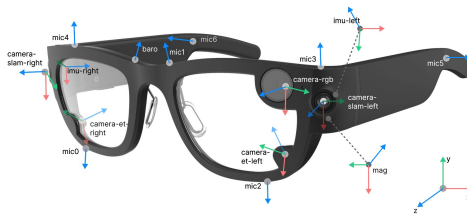


Power-Efficient SLAM for AR Glasses



Easton Wei

Under the supervision of
Prof. Yao Liu and Zihao Ding

About Me

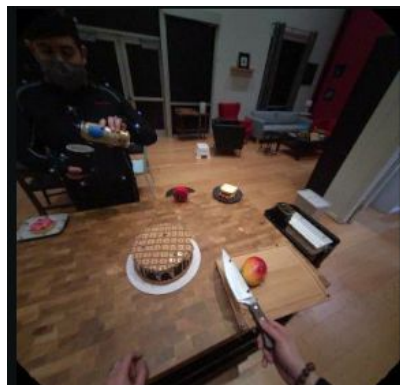
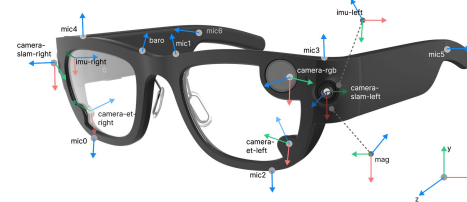


Easton Wei

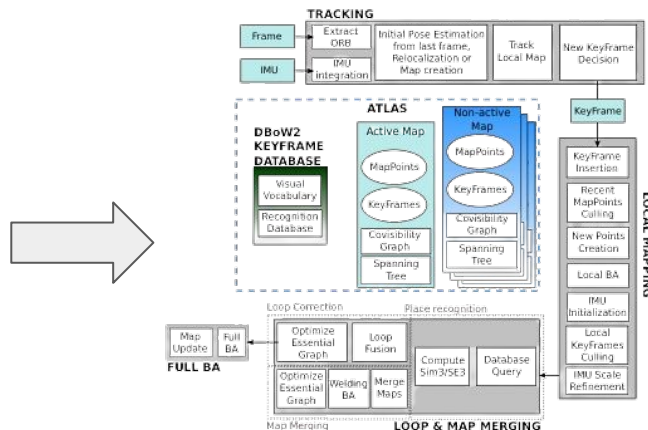
I am a rising freshman at WW-P
High School North.

SLAM for AR Glasses

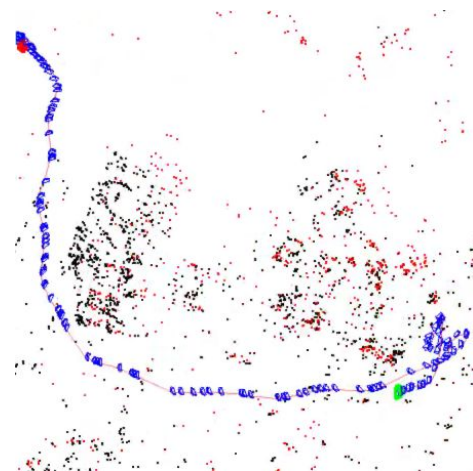
- AR (Augmented Reality) requires efficient, continuous processing of visual data
- Specifically, SLAM (simultaneous localization and mapping) is required for many AR core functions



Input frame + IMU data



ORB-SLAM3 pipeline [1]



Output trajectory + points

The Problem: Power Efficiency

- SLAM requires a continuous on-device visual/inertial stream to function
- Capturing and transmitting the images from the glasses consumes a lot of power; glasses overheat within minutes and battery drains quickly



Main Focus

- Main focus of this project: **study how different recording configurations impact SLAM quality and power usage**
- Two potential ways to decrease the power usage:
 - Decreasing framerate (this project)
 - Decreasing resolution (future work)



