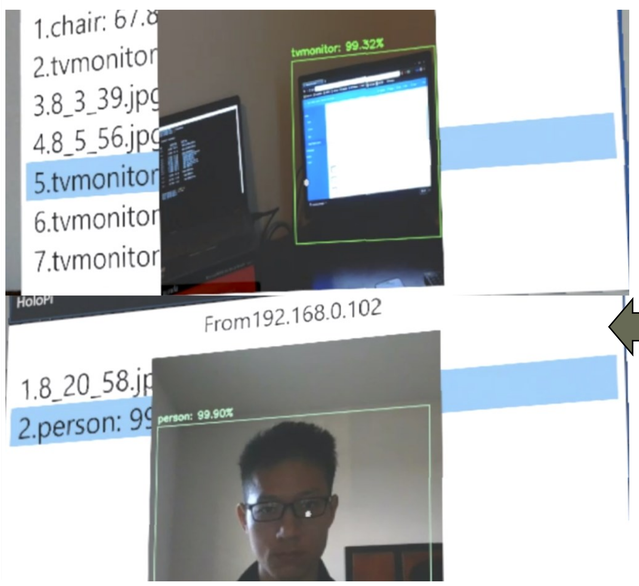
Combining cooperative percep-tion with machine learning can aid in Complex Aircraft Mainte-nance and repairs, where experts and trainees alike are able to share the vision and assist re-motely while the system can de-tect and highlight important areas for the on-site person to check.



The equipment used is labelled as follows: 1.) Two HoloLens [Gen 1]. 2.) Two Raspberry Pi [Gen 4]. 3.) Two Raspberry Pi [Gen 3]. 4.) Watt's Up Pro 5.) Movidius Compute Stick. Note that item 4 is not included in the image, but is represented by a smaller replacement device resting in between the two Raspberry Pi (Gen 4)s.

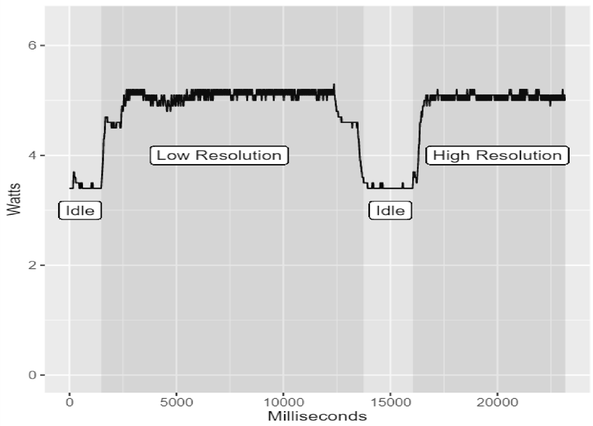
From an overhead schematic view, we have three layers of separation. Each connected AR/MR device is responsible for two parts, raw data collection and result reception. On the Edge Device, we also have two primary functions, communi-cation facilitation as well as data processing. Each connected device will transfer their raw data to the Edge De-vice, where detection is being done. After detection has been done by the Edge, it will then relay the results to all recipient devices.



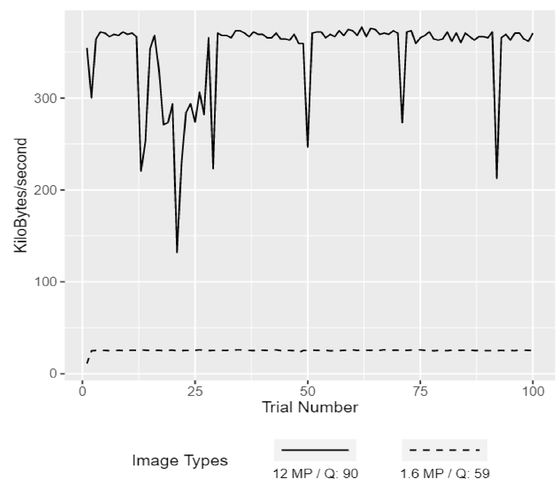


The list of objects available from the Edge is dis-played on the left and the processed image with bounding box is displayed on the right. In the top image, we have a monitor selected and in the bottom a person. Both cases yield a high accuracy of 99%.

Results



The above shows the power usage over time of a Raspberry Pi 4 with Movidius Computer Stick. This dataset is representative of both idle and ex-tended operation time periods processing low resolution and high resolution images.



The above shows the throughput in KB/s of image up-load and detection. High resolution 16MP JPEG image is 3000x4000 pixels at 90quality while the low resolu-tion is 1.6 MP JPEG 1080x1440at 59 quality.