

Vision Quadchart

14/04/24

Demonstrating Visual-Inertial A&OD & On-Orbit Edge Computing

15 days before May 1st

Progress summary

Updates

- Dataset:
 - Dataset download from 16 regions for new RC dataset
- RC:
 - Completed modifying script for multi-hot encoded data
 - Figured out how to use PSC properly for training
 - Data being moved to PSC for training as we speak
- LD:
 - Changed tuner to tune with L2 norm as a fitness metric
 - Found best hyperparameters for 17R through full tuning
 - Retrained on 17R with tuned hyperparameters

Blockers

-

Weekly Plan

- Vision
 - Localized hyperparameter search on 16 regions
 - Retrain 16 regions with tuned hyperparameters

Interface dependencies

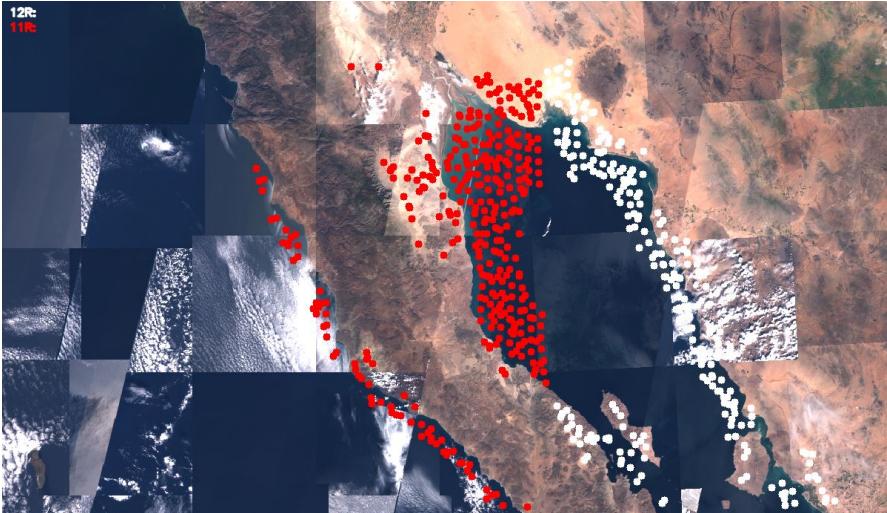
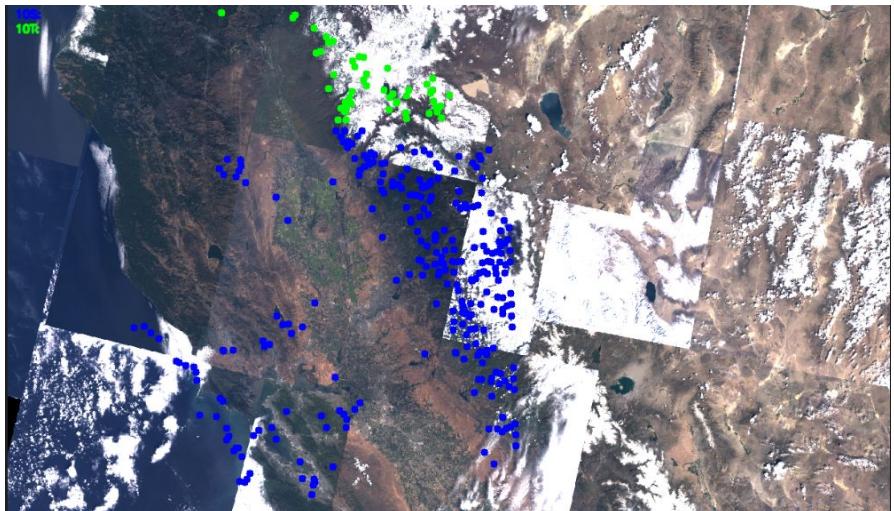
- Integrating image passing pipeline with GNC/avionics

