MACHINE LEARNING FOR EXTREME TRAVERSE LUNAR EXPLORER

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PROBLEM STATEMENT

- This project requires to deploy Machine Learning algorithms to enhance the on-field data characterization capabilities of the NASA-JPL EELS (Extant Exobiology Life Surveyor) robot.
- This project requires performing semantic terrain segmentation on the vision (and potentially LiDAR data) collected by EELS in ice crevasses and glacial-like extreme subterranean environments. The project also requires to combat limited data availability in space missions, work with real unannotated data from JPL and inference on sensor-fusion requirements.

Fig 1. NASA – JPL EELS Snake Robot

APPROACH

- Unsupervised Domain Adaptation to perform Semantic Segmentation on synthetically generated data as source domain and unannotated NASA-JPL data as target domain.
- Combat limited data availability by zero-shot semi-automated data generation pipeline with semantic labels for vision data using UnReal Engine. This pipeline can be re-used by NASA-JPL for other projects that need more vision data.

SYNTHETIC DATA GENERATION

- Generated synthetic vision data (images and labels) using Unreal Engine 5.1.1.
- Used Quixel Megascans Bridge library for assets.
- Created blueprint scripts for procedural content generation, material switching for auto-generating semantic labels of the scene with a click of button and domain randomization for generating large datasets.

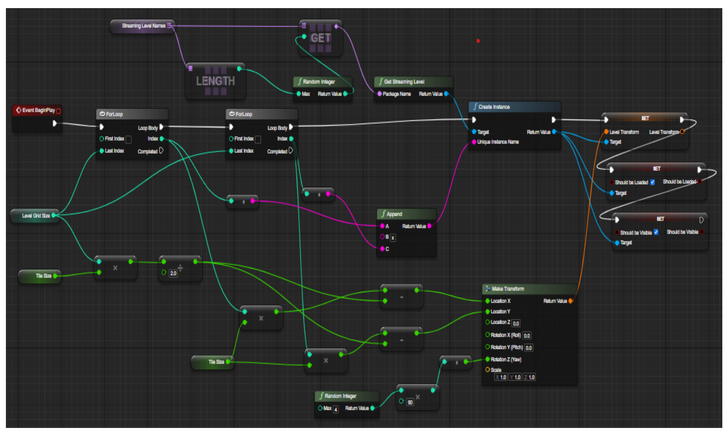


Fig 2. Blueprint Script for Synthetic Data Generation in UnReal Engine

UNSUPERVISED DOMAIN ADAPTATION (UDA)

- UDA adapts a model trained on one domain (source) to a novel domain (target) using minimum labeled data and addresses the distribution change due to domain shift where the two domains are related but not identical.

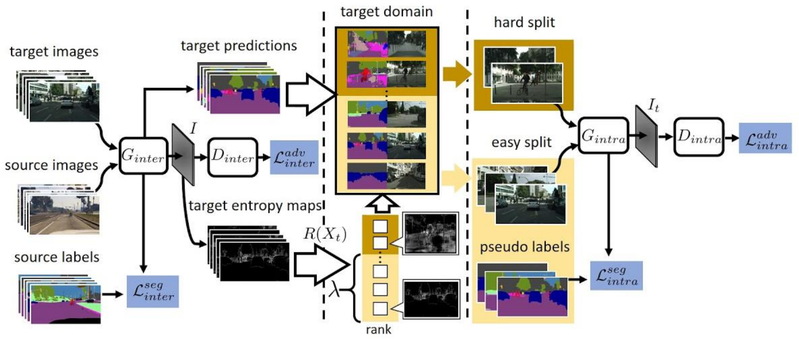
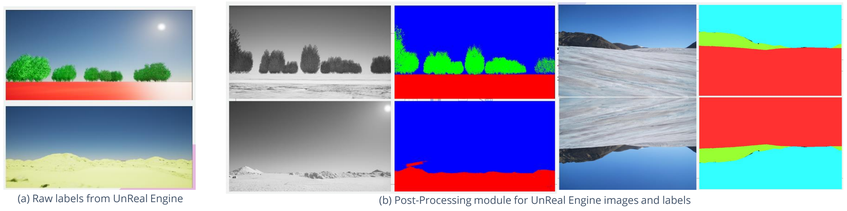


