

Quadchart

29/01/24

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

Progress summary

94 days before May 1st

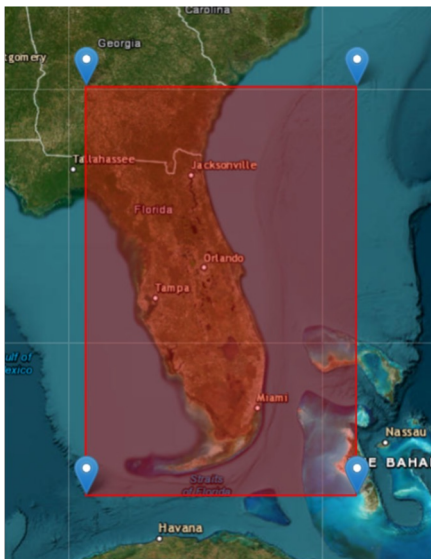
- Dark room testbed
 - Developed first iteration of dark-room test bed for V1 prototype
 - Completed single-camera calibration
 - Workstation and Jetson set-up
- Vision
 - Dataset pipeline changes & automated saliency-based landmark annotation
- Implemented all perturbations, sensor, and magnetorquer models in simulation
- Working prototype for A&OD (Batch optimization)
- Team changes: 1 out, 3 in
 - Task allocation and schedule updates

Vision

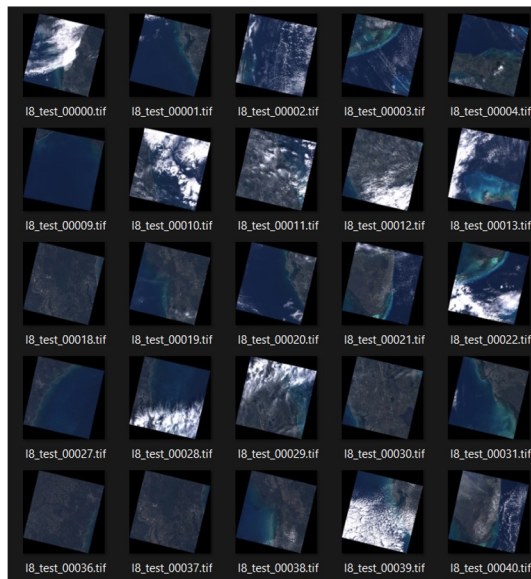
- New training plan for RC+LD structure
- Dataset Pipeline Design changes:
 - Data Access: USGS M2M API -> Google Earth Engine (more data)
 - Region Annotation: World Referencing System -> Military Grid System (for non-landsat images)
 - Preprocessing: Training image GSD 30m -> GSD 150mm (Camera lens 16mm -> 3.2mm for bigger FOV)
- Military Grid System based dataset download
- Automated saliency-based landmark annotation
- Small dataset for training & testing for V1
- **Next Steps**
 - Fully automated dataset pipeline on Workstation
 - Training RC net and LD net for V1
 - Refine landmark annotation (used less accurate code due to workstation fan issue)