Vision

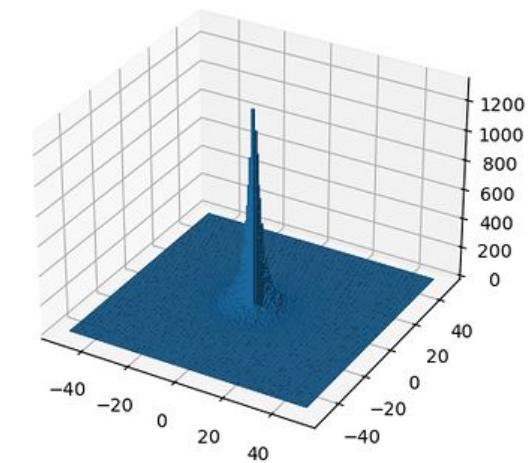
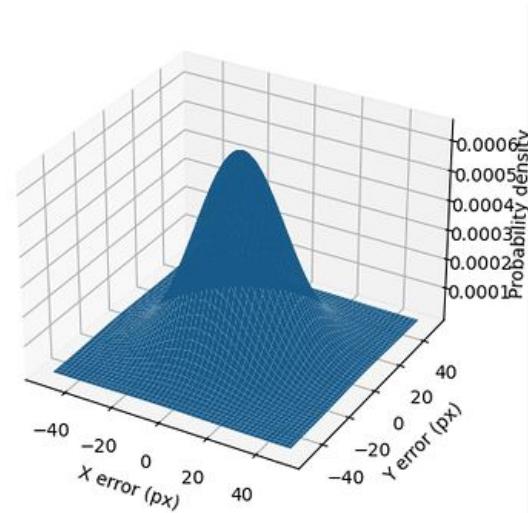
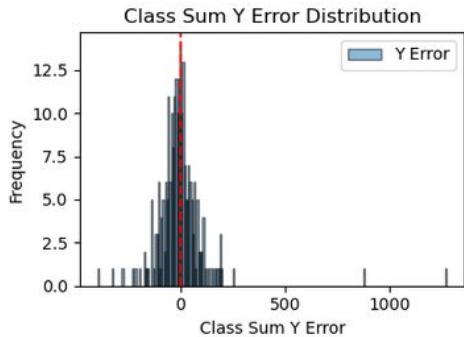
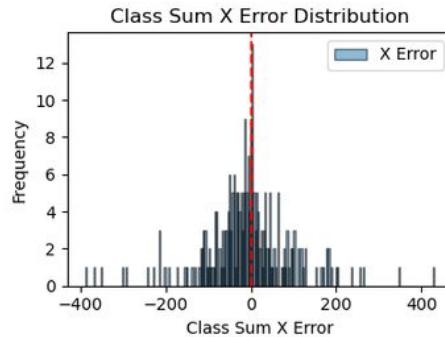
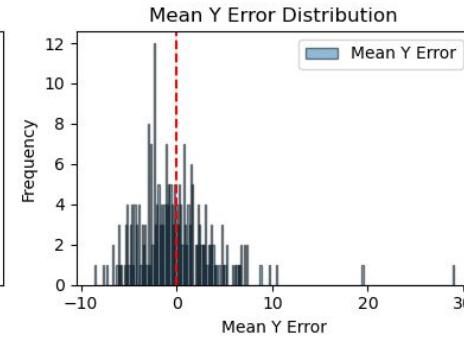
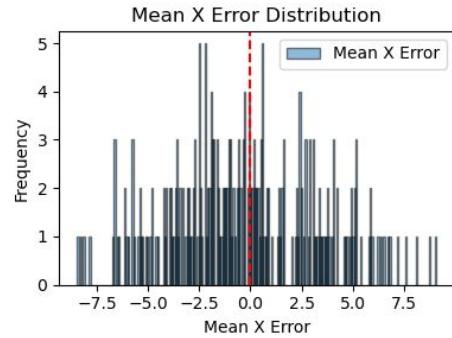
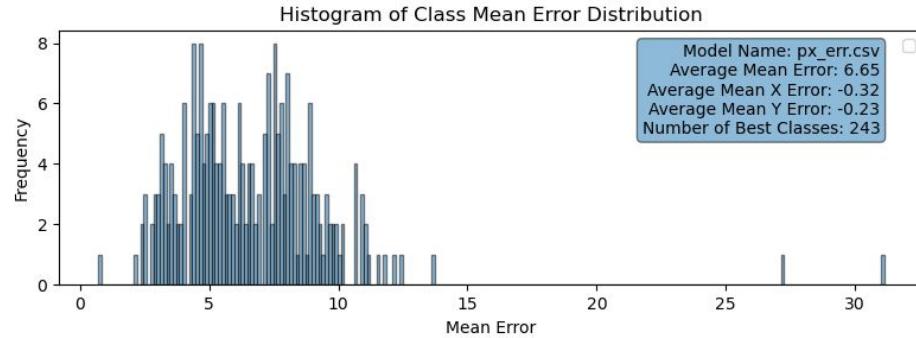
- **RC:**
 - New 16 + 1 (“None” region) regions of new training data
 - Mosaics of sentinel-2/landsat image that matched the land cover of camera image to support full size image inference
 - “None” region consists of images from ~200 regions excluding the 16 region
 - Relabeled image to multi-hot encoded region
 - Each bit reflects the region where their landmarks are located
- **LD:**
 - Added px error histogram (among best classes) in model evaluation
 - Changed tuner to tune with L2 norm as a fitness metric instead of mAP
 - Found best hyperparameters for 17R through full tuning (larger search space)
 - Retrained on 17R with tuned hyperparameters
 - Running localized tuning on other regions with smaller search space

```
box: 6.95499
mse: 9.57985
cls: 1.79619
dfl: 1.62749
hsv_h: 0.01264
hsv_s: 0.50185
hsv_v: 0.27928
translate: 0.11025
scale: 0.45495
shear: 0.0
perspective: 0.0
flipud: 0.0
mosaic: 0.79163
```

Visual inspection of regional landmark distribution on each image



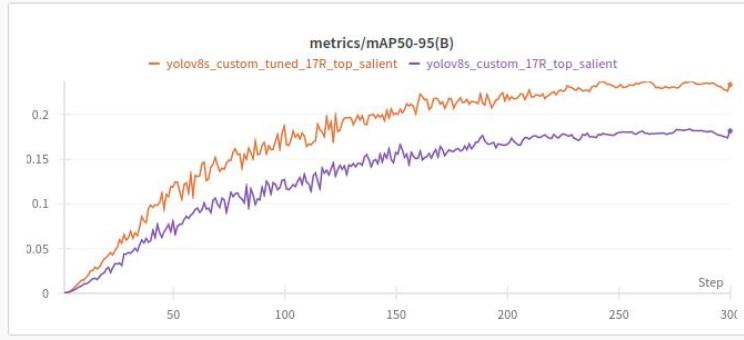
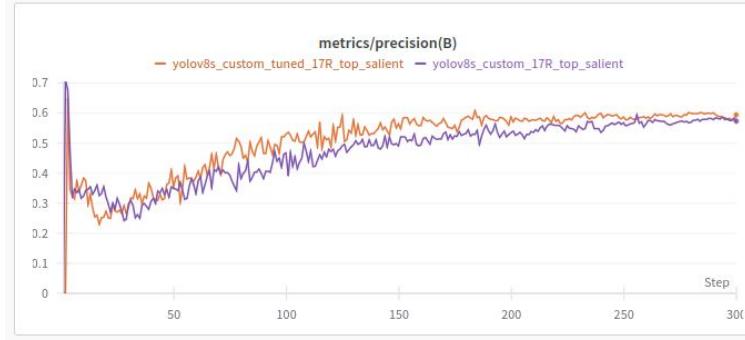
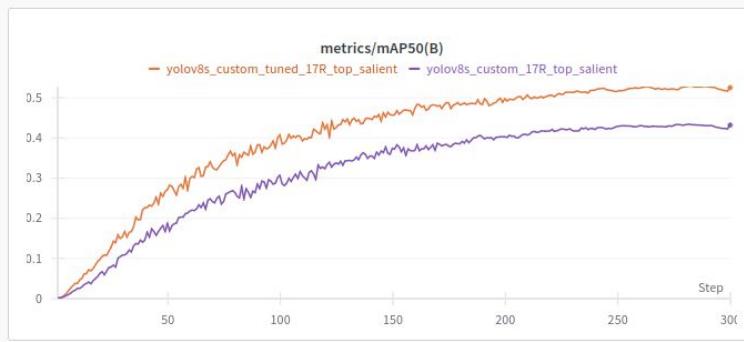
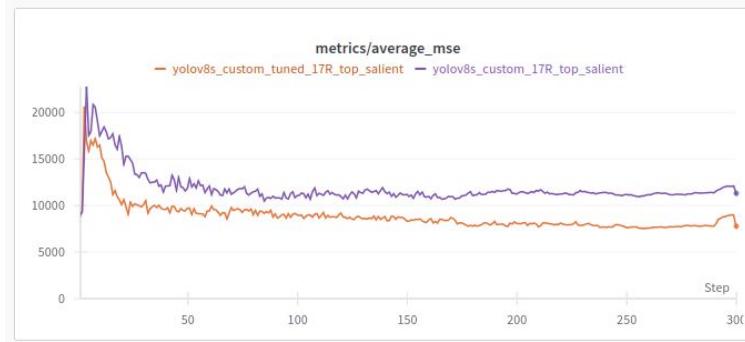
VisionTrainingGround > RCnet > 16_regions_dataset > train > label >  s2_11R_00561.txt