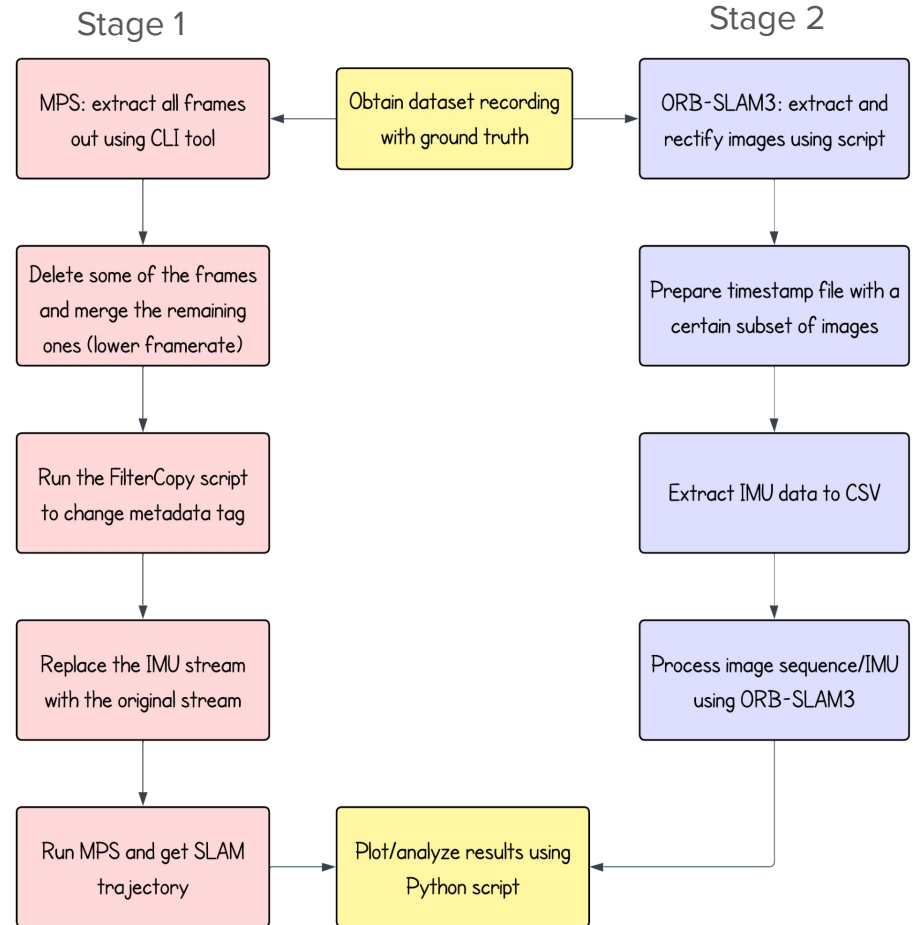
Higher Framerate (10fps)



Lower Framerate (3fps)

Experimental Design

- Objective: **profile how different framerates affect SLAM outputs**
- Compare different SLAM systems in the process
 - ORB-SLAM3 [1]
 - MPS [2]
- Explore consistency across the Aria Digital Twin dataset



[1]: Campos, Carlos, et al. "Orb-slam3: An accurate open-source library for visual, visual-inertial, and multimap slam." *IEEE transactions on robotics* 37.6 (2021): 1874-1890.