V1 Dataset Prep

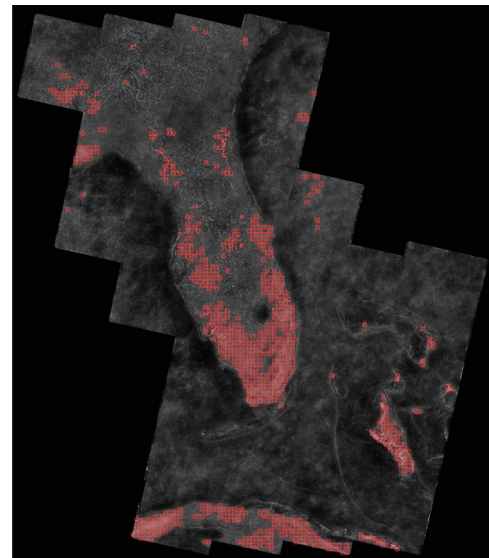
One Region: R17



~500 images GDS 150m



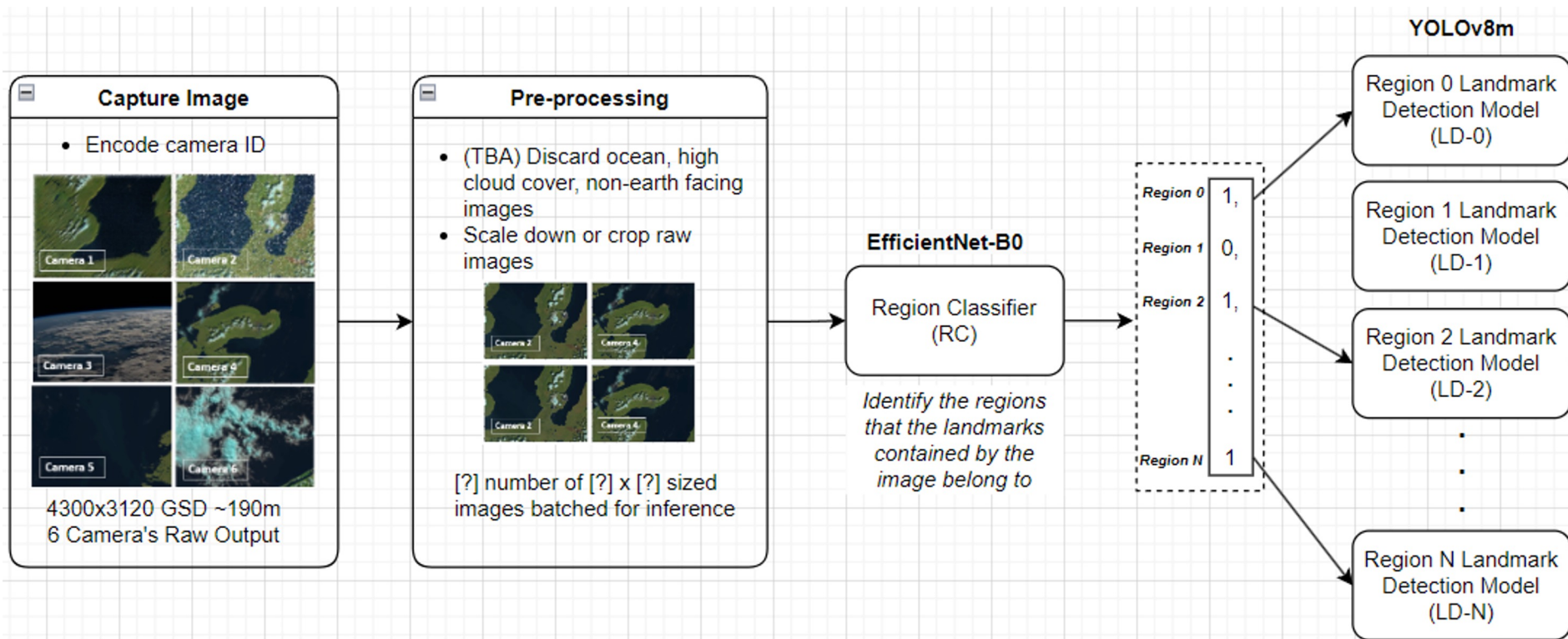
Top 1000 salient landmarks



Labeled with real lat/lon:

Top-Left Longitude,Top-Left Latitude,Bottom-Right Longitude,Bottom-Right Latitude
 -79.489400090212,25.80369695391825,-79.44429409111412,25.751627180421764
 -82.10554803788904,24.60609216349909,-82.06044203879117,24.554022390002604
 -82.33107803337845,24.501952616506117,-82.28597203428056,24.449882843009632
 -82.24086603518268,24.554022390002604,-82.1957600360848,24.501952616506117
 -79.17365809652684,25.543348086435824,-79.12855209742895,25.49127831293934
 -79.12855209742895,25.49127831293934,-79.08344609833108,25.439208539442852
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 -82.28597203428056,24.554022390002604,-82.24086603518268,24.501952616506117
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New Inference/Training Plan

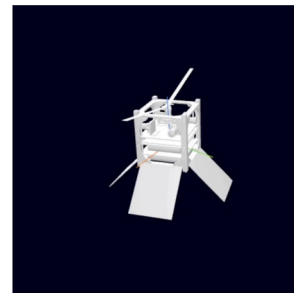


Simulation

Developing simulator to test and validate detumbling, A&OD, and FSW algorithms and support Software-in-the-loop (SIL) testing.