Default Models vs Custom Models (evaluated on test set)

LD models	px error	# of best classes	mAP50	mAP50-95
yolov8s_10S	6.65	243	0.7095	0.2895
yolov8s_10T	7.74	358	0.7438	0.3360
yolov8s_11R	6.53	247	0.7386	0.3949
yolov8s_12R	2.91	482	0.9553	0.7043
yolov8s_16T	8.13	169	0.5276	0.2380
yolov8s_17R	6.82	106	0.3470	0.1305
yolov8s_17T	8.98	106	0.4389	0.2081

yolov8s_custom_10S	7.01	266	0.7624	0.3729
yolov8s_custom_10T	6.29	393	0.8104	0.4375
yolov8s_custom_11R	6.66	275	0.7552	0.4249
yolov8s_custom_12R	3.21	482	0.9539	0.6928
yolov8s_custom_16T	8.03	217	0.5881	0.2893
yolov8s_custom_17R	6.70	118	0.3589	0.1475
yolov8s_custom_17T	9.20	123	0.4805	0.2379



Model	Test Pixel Error	Test MSE	Test mAP50	Test mAP50-95
yolov8s_custom_17R	14.4033	1240.926	0.3589	0.1475
yolov8s_custom_tuned_17R	11.875	708.705	0.45236	0.1985

Camera Calibration

- Achievement
 - Done whole calibration test for 3 cameras with the new setup
 - Done verification process of the rvecs and tvecs.
 - Rvecs: Use Rodrigues in Opencv to convert into rotation matrix, convert the rotation matrix into euler angles and compare with the recorded data
 - There exists some error.
 - Ex.:`array([[0.05963794],[0.57184276], [0.00154975]]) ->`
Roll: 3.87°, Pitch: 32.74°, Yaw: 1.23°
 - Tvecs:
 - Compare the test result with the record data: error exist
 - data=648mm
- Next steps
 - There still are 3 cameras not found. Process all the cameras
 - Realize 3d visualization for the extrinsic will be more straightforward
 - Other available jetson orin?



```
test_cam2_recalibration.txt
intrinsic matrix: [[3.37920153e+03 0.0000000e+00 2.30896135e+03]
[0.0000000e+00 3.37097108e+03 1.25431568e+03]
[0.0000000e+00 0.0000000e+00 1.0000000e+00]]
distortion: [[ 0.04354857 -0.02756639 0.00263099 -0.00145289 -1.38439898]]
rvecs: (array([[ 0.05963794],
[ 0.57184276],
[ 0.00154975]]), array([[ 0.05963794],
[-0.16939664],
[-0.01105067]]), array([[ 0.07599844],
[-0.69301895],
[-0.0129828 ]]), array([[ 0.06150426],
[ 0.74155877],
[ 0.00393857]]), array([[ 0.06293112],
[-0.00104543],
[-0.01922163]]), array([[ 0.06357937],
[ 0.32729267],
[-0.00208082]]), array([[ 0.07260805],
[-0.50552833],
[-0.01169942]]), array([[ 0.06268261],
[ 0.21333713],
[-0.00104543]]), array([[ 0.0727938 ],
[-0.32771774],
[-0.01169815]]), array([[ 0.06291603],
[ 0.04006562],
[-0.00791406]]))
tvecs: (array([[-72.16365515],
[-178.60757212],
[ 0.00000000]]), array([[ -84.87398226],
[-175.12304284],
[ 605.81937479]]), array([[ -60.75126052],
[-173.0068971 ],
[ 558.76134935]]), array([[ -62.62221873],
[-179.29744405],
[ 689.22407521]]), array([[ -50.33758029],
[ 539.83159384],
[ 548.83159384]]), array([[ -80.18958273],
[-177.82398019],
[ 660.35577798]]), array([[ -71.86212595],
[-173.65611858],
[ 572.80783247]]), array([[ -84.91325451],
[-177.07186667],
[ 643.04656111]]), array([[ -79.70838922],
[-174.32237043],
[ 588.36341939]]), array([[ -86.65456299],
[-176.26289001],
[ 627.59490521]]))
```