[2]: <https://www.projectaria.com/>

Tools Used

- Aria glasses from Meta [2]
 - Wearable sensors designed to replicate the capability/form factor of future AR glasses
 - They include three cameras and an IMU (Inertial Measurement Unit)
- Software
 - Aria SDK
 - VRS library
 - ORB-SLAM3
- Dataset
 - Aria Digital Twin dataset, with ground truth trajectories



Stage 1: MPS Accuracy Analysis

- **MPS** (Machine Perception Services) is a SLAM service provided by Meta
- Designed specifically for Aria data, and no calibration is required
- The problem: black-box service with strict health checks implemented
- Takes a long time to process recordings, cannot be run live



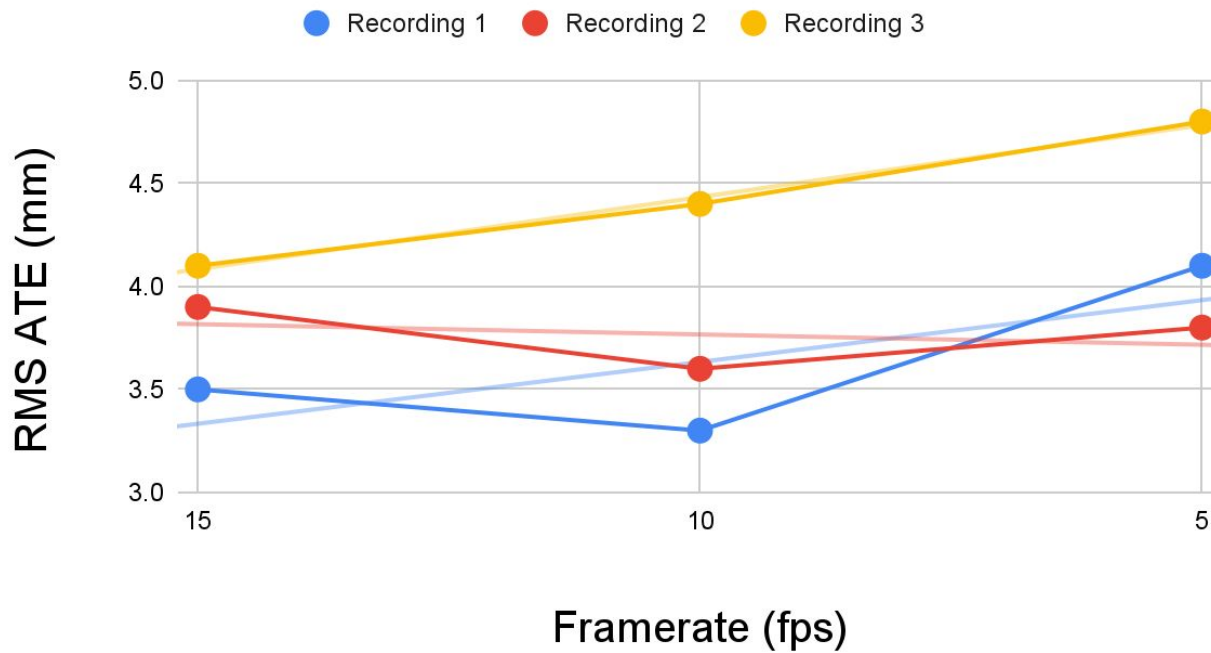
Solutions Found

- Use the VRS tool to extract the frames one-at-a-time, then merge a selected subset of them later
- Use FilterCopy function to change the metadata tag that MPS is flagging

```
142    // Sample function that copies a file, and reduces the image height by half
143    ▼ int halfHeightImageFilter(const string& sourceFile, const string& outputFile) {
144        CopyOptions options(false);
145
146        FilteredReaderReader filteredReader(sourceFile);
147        IF_ERROR_LOG_AND_RETURN(filteredReader.openFile());
148
149        return filterCopy(filteredReader, outputFile, options, makeImageResizeFilter);
150    }
```

