Trip Report

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

Validation Test Site Data Acquisition and Analysis

Corpus Christi, TX

December, 2021

Overview

This trip report covers fieldwork performed on the project, "Uncrewed Aircraft Systems, Machine Learning and Polarimetric Imaging for Enhanced Marine Debris Detection and Removal." The project is sponsored by the NOAA UxS Research Transition Office and led by NOAA PIs, Tim Battista of the National Centers for Coastal Ocean Science (NCCOS) and Amy Uhrin, Chief Scientist of the Marine Debris Program (MDP). The project is a collaboration between NOAA and Oregon State University (OSU). The primary OSU project personnel are Kyle Herrera (MS student, technical lead) and Chris Parrish (associate professor, OSU PI). The overarching objective of this fieldwork was to perform validation of procedures for marine debris detection and recognition using UAS imagery, which were initially developed and tested in an earlier phase of the project using data from Neptune State Scenic Area on the Oregon coast. Specific goals of the fieldwork included:

1. Acquire RGB imagery from multiple UAS at a variety of flying heights and times of day (corresponding to different illumination conditions) over multiple project sites containing different types, densities, and spatial distributions of debris items.
2. Test the ability to process the RGB imagery through the machine learning (ML) model developed by project partner, Ross Winans, to auto detect and label debris items. While the model had been developed and tested prior to this fieldwork, it had not been tested in real time (i.e., while in the field) and had not been applied to the types of debris present on the Texas coast.
3. Collect polarimetric imagery (PI) at the various sites using a 14-ft pole-mounted camera.
4. Collect PI imagery from a USCG helicopter flying at an altitude and speed designed to replicate what would be feasible from a UAS operating under FAA Part 107.

The site chosen for this fieldwork included barrier islands on the Texas coast along the Gulf of Mexico, which are known hotspots for marine debris accumulation, due to prevailing winds currents, circulation patterns, and the orientation of the coast. Three specific sites were selected: 1) North Padre Island: Bob Hall Pier south to the border of the Padre Island National Seashore (PINS), 2) Mustang Island, and 3) San José Island. The locations of these sites are shown on the map in Fig. 1.

Figure 1: Texas field sites.

The fieldwork was performed by team members from NOAA and OSU, assisted by colleagues at Texas A&M University-Corpus Christi (TAMUCC), as well as Tracy Weatherall from the University of Texas Marine Science Institute. Details of the fieldwork are summarized in Table 1.

Personnel	Tim Battista (NOAA), Kyle Herrera (OSU), Chris Parrish (OSU), Jake Berryhill (TAMUCC) Mike Starek (TAMUCC), Tracy Weatherall (UTA)
Dates	12/6/2021 – 12/17/2021
Field sites	Bob Hall Pier to PINS (Site A), Mustang Island (Site B), and San José Island (Site C) (see Fig. 1)

Platforms	Skydio 2, DJI Phantom 4 Pro, DJI Phantom 4 Pro RTK, Wingtra WingtraOne
USCG platform	MH65 Echo
Base of operations	Corpus Christi, TX

Daily Field Log and Key Accomplishments

The following sections detail the objectives and accomplishments on each day of the fieldwork.

12/6 – Monday

- Project personnel arrived onsite (Tim and Kyle), began setup and field recon

12/7 – Tuesday

- Retrieved project equipment shipped to TAMUCC from OSU, assisted by Jake Berryhill
    - Stored at hotel for duration of fieldwork
- Local purchase of field supplies and food
- Site inspections performed by Tim and Kyle to evaluate local debris conditions
    - Drove entire shoreline from North PINS to Part Aransas
    - Site (A) Bob Hall Pier to PINS
        - Good, dispersed debris along dune line
        - Sufficient 3-mile stretch for surveys
        - Mostly plastics on seaward side of dune, few objects on back of dune
        - Plastic, Styrofoam, cloth, shoes, small ropes, wood, cans
        - Set GPS markers for best debris stretches
    - Site (B) Mustang Island
        - Well maintained stretch of coastline
        - Minimal visible debris, due to routine cleaning
        - More developed stretch of shore
        - Fishermen & surfers observed
    - Determination:
        - Bob Hall to PINS had most workable debris for entire Padre Island stretch
        - Insufficient debris counts from Mustang Island to Port Aransas