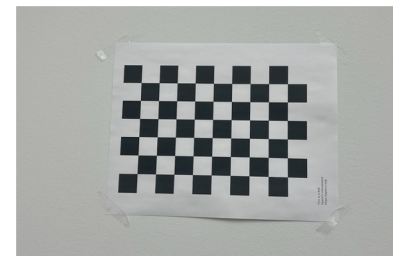
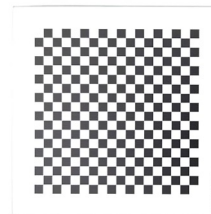
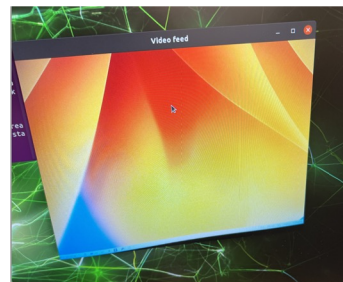
Progress

- Incorporated atmospheric drag and third body effects in orbital perturbations.
- Added sensor model for gyro, magnetometer, sun sensor and GPS.
- Implemented magnetorquer model.
- Implemented B-cross control along with unit tests.



Dark room testbed

- Initial setup for V1 pipeline testing in dark-room environment along with associated hardware
- Progress
 - Camera position and parameters adjustments for field-of-view on projector
 - Camera interface software
 - Single-camera calibration pipeline and generated camera intrinsic and extrinsic matrices and distortion parameters
- Next steps
 - Calibrate all 6 cameras, w/ chessboard
 - Research towards multi-camera calibration (mock-up Cubesat)
 - Research and experiments (?): match images captured from screen to actual image in dataset
 - Report testbed errors
 - Start V2 dark room design



Testbed hardware / FSW - next steps

- Initial discussion w/ Comms for telemetry and command
- Jetson <-> PyCubed intercommunication driver requirements w/ Avionics
- Next steps
 - Dark room test bed
 - Metrics data logging (latency, power, cpu, gpu, ..) on Jetson for V1
 - PyCubed board (acquired one for GNC usage)
 - Set-up basic I/O w/ simulation for Software-in-the-loop testing
 - Learn Pycubed stack and implement basic flight software
 - Inference V1
 - Test inference pipeline on V1 testbed (Jetson)