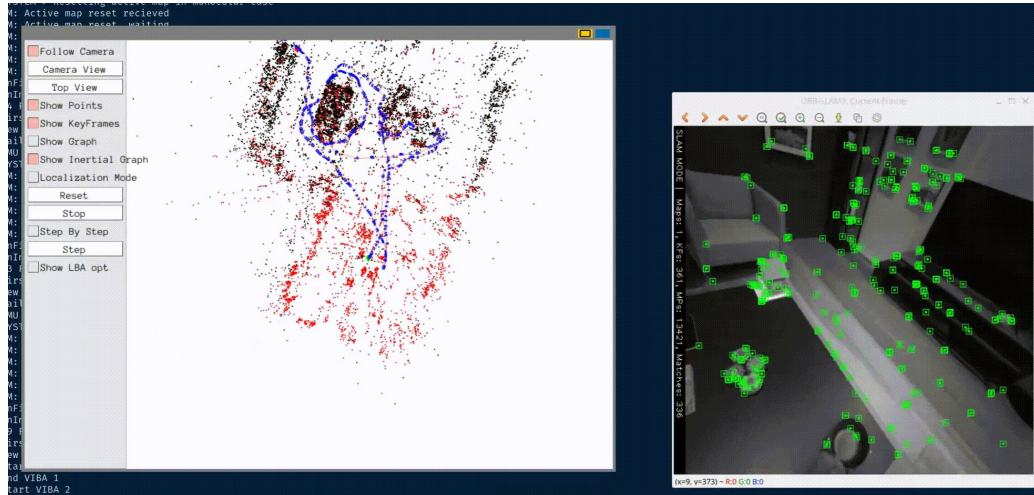
Results

Results on MPS after decreasing framerate



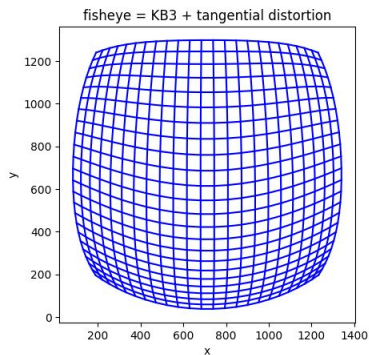
Stage 2: Analysis Using ORB-SLAM3

- ORB-SLAM3 [1] is an open-source SLAM library
- Supports monocular, monocular-inertial, stereo, and stereo-inertial SLAM
- Runs locally, so you can see detailed logs and outputs

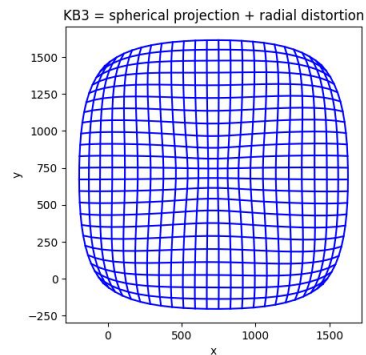


The Problem: Camera Calibration

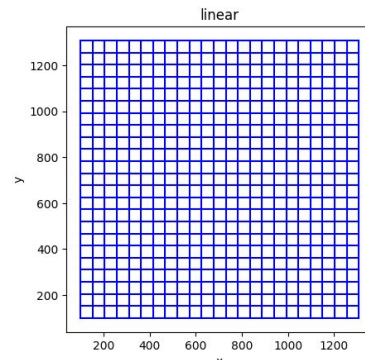
- The images from Aria cameras follow a rather complicated calibration (or “shape”) called Fisheye624
- ORB-SLAM3 only accepts simpler calibrations like pinhole, which is incompatible with Fisheye624



Fisheye62 calib (simpler variant of Fisheye624)



ORB-SLAM3 supported calibrations

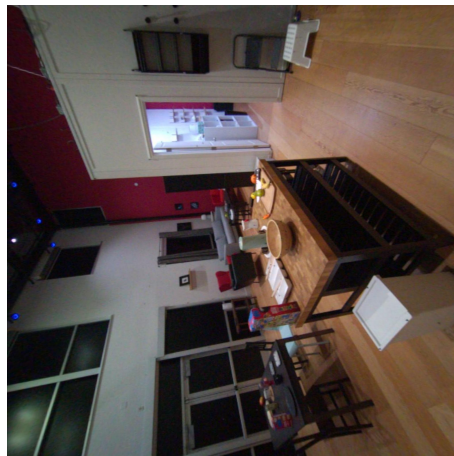


The Solution: Code for Rectification

- Found preprocessing script from “Photoreal Scene Reconstruction from a Egocentric Camera” [3]
- Turns the Fisheye624 raw images into rectified pinhole images