12/8 – Wednesday

- Meeting with USCG to discuss mission objectives, weather, schedule etc.
    - Primary AOI shared:
        - North Boundary PINS to 4km north
            - Start: 27º 29’ 30” N, 97º 16’ 0” W
            - End: 27º 31’ 28” N, 97º 15’ 0” W
    - Secondary AOI: San José Island for debris inspection/visual analysis
    - Approved for GoPro on helmet in cabin

    - Flight scheduled for 12/9
- Began UAS acquisition at Site (A) Bob Hall Pier to PINS
    - 3 UAS flights with OSU P4RTK
    - ~1500 m each flight plan, total 4500m coverage
    - 2D photogrammetry
    - 30^{o} off nadir for optimal ortho processing
    - Pilings to trash pile @ 2cm GSD (73m AGL)
    - 3 marine debris object validation video transects across beach

12/9 – Thursday

- Reconvened with USCG, due to local weather conditions
    - Poor visibility: heavy fog not dissipating in time
    - Were able to reschedule helo flight for 1000 on 12/15 (Wednesday)
    - USCG pilots informed of good macro debris noted during previous flights over San José
    - Helo mission plan is for Site A and Site C – San José Island
- 3 more UAS flights performed at Site A in afternoon once fog lifted (1200)
    - 1000m stretch of coast each flight plan
    - Flew PINS pilings to 3km north
    - High detail 3D mapping missions done by Jake and TAMU P4RTK
    - Setup TAMU base station roughly in middle of 3 survey areas
        - Laid out 20 ground control targets and surveyed in with rover
- Tim and Tracy performed MDP transect protocol in survey area A3
    - Included removal of macro debris, surprising amount
    - Coordinates taken on corners of 100m^2 area
    - Conducted 3 individual cross-beach marine debris surveys. End coordinates and frame pictures

Figure 2: Tracy Weatherall performing debris survey transect.

Figure 3: Example of debris items from Padre Island.

12/10 – Friday

- Overcast & gusty conditions, sand kicking up on beach
- Performed polarimetric acquisition at Site A when sun came out
    - Captured 2 ortho debris scene setups with ground targets shot in

        - 1 done in A3, 1 in A2
    - Also captured singular debris scenes for individual analysis
    - 12’ pole length, 14.5’ sensor AGL
    - Polarimetric rig included fishing pole belt mount for stability/mobility

Figure 4: Pole-mounted PI camera acquisition at Padre Island.

12/11 – Saturday

- Local storm/wind event at Corpus Christi, super gusty
- Bad conditions for both UAS & polarimetric acquisition
- Team (Tim, Chris, and Kyle) had organizational day at hotel
    - Worked on project report outline, deliverables, QPB, & responsibilities
    - Discussed best practices, operational parameters, intended audience, and desirable outcomes
- Processed orthoimage from A1 UAS acquired 12/8

12/12 – Sunday

- San José day 1
- Team (Tim, Chris, and Kyle) took ferry out to island at 0700 via Fisherman’s Wharf
- Initial walk down/evaluation:

    - Reliable debris counts with sufficient macro-objects
    - Larger swath of debris distribution (dune to water line)
    - Some objects recently washed ashore
    - Mostly plastics with buoys, ropes, tire fragments, processed wood, foam, metal
- Setup staging area at beached derelict vessel, near communications tower
- Early weather: chilly, slight wind but sunny
- First did UAS flights with Skydio 2 at 0800 with 6 ground targets in survey
    - 2cm GSD @ 60m AGL
    - Short flight length (~0.5mi) but good debris within
- Acquired polarimetric imagery starting at 1000
    - Dataset comprised of solo scenes and conglomerate debris field
    - Occupying ground control targets longest part of procedure (15 min each)
    - Consolidated local debris objects into debris field (125' x 25') for PI ortho generation
        - Aggregated debris from roughly 1km^2 of beach area
        - 3 track lines total, all facing the sea
        - Roughly 3' between frames, producing 82 images total
        - 5 targets included for ground reference
        - Robust classification for
            - Plastic
            - Ropes/netting
            - Wood
        - Debris noted in scene
            - >20 plastic (ranging from bottles up to partial barrels & containers)
            - 12 ropes/netting
            - 12 wood fragments
            - 2 tire fragments
            - Few of each of the following: flip flops, glass, buoy, metal, Styrofoam

Figure 5: Skydio 2 operations at San José Island.