01/04/24

Demonstrating Visual-Inertial A&OD & On-Orbit Edge Computing

29 days before May 1st

Progress summary

Updates

- Dataset:
 - Dataset download from remaining regions
- RC:
 - Working to change training data - training, validation vs test data has completely different distribution - using full image vs chopped up images for context
- LD:
 - Added L2 norm as metric to evaluation script and custom YOLO model
 - Tuning hyperparameters through grid search

Blockers

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Weekly Plan

- Vision
 - Complete tuning of LD model hyperparameters
 - Retrain on 16 regions
 - Improving RC training data

Interface dependencies

- Integrating image passing pipeline with GNC/avionics

Vision

- **RC:**
 - Working to change training data - training, validation vs test data has completely different distribution - using full image vs chopped up images for context
- **LD:**
 - Changed post-processing evaluation script to report L2 norm as well
 - Added L2 norm calculation to custom YOLO model as a logged metric
 - MSE used in loss
 - Tuning hyperparameters through grid search on 17R
 - Including weight on each loss component

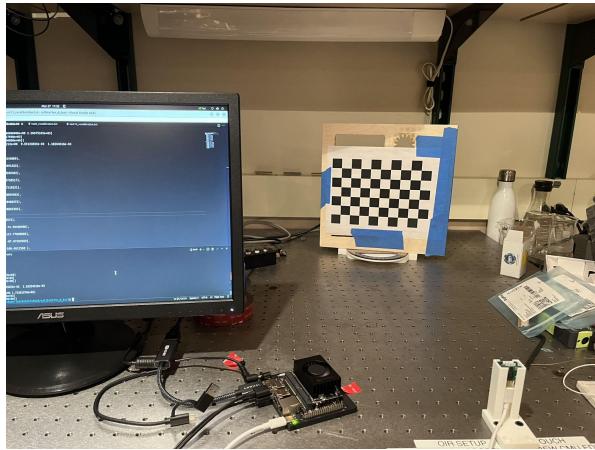
16 Regions evaluated on test images:

LD models	px error	# of best classes	mAP50	mAP50-95
yolov8s_10S	6.65	243	0.7095	0.2895
yolov8s_10T	7.74	358	0.7438	0.3360
yolov8s_11R	6.53	247	0.7386	0.3949
yolov8s_12R	2.91	482	0.9553	0.7043
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yolov8s_17R	6.82	106	0.3470	0.1305
yolov8s_17T	8.98	106	0.4389	0.2081
yolov8s_18S	6.39	305	0.7702	0.4121
yolov8s_32S	7.38	202	0.5822	0.3000
yolov8s_32T	7.59	398	0.7362	0.3630
yolov8s_33S	7.82	201	0.6361	0.2828
yolov8s_33T	9.97	148	0.5740	0.2032
yolov8s_52S	8.07	255	0.6827	0.3494
yolov8s_53S	7.11	259	0.7253	0.3598
yolov8s_54S	9.13	166	0.4034	0.1651
yolov8s_54T	8.35	92	0.3346	0.1154

Camera Calibration

- Achievement
 - Completed the code for extrinsic test
 - Done one camera calibration process with the new setup
 - Intrinsic parameters almost matched with the one get previously
 - Data(the distance from camera to the chessboard & orientation) collected for each calibration process
- Next steps
 - Validate the rotation and translation vectors.
 - Continue doing the whole process for calibrating both intrinsic and extrinsic.

```
intrinsic matrix: [[3.23471470e+03 0.0000000e+00 2.26675245e+03]
[0.0000000e+00 3.22243237e+03 1.46917848e+03]
[0.0000000e+00 0.0000000e+00 1.0000000e+00]]
```



25/03/24

Demonstrating Visual-Inertial A&OD & On-Orbit Edge Computing

36 days before May 1st

Progress summary

Updates

- Dataset:
 - Dataset download from remaining regions
- RC:
 - Moved all RCnet data to ECE Cluster - scp takes time - use rsync
- LD:
 - Training LD with custom loss function to tune MSE loss component
 - Pruning undetected classes

Blockers

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Weekly Plan

- Vision
 - Evaluate LD models with pruned classes
 - Grid search LD model hyperparameters
 - Improve RC mode performance
 - Complete first version vision system on flight software

Interface dependencies

- Integrating image passing pipeline with GNC/avionics

Vision

- **Dataset:**
 - Uploading datasets to shared google drive
- **RC:**
 - Moved all RCnet data to ECE Cluster - scp takes time - use rsync for faster copy / checking
- **LD:**
 - Training LD with custom loss function on 17R
 - mAP and MSE improvement using custom loss function on 17R
 - MSE lowered by 30% on test set
 - mAP50 increase by 9.9%
 - Previous error reported was MSE - square of Euclidean distance
 - Pruning undetected classes from trained models
 - Identified classes detected within 10 px error (euclidean distance) for each region
- **FSW-Jetson:**
 - Integrating RC + LD inference with camera interface

Camera Calibration

- Achievement
 - Continue doing the testbed calibration test mentioned last week
 - CAD done (a rotatable chessboard base)
- Next steps
 - Move forward to calibrate all the cameras
 - Extrinsic from centre of the cube (orientation)

18/03/24

Demonstrating Visual-Inertial A&OD & On-Orbit Edge Computing

44 days before May 1st

Progress summary

Updates

- Dataset:
 - Dataset download from remaining regions
- RC:
 - RCNet trained with 17 instead of 16 classes (no_landmarks is 17th class)
- LD:
 - Training LD with custom loss function on 16 regions
 - Pruning undetected classes

Blockers

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Weekly Plan

- Vision
 - Tune LD model hyperparameters
 - Improve RC mode performance
 - Complete first version vision system on flight software

