Project Briefing

Unmanned Aircraft Systems, Machine Learning and Polarimetric Imaging for Enhanced Marine Debris Detection and Removal

NCCOS Marine Spatial Ecology Division
Oregon State University
NOAA Marine Debris Program

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Executive Summary

- Marine debris poses risk to the public and marine life
- NOAA's Marine Debris Program is Federal lead for addressing marine debris
- Previous research has demonstrated that UAS can benefit marine debris mapping
    - However, projects to date have not yet produced operational tools and procedures for use of UAS in NOAA MDB
- **GOAL: transition the Technical Readiness Level of UAS for marine debris detection, identification, and removal through development of operationally-ready procedures**

Mission Goals and Objectives

- Test and Evaluate
  - Optimal UAS acquisition parameters for marine debris detection
  - UAS platforms and payloads (imaging sensors)
    - Primary considerations:
      - Suitability for operational use by NOAA MDP
      - Platform-agnostic
  - Processing and analysis procedures
- Operational
  - Data Buy through Oregon State University
  - Prioritization of areas for debris removal
  - Standard Operating Procedures development
- Research
  - Machine learning algorithms for auto-detection and identification of marine debris
  - UAS-based polarimetric imaging
  - Long-term monitoring and rapid response (e.g., post hurricane or tsunami)

Project Focus

- Shoreline macro-debris (> 1 m in size)
  - Most typical type of debris for MDP-supported cleanup, monitoring, or detection operations
- Directly addresses objectives of the MDP FY16-20 Strategic Plan Research Goal:
  - "Identify, assess and reduce the impacts of marine debris through detection, monitoring, source identification and innovative solutions (MDP 2015)."

Potential Platforms (COTS)

Solo

- Inexpensive, lightweight platform

S900

- Greater lift
- May use for PI camera tests

Heatmaps Representing Concentrations of Marine Debris

** Proof-of-concept: mock-up created through hand digitization*

Level of accumulation informs removal /remediation decisions

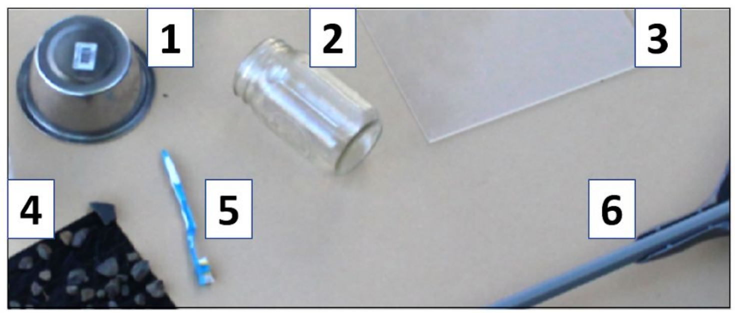
Machine Learning

- Goal: auto detection and classification of marine debris
  - Hierarchical classification
    - Binary: belongs at beach vs. doesn’t belong at beach
    - Material type classification: plastic, wood, foam, metal
    - Identification: bottle, fishing net, nylon line, buoy/float, crab trap, flipflop, etc.
- Not inventing new ML algorithms
  - Utilize existing ML frameworks
    - Tensorflow, Pytorch
- Research focus areas
  - Size of training database
  - Performance of various models
    - Performance metrics: precision, recall, and receiver operating characteristic (ROC) curves
- Collaboration with Ross Winans, NOAA OCM and University of Hawai‘i at Mānoa MS student, to incorporate marine debris deep learning training dataset and development

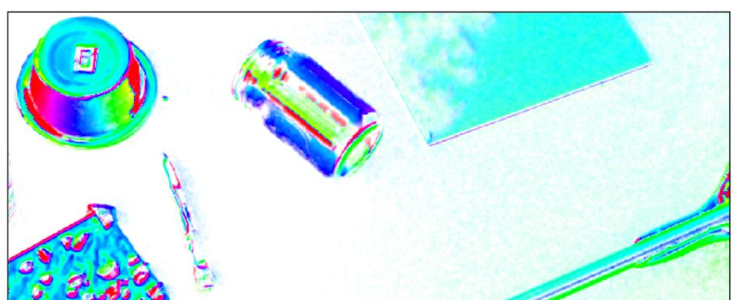
Polarimetric Imaging

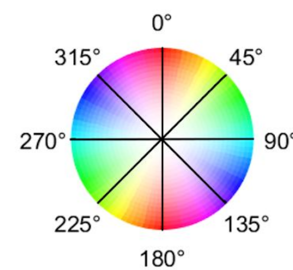
- Polarimetry = measurement and interpretation of the polarization state of transverse light waves reflected by object
- Useful for identification of human-made objects within a scene

Combination of spectral and polarimetric imaging info can facilitate both detection and recognition