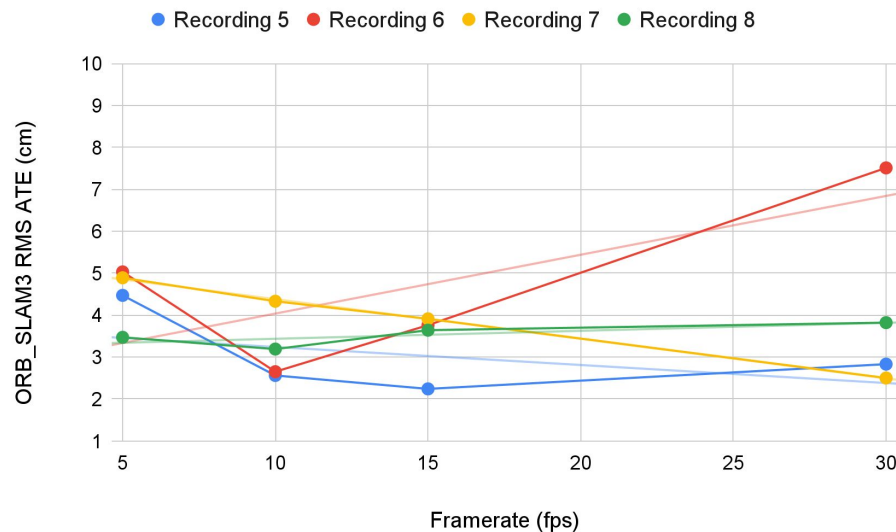
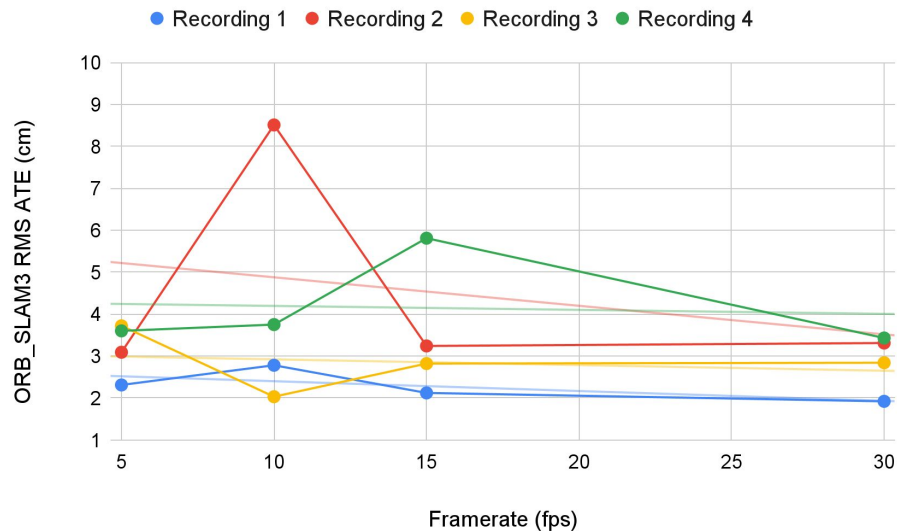
Before (Fisheye624)



After (Pinhole)