Team schedule status

A	B	C	D	E	F	G
Flight Version	Version name	Module	Tasks	Assignment	22 Jan	29 Jan
V1	Nadir-only Payload Pipeline Validation	Single-camera calibration	Camera interface (Jetson)	Atharv Pulapaka		
			Calibration software pipeline 1 camera	Tianxin Li		
			Calibrate 6 cameras (id them) and store parameters	Tianxin Li		
			Multi-calibration research	Tianxin Li		
		Dataset	Image pre-processing & img storage pipeline	Atharv Pulapaka		
			Body vector transfo + landmark retrieval	Atharv Pulapaka		
			Set-up workstation	Sachit Goyal		
			Download dataset on workstation + annotate	Eddie Li Jash Shah		
		Training system	Saliency-based annotation automation	Eddie Li		
			TIF -> lat-long to ECI landmark database	Atharv Pulapaka		
			Training plan	Eddie Li		
			Train RC net (all regions)	Jash Shah		
		Inference	Train LD net (1 region)	Haochen Zhang Eddie Li		
			Implement inference pipeline (Jetson)	Haochen Zhang		
			Integrate w/ camera interface	Haochen Zhang Atharv Pulapaka		
			Test RC & LD pipeline on Jetson	Haochen Zhang Eddie Li		
		Batch optimization	Conversion to body vector + landmark retrieval from the database	Atharv Pulapaka		
			Prototype optimization	Ibrahima Sory Sow		
			Simulation validation + test on Jetson	Ibrahima Sory Sow		
			Integration test w/ inference	Ibrahima Sory Sow		
		Simulation	Perturbations and sensor models	Elakhya Nedumaran Atharv Pulapaka		
			Vision measurement model	Atharv Pulapaka Ibrahima Sory Sow		
		MCM (Magnetic Control)	Initial Bcross Monte-Carlo	Elakhya Nedumaran		
			FSW version ready for SIL	Elakhya Nedumaran		
		Test-bed	Install dark room set-up (covers, tent, whatever)	Luyi Tang		
			Get screen	Luyi Tang		
			Camera mount	Luyi Tang		
			Research & experiments - image matching	Luyi Tang		
		PyC	Report testbed errors	Luyi Tang		
			V2 darkroom design	Luyi Tang Ibrahima Sory Sow Luyi Tang		
			Metrics data logging (latency, power, cpu, gpu, ..)	Sachit Goyal		
			Familiarize w/ current PocketCube board	Sachit Goyal		
			Set-up basic I/O w/ simulation (SIL prep)	Sachit Goyal		
			Intercommunication design dev (PyC <-> Jetson)	Sachit Goyal		

Next steps

- Finalize V1 prototype integration and testing before this Friday
 - Test of the entire pipeline in the dark room from pixel to A&O estimates
 - Report preliminary results
 - Pixel errors for landmark detection
 - A&O accuracy
 - Testbed source of errors
- V2 refinement based on learnings

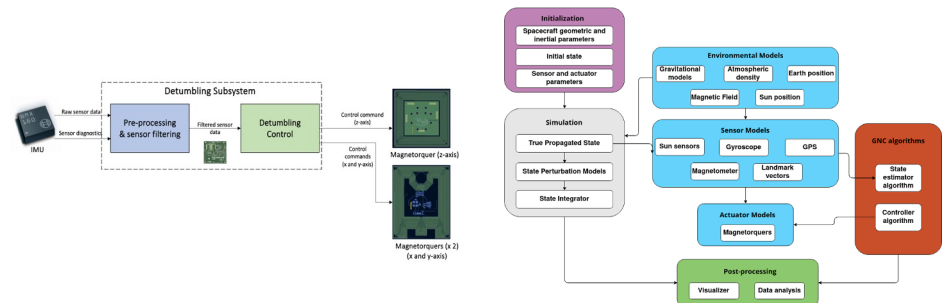
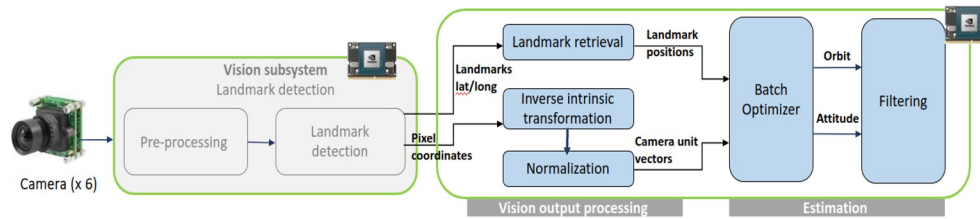
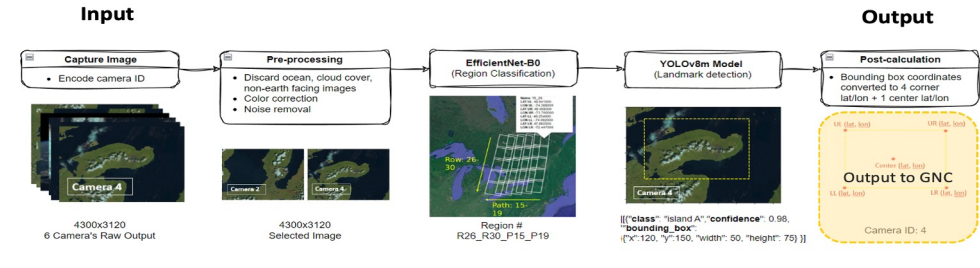
22/01/24