Interface dependencies

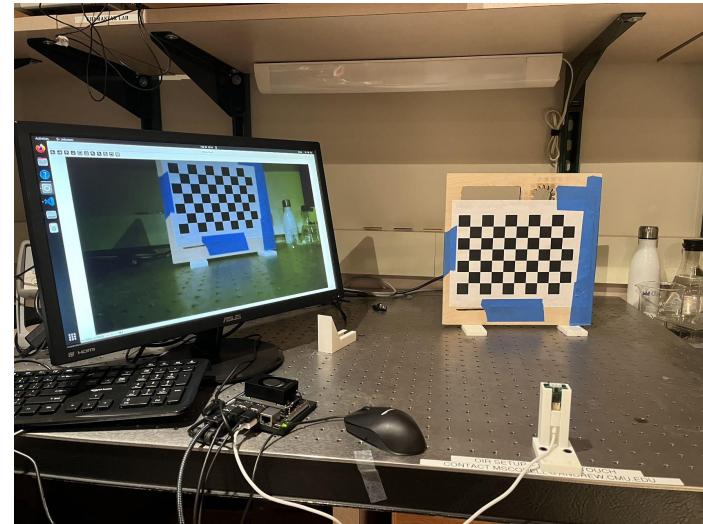
- Integrating image passing pipeline with GNC/avionics

Vision

- **RC:**
 - RCNet trained with 17 instead of 16 classes (no_landmarks is 17th class)
 - Still tuning parameters to maximize mAP - got ~70% with 16 classes but back to ~30% with 17 classes
- **LD:**
 - Training LD with custom loss function on 16 regions
 - Pruning undetected classes from trained models
- **Jetson:**
 - Moving testbed pipelines to flight software
 - Developing RC + LD inference with multi-camera input

Camera Calibration

- Achievement
 - The optical table is level
 - Done 10 calibration tests with fixed camera and solid chess board setup
 - More precise Intrinsic matrix computed
 - Tested the camera.py script and merged it into the whole pipeline
- Next steps
 - Move forward to calibrate all the cameras
 - Extrinsic from centre of the cube (orientation)



11/03/24

Demonstrating Visual-Inertial A&OD & On-Orbit Edge Computing

65 days before May 1st

Progress summary

Updates

- Dataset:
 - Dataset download from 16 regions
- RC:
 - RC net trained with 16 classes - ~45% mAP
 - RC net class implemented on Jetson
- LD:
 - Trained LD for 16 regions on top salient landmarks
 - Evaluated class wise and average MSE for 16 models
 - Models deployed on Jetson

Blockers

- Computing resources for LD training

Weekly Plan

- Vision
 - Continue training experiments with pruning
 - Improve mAP of RCnet - finetune hyperparameters
 - Complete and test camera to landmark pipeline on Jetson

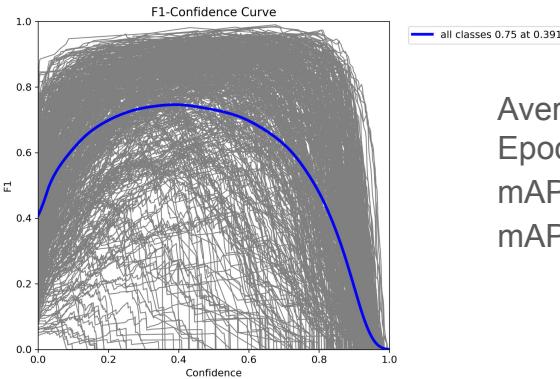
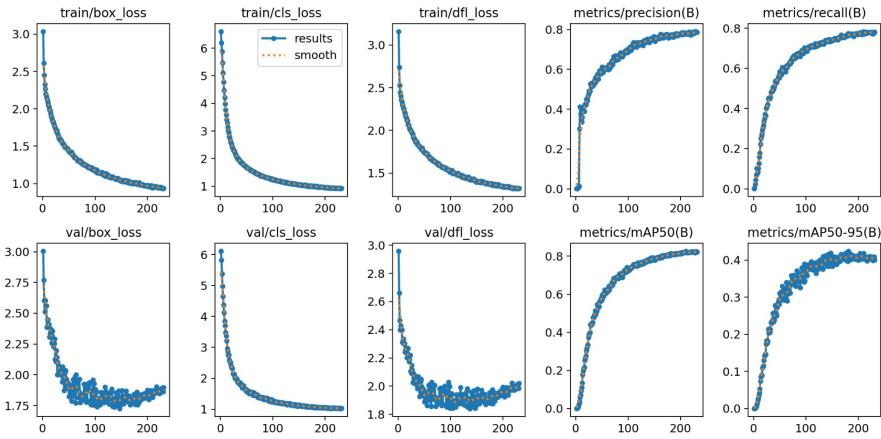
Interface dependencies

- Integrating image passing pipeline with GNC/avionics

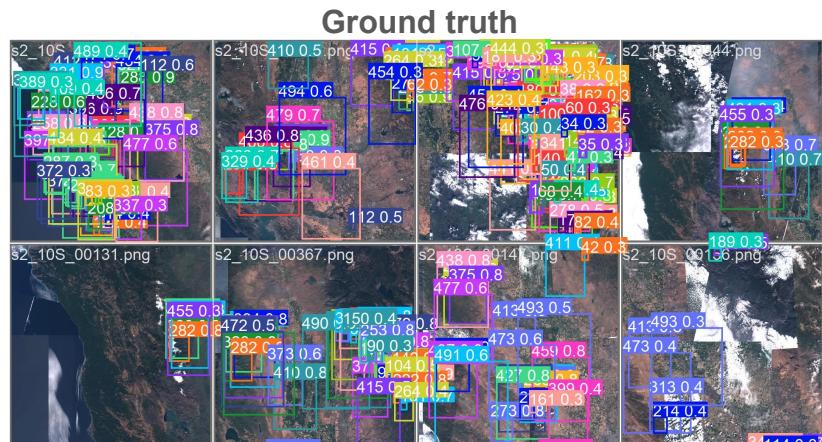
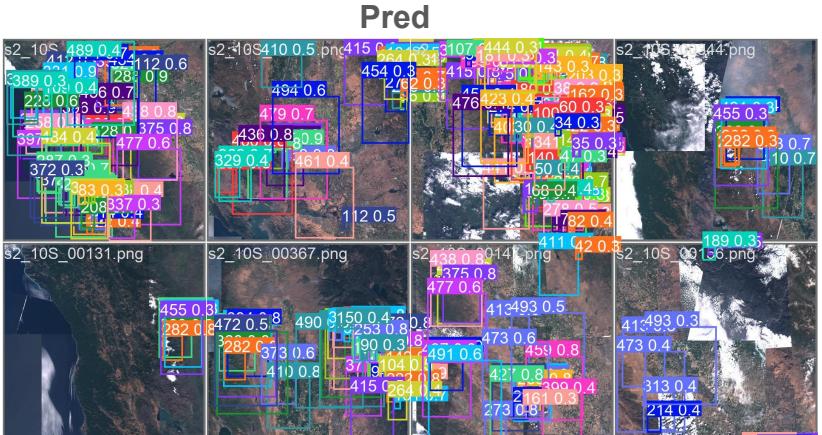
Vision