Fig 3. UDA IntraDA Model



(a) Raw labels from UnReal Engine

(b) Post-Processing module for UnReal Engine images and labels

Fig 4. Data Generation & Post UE Processing to feed IntraDA model

NON – DEEP LEARNING APPROACHES

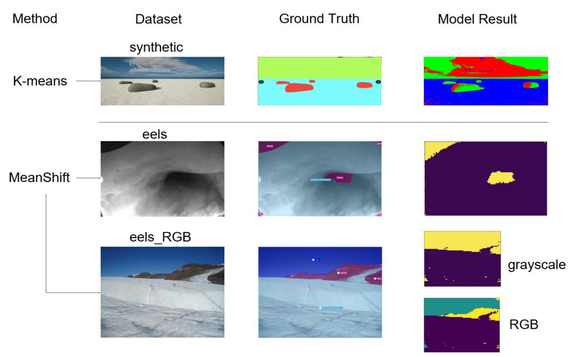


Fig 5. Non Deep Learning Approaches for Semantic Segmentation

QUALITATIVE RESULTS & INFERENCES

Table – 1. Phase-wise Training and Testing data information

PHASE	TRAIN	TEST	RGB / Grayscale	# Train Images	# Test Images
PHASE 5	SYNTH Grayscale* zero shot	JPL EELS	Grayscale	190	123
PHASE 6	SYNTH RGB*	JPL ICENET	RGB	582	31
PHASE 7	SYNTH Grayscale* few shot	JPL EELS	Grayscale	743	279

** Trained with augmentation by adding rotation, dimming, and noise*

Table – 2. Phase-wise Per-pixel Accuracy Comparison

PHASE	Snow	Sky	Others	Whole PA
PHASE 5	21.68	74.75	0.73	35.57
PHASE 6	90.85	0.8	9.64	86.79
PHASE 7	95.67	8.18	0.01	82.19

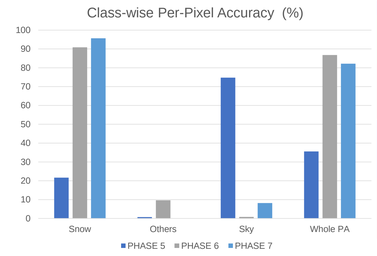


Fig 6. UDA Model Testing PA Phase Comparison

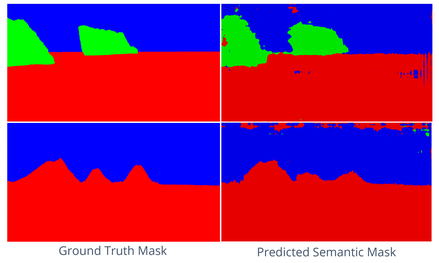


Fig 7. UDA Qualitative Results

- Grayscale images have significantly less information than RGB images to describe textures that is crucial in per-pixel classification in semantic segmentation.
- We propose a grayscale few-shot training that includes some real EELS grayscale data. The resulting performance can improve by 46.62 PA.
- When noise is added to image during augmentation, the per-pixel accuracy increases the most in predicted semantic masks.

FUTURE WORK & REFERENCES

- 1000 images per class for training and testing and adapt IntraDA to semantically segment consolidated snow, non-consolidated snow, and ice categories
- Combine Vision & LiDAR modalities for adding depth information to detect rocks covered with snow.

[1] F. Pan, I. Shin, F. Rameau, S. Lee, and I. S. Kweon, "Unsupervised Intra-domain adaptation for semantic segmentation through self-supervision," arXiv.org, https://arxiv.org/abs/2004.07703 (accessed May 22, 2023).
[2] Unreal image generation and segmentation ML with Python – Udemy, https://www.udemy.com/course/unreal-image-generation-and-segmentation-ml-with-python/ (accessed May 22, 2023).
[3] "JPL Robotics: Exobiology Extant Life Surveyor (eels)," NASA,https://www-robotics.jpl.nasa.gov/how-we-do it/systems/exobiology-extant-life-surveyor-eels/ (accessed May 22, 2023).

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