12/13 – Monday

- Initial plan was data collection at San José but cancelled due to rain
- Instead took a data processing day at TAMUCC campus, assisted by Jake
- Got Ross' updated model pulled down from GitHub
    - Performed some initial inferencing to observe performance on SJ Skydio imagery
    - Team discussed optimal input formats based on field experience
- Performed polarimetric processing to generate orthos from San José dataset

12/14 – Tuesday

- San José data acquisition day 2 with Tim, Kyle, and Jake
- Good UAS flying conditions; sunny with moderate wind
- Utilized stretch of shoreline 1km north of previous data collection
    - Amazing debris counters/density – best of the trip
- Flew 3 separate surveys with P4RTK (Jake operating)
- 2D photogrammetry survey plans
- Collected imagery at 3 different altitudes for range of model inputs and testing capabilities
    - 3.3 cm GSD, 2 cm GSD, and 1.5 cm GSD

    - Ideal model range (1-3 cm GSD)
- After UAS flights, Kyle setup another debris scene for ortho generation
    - Different focus on material type from prior San José debris field
        - 20 flip flops/shoe soles
        - 12 buoy/Styrofoam floats
        - 27 glass bottles/fragments
        - 10 aluminum cans/fragments
        - 6 wood pieces
        - 3 tire fragments
        - Few miscellaneous objects mixed in
    - Debris field was roughly 8’ x 20’, no targets, ~8 images to capture
    - 1st set: pole length 13’ 8”, 14’ 9” sensor AGL
    - 2nd set: pole length 15’ 6”, 16’ 8” sensor AGL
        - Highest sensor height AGL of pole setup in project

12/15 – Wednesday

- USCG helicopter flights. Decent weather, partly cloudy; some sun
    - 0830 arrival at facility, 0930 prep & brief with crew, 1000 takeoff
    - 4 flight strips total, ~120 images each, ~15 knots flight speed
        - (1) Site A @ 125’ AGL
        - (2) Site A @ 250’ AGL
        - (3) San José @ 150’ AGL
        - (4) San José @ 300’ AGL
            - Crew hovered over 2 San José debris fields for specific acquisition
    - FLIR camera performed surprisingly well at flight speed
        - Managed minimal blur with helo vibrations and wind outside cabin
        - Good focus of shoreline with quick shutter speed
        - Ideal exposure values ranged 2000-3000
- Tim & Jake provided ground assistance during this time at Site A
    - Performed UAS mission with ground truthing to have comparison dataset
    - 7 stratified random marine debris object validation video transects across beach

Figure 6: Project team member, Kyle Herrera, prior to flights on USCG MH65 Echo.

Figure 7: PI imagery acquisition aboard USCG MH65 Echo.

12/16 – Thursday

- Chris and Kyle packed up gear and shipped back to OSU via FedEx
- Collected all the data desired by this time
    - Had 2 sites heavily surveyed with different debris conditions, the best locally available
    - Surveyed with different UAS platforms (Skydio 2 & P4RTK) at varying altitudes and flight conditions
    - Acquired sufficient polarimetric imagery of material types available at varying illumination conditions and sensor heights
- Organized/consolidated project files & imagery, performed more polarimetric processing
- Field crew get-together in evening (Tim, Chris, Kyle, and Jake)

12/17 – Friday

- Return travel day

Summary

The fieldwork was deemed successful. At the time of completing this trip report, final results from the project were not available but will be provided in the final project report. However, initial results obtained while in the field indicated that UAS can be an effective and efficient tool for marine debris detection. A key operational finding from the fieldwork was that multirotor aircraft generally seem better suited to coastal data collection than fixed wing or hybrid (vertical takeoff and landing, converting to fixed wing during flight), due to their ability to handle higher wind speeds (at least for the platforms tested in this study) and greater portability.

The project team would like to extend our sincere gratitude to project partners from Texas A&M Corpus Christi, Professor Mike Starek, and Jake Berryhill, who graciously lent their time and equipment to this project. Their extensive local knowledge and technical expertise were key factors in the successful data collection. We also gratefully acknowledge LT Lisa Campbell, USCG, and Tracy Weatherall from The University of Texas Marine Science Institute.