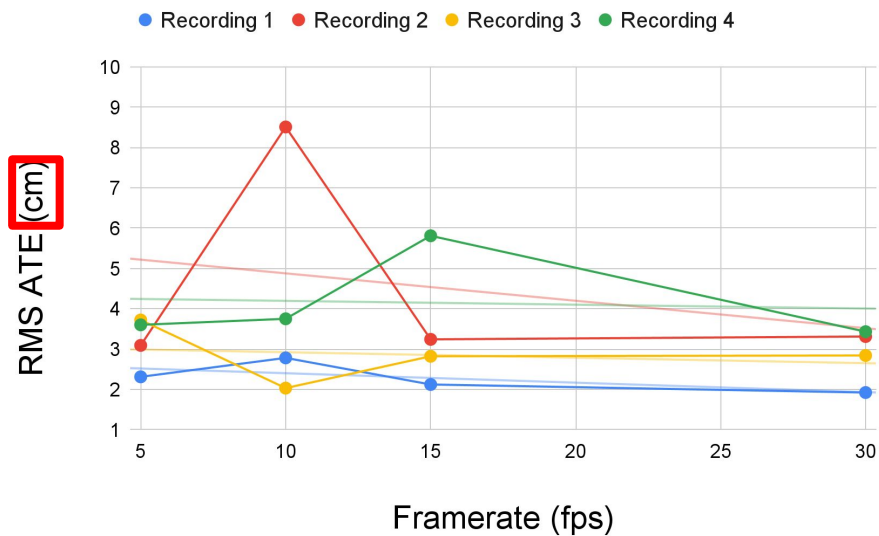
Results

- Most lines of best fit have low slopes, indicating that ORB-SLAM3 is robust to changes in framerate

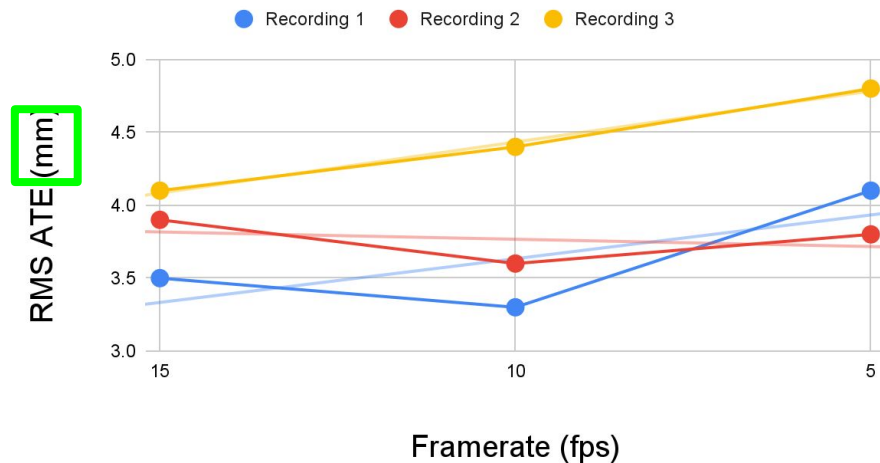


ORB-SLAM3 vs. MPS

Results on **ORB-SLAM3** after decreasing framerate

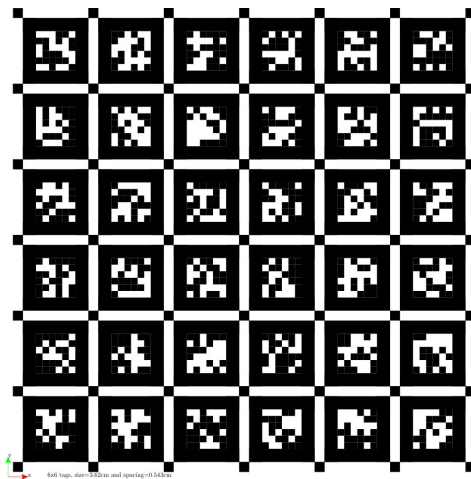


Results on **MPS** after decreasing framerate



Future Work

- Profile the performance of ORB-SLAM3 on stereo/inertial mode
- Perform quantitative power profiling to see how well decreasing framerates and resolutions boost power efficiency in real life
- Run a live ORB-SLAM3 pipeline to evaluate real-time performance



Thank you!