- **RC:**
 - Trained RCnet for classifying 16 regions
- **LD:**
 - Trained base LD net for 16 regions on top salient landmarks at different scales
 - 16 region training result in [Vision Gallery](#) and [YOLO Training Report](#)
 - Evaluated trained models: MSE, missed, extraneous detections
- **Jetson:**
 - RC and LD models deployed on Jetson
 - Implemented RC to LD batch prediction and evaluation pipeline and RC model individual testing script
- **Compute:**
 - Request to access the Data Science Cluster from [ECE community cluster](#) granted
 - GPU hours: ~ 11 (max yolo training time)*32 + 6 (rc training time) * 2 ≈ 350
 - Data Storage: 50 (yolo dataset) + 40 (rc dataset) + 25 (additional) = 115 GB

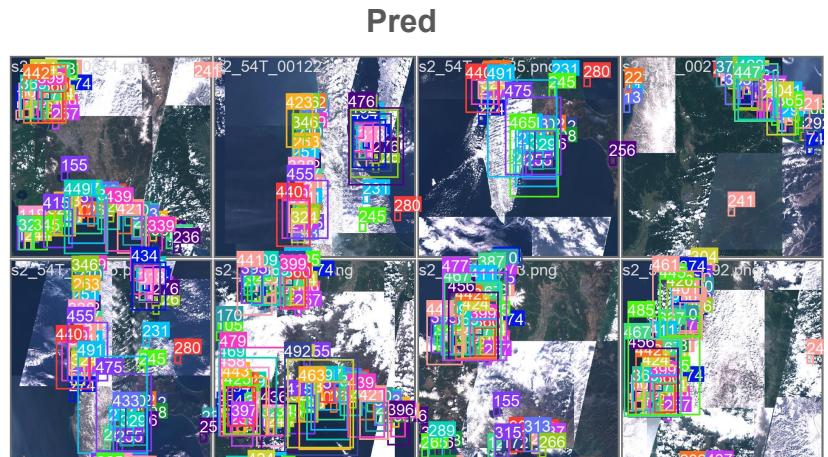
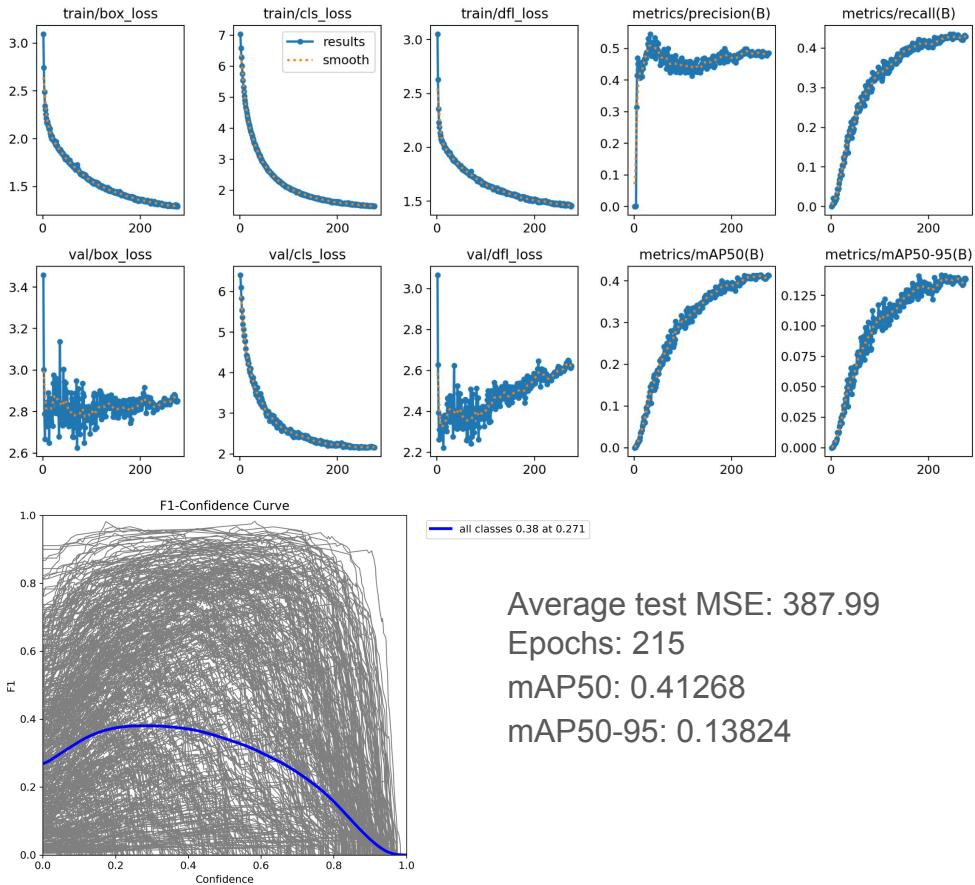
10S - California