(1) Aluminum bowl
(2) Glass mason jar
(3) Acrylic panel
(4) Plastic trash bag
(5) Toothbrush
(6) Plastic broom handle





Investigation of PI Cameras

- Will be conducting market research for procurement
- Key specs
  - Cost
  - Resolution
  - Chip size (pixels and microns)
  - Lens
  - Frame rate
  - Spectral bands
  - Polarimetric info
  - Size, weight, power requirements

FLIR Blackfly S USB3: https://www.flir.com/products/blackfly-s-usb3/?model=BFS-U3-51S5PC-C

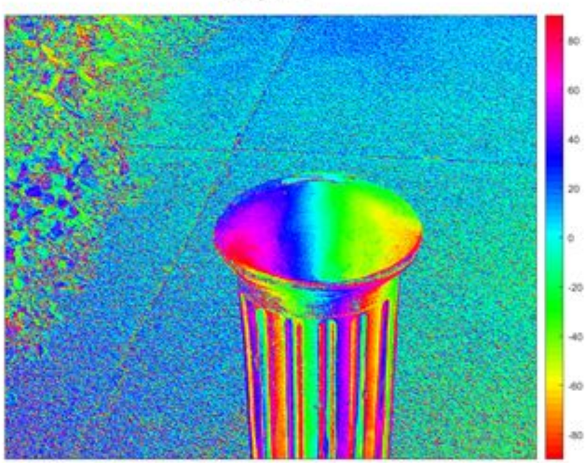
PolarCam G5: https://www.4dtechnology.com/products/imaging-polarimeters/