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

Payload-GNC-FSW - Team merging

- PDR
- Initial work on AD/OD Pipeline
- GNC hardware selection
- Datasets
- Orbit analysis
- Simulator v1
- FSW Functional architecture
- Detumbling control
- Helmholtz Cage Design
 - Cancelled \Rightarrow Dark room testbed

\Rightarrow Lots of cross-development with Avionics & Comms

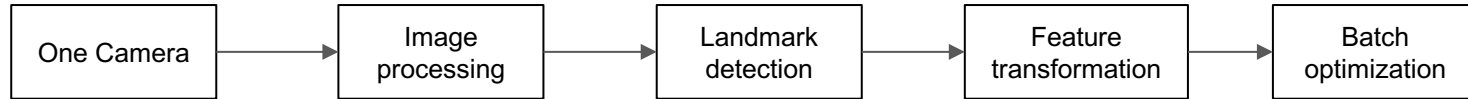


Plan for the semester

- Payload-GNC-FSW coupled development
- **Two-week development cycles** with predetermined milestones, plan and deliverables
 - Design iterative prototypes of full pipeline to reach final project completion
 - Each prototype is **fully-functional** and includes development, unit testing and integration testing with hardware
- Why?
 - Quick feedback and learning on the whole development process (both HW and SW)
 - Hands-on approach w/ hardware and boards
 - Consistent validation and metric improvement
 - Motivation

V1: Nadir-only Payload Validation

- Validation of A&OD pipeline in **dark-room testbed** with a **single-calibrated camera** on **Jetson**.
- Camera captures an image from a well-positioned screen, which is pre-processed and LD net is applied. Necessary transformations then batch optimization to determine attitude and orbit.
- **Simulation of a LandSat pass and report average accuracies**



- Determine landmark catalog size
- Obtain average number of landmarks per images (number of features)
- Define validation metric for landmark detection net
- Determine attitude and orbit estimation accuracy
- Build dark-room testbed in the lab, implement on testbed and find error margins
- Run MCM simulation and analyse performance

100 days before
May 1st

V1: Nadir-only Payload Validation \Rightarrow Feb 2

Module	Tasks	Assignment
Single-camera calibration	Camera interface (Jetson)	Tianxin Li
	Calibration software pipeline 1 camera + document	Tianxin Li
	Calibrate 6 cameras and store parameters	Tianxin Li
	Image pre-processing	Atharv Pulapaka
LD dev: Dataset	landmark vector transformation	Atharv Pulapaka
	Download whole dataset on workstation	Nathan Zhu
	Extract nadir-only data and organize datasets (develop dataloader)	Nathan Zhu
	Use auto-annotation engine (Kyle) to label data	Eddie Li Nathan Zhu
LD Dev: Training system	Get validation metric	Eddie Li
	Develop initial training pipeline	Eddie Li
	Initial LD training (initial quick ablation)	Eddie Li
	Implement inference pipeline on Jetson, from initialization to inference (dummy weight)	Tianxin Li
Inference	Integrate w/ camera interface	Tianxin Li
	Set-up 24/7 Jetson SSH	Nathan Zhu
	Prototype optimization	Ibrahima Sory Sow
	Simulation validation (+ test on Jetson)	Ibrahima Sory Sow
Batch optimization	Simulation development (add all perturbations and current models)	Ibrahima Sory Sow Elakhya Nedumaran Atharv Pulapaka
	Initial Bcross Monte-Carlo	Elakhya Nedumaran
MCM (Magnetic Control Module)	Install dark room set-up (covers, tent, whatever)	Luyi Tang
	Get high-res big screen	Luyi Tang Nathan Zhu
	Camera/satellite mount (alignment)	Luyi Tang
	Integrate with calibration set-up	Tianxin Li
Integration	Pipeline integration (Jetson) and testing	