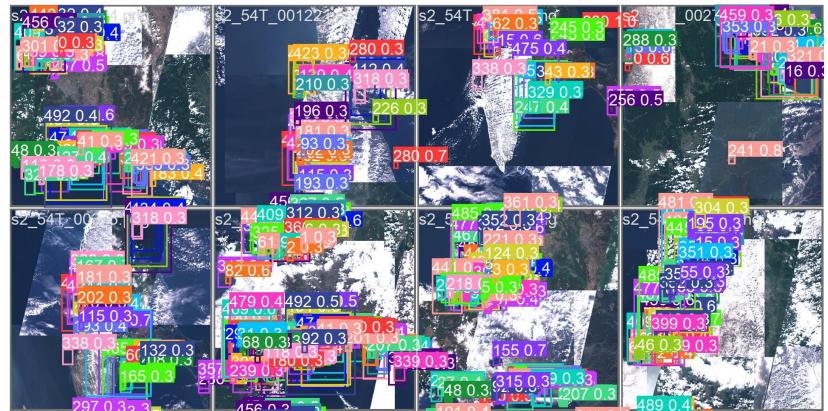
Average test MSE: 968.34
 Epochs: 231
 mAP50: 0.82285
 mAP50-95: 0.40043



54T - Sapporo, Japan

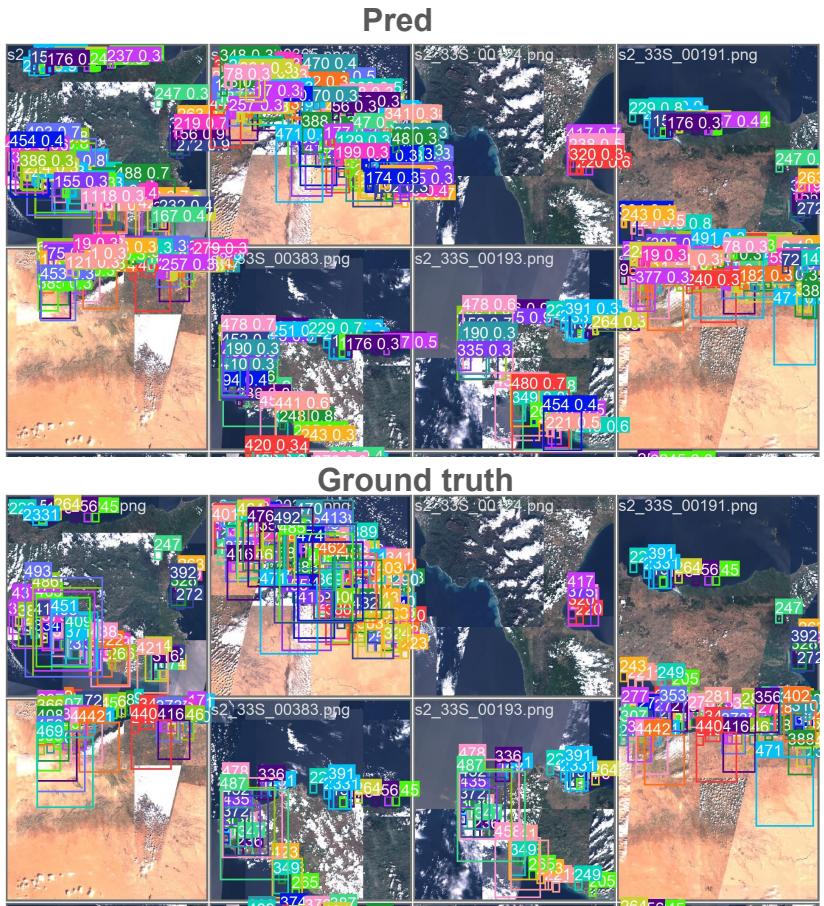
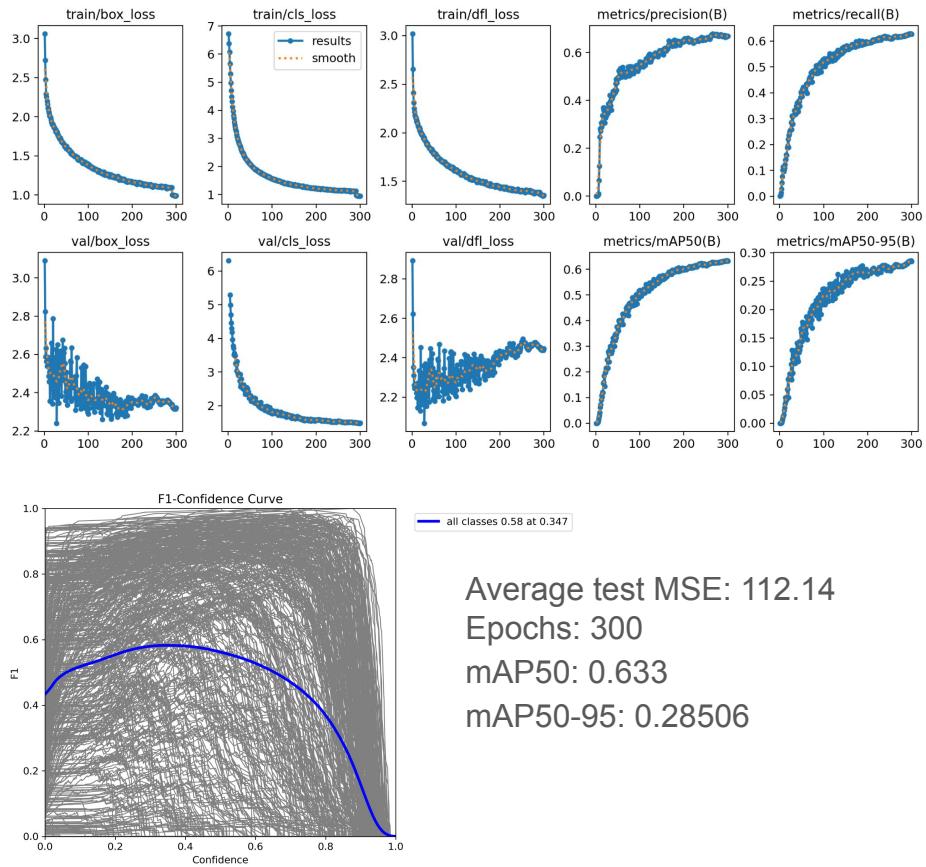