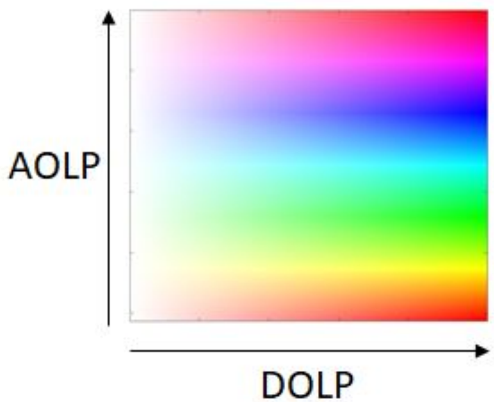
Latest Results

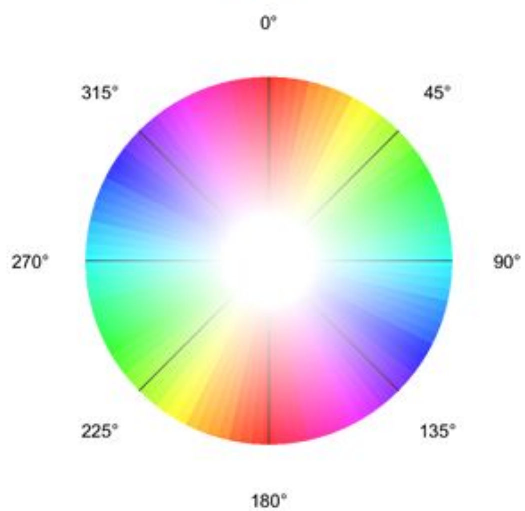
- Bivariate AOLP and DOLP Visualization

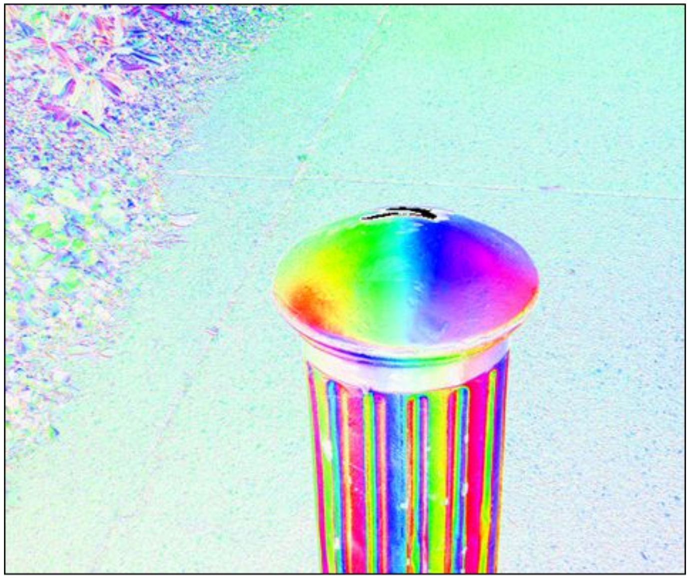
DOLP

AOLP





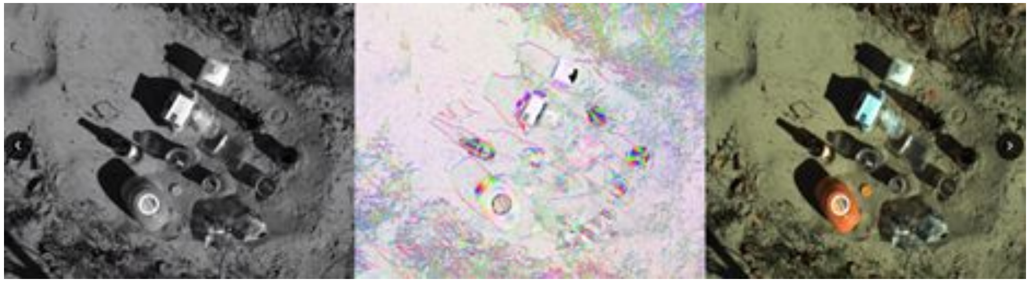




■ = oversaturated

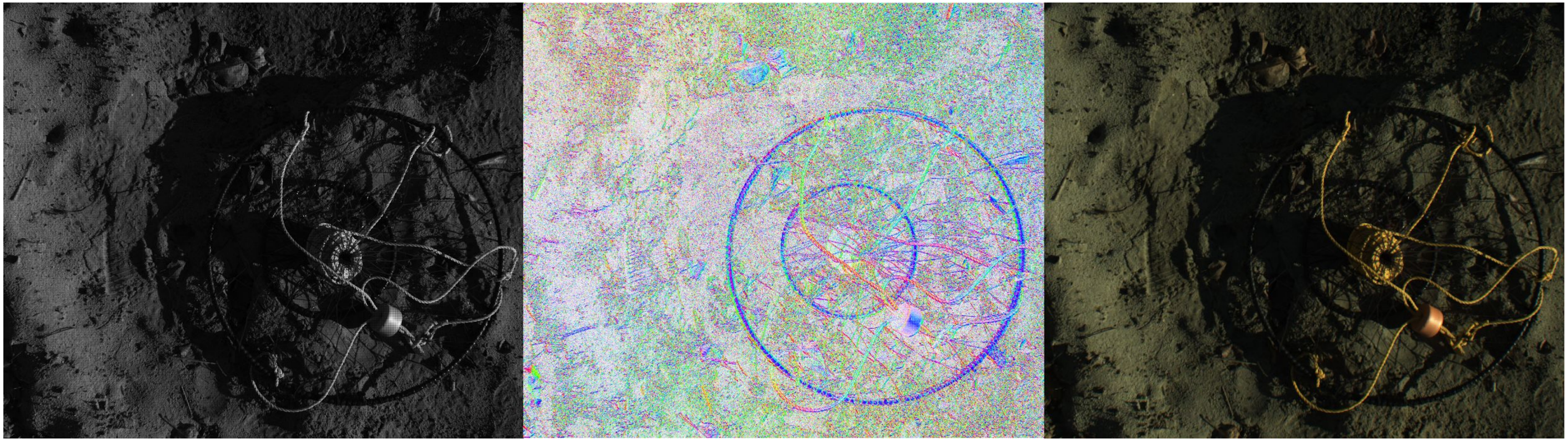
Latest Results

- Created simulated beach at OSU wave lab
- Uses natural OR beach materials left over from previous experiments
  - Simulates backshore/dune
  - Populated with various debris items
- Extendable pole simulates perspective from UAS



Latest Results

Crab Trap



Left: greyscale image. Middle: PI DOLP/AOLP image. Right: RGB image

- Metal edges clearly discernible in PI imagery

Concept of Operations: Study Sites

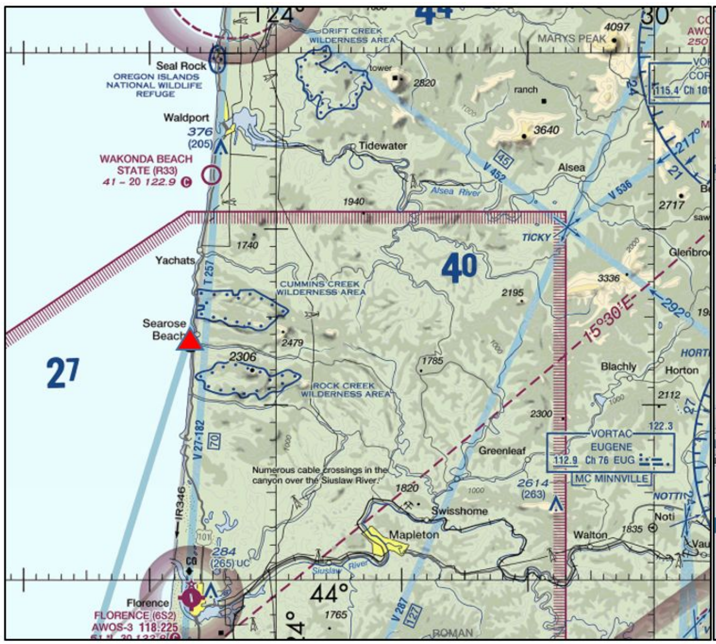
Two study sites:

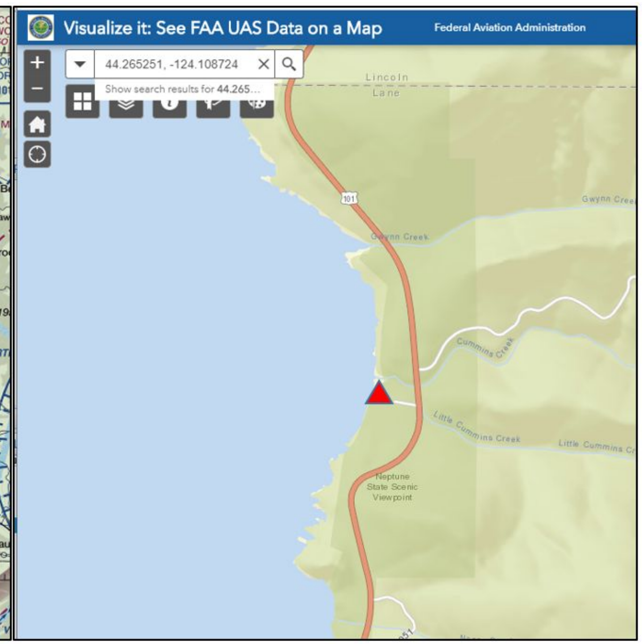
1. Controlled testing and training site (JUN21)
   - Debris items will be placed, accurately surveyed, and flown with range of parameter settings
   - Identified location: Neptune State Scenic Viewpoint, south of Yachats, Oregon
     - Encompasses range of shoreline types/features: rock outcrop, sand, vegetation, cliff, and creek outflow

2. Validation site (SEP21)
   - Test procedures operationally at Kamilo Pt, HI, a site known to have persistently high densities of macrodebris

Testing/Training Site: Neptune State Scenic Area

- Neptune State Park in Class-G airspace. OPRD Scientific Research Permit Required
- Flights: surface to 400 ft AGL, operations 150-400 ft
- Flights under Part 107, OSU UAS policies and procedures, NOAA UAS Handbook, & AOC-approved

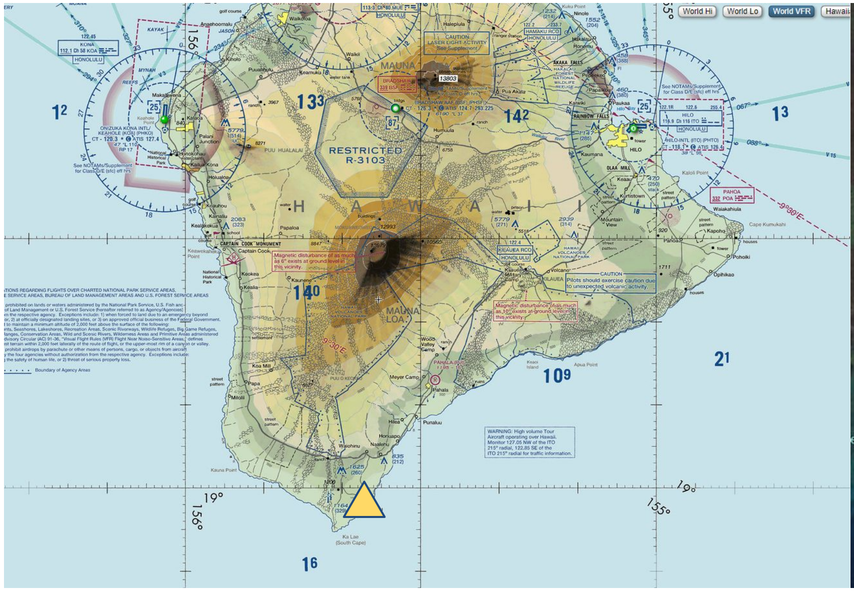




▲ = Neptune State Scenic Viewpoint test site

Validation Site: Kamilo PT, HI

- Same operational approval and CONOPS as for tetsing site.
- Flights: surface to 400 ft AGL, operations 150-400 ft
- Flights under Part 107, OSU UAS policies and procedures, NOAA UAS Handbook, & AOC-approved



△ = Oahu validation site

Outcomes

- Georeferenced heat map of debris concentration
  - Debris items per unit area as GIS data layer
- Software algorithms implemented in high level programming language (e.g. Python, MATLAB)
- Training dataset which can be used for future machine learning and algorithm development
- Capacity building for MDP Staff
  - Build MDP capacity to evaluate, plan, and execute field UAS operations.
- **End goal: SOPs**

Questions

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