Ground truth



Average test MSE: 387.99
Epochs: 215
mAP50: 0.41268
mAP50-95: 0.13824

33S - Sicilia, Italy



26/02/24

Demonstrating Visual-Inertial A&OD & On-Orbit Edge Computing

Progress summary

65 days before May 1st

- **Updates**
 - Dataset:
 - Dataset download from 16 regions
 - RC:
 - Prepared data ready for RCnet, ready to train on N salient data regions
 - LD:
 - Customized Yolo loss function
 - Prepared training datasets from mass data download
 - Training LD for 16 regions on top salient landmarks at different scales

Blockers

- Computing resources for LD training
 - [ECE Community Compute Clusters](#)
 - [Pittsburgh Supercomputing Center](#)
 - ROBO Cluster

Weekly Plan

- Vision
 - Continue training experiments with pruning
 - Deploy trained models onto Jetson for GNC integration
 - Improve mAP of RCnet - finetune hyperparameters

Interface dependencies

- Integrating image passing pipeline with GNC/avionics

Vision

- **Dataset**
 - Downloaded data from 16 polarized regions -> [Dataset Download Report](#)
 - Created YOLO datasets for 16 regions (train, val, test from different sources/years)
- **Training**
 - **RC:**
 - Prepared new larger dataset ready for RCnet, ready to train on N salient data regions
 - **LD:**
 - Customized YOLO loss function with an additional MSE (centroid pixel error) loss
 - Weighted using box weight
 - Customized YOLO validator batch/class metrics tracking throughout training
 - MSE per class
 - Batch average
 - Training a base LD net with for 16 regions on top salient landmarks at different scales
 - Script for evaluating trained models: MSE, missed, extraneous detections
 - Pruning landmarks after training

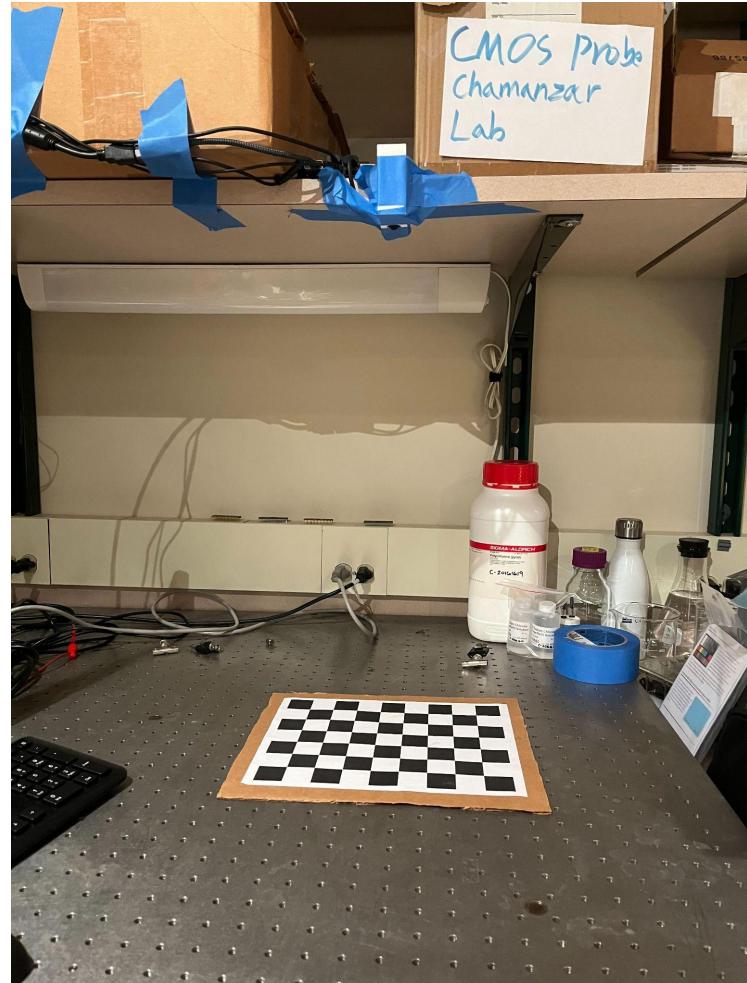
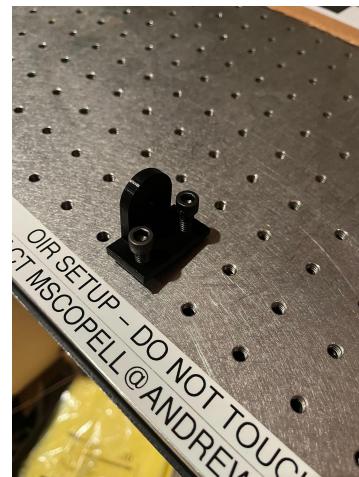
Calibration

Achievements:

- Finished the calibration test with optical table settings
 - The result is reasonable than before
 - Camera mounts are prepared

Next Step:

- Do multiple calibration and get the average, compare with the spec
 - Try with the mount equipments
 - Solid chessboard



Calibration

Color correction

Achievements:

- Finished data collection, and a test for color correction

Problem found:

- The images taken is vague
 - How to adjust the focal length of a CMOS camera?

