GPS/Inertial Micro-Camera for Oceanographic Properties and Shallow Water Hydrography

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Overview

• Problem Statement
• Micro-Camera System
  • Payload
  • Image Processing / Ground Station Software
  • Bathymetry Software
• Test Results
**Bathymetry** is the underwater equivalent to topography

**Littoral Zone** is the ocean region extending from the high water mark to the shoreline areas that are permanently submerged.
Key Technical Challenge

- Current AROSS system has proven use of registered imagery for depth inversion
- Naval METOC officers deployed with Special Operations teams need organic capability to recon multiple beaches and collect water depths
- Key challenge is for reduced SWAP payload to fit on small Tier I UAV

Typical Tier I UAV

- Range: 10 km
- Endurance: 2.5 – 9 hours
- Airspeed: 25-50 km/hr
- Nominal payload weight: 600 - 900g
- Power: 6 -12 W
Military & Civilian Need for UAV Based Bathymetry/Mapping/Targeting

• Bathymetry
  • Army Corp of Engineers
    • High resolution shoreline data for modeling for forecasting
  • Littoral Battlespace Sensing, Fusion, and Integration (LBSF&I)
    • Bathymetry surveys critical for weather modeling and mission planning operations
  • Naval METOC Personnel
    • Bathymetry data from shallow regions in support of littoral operations

• Mapping/Targeting
  • NOAA and NGA
  • Military Mission Planners
    • Near real-time targeting data/Bomb Damage Assessment

• Civilian Commercial Applications
  • Low-cost Rapid Coastal Surveys
  • Precision Land Maps
  • Wave Modeling
GPS/INS Requirements

- Why is bathymetry processing so difficult in a small UAV?
  - Region of Interest
    - 1 km x 5 km shoreline
    - Bathymetry grid - 100 m x 100 m cells
  - Imaging Requirements
    - Image capture at 2 Hz over region of interest
    - ½ pixel smear (objective) and 1/5 pixel smear (Goal)
    - Average resolution of 1 meter/pixel
  - Absolute ground accuracy
    - Under 10 meters (objective) – Under 2 meters (Goal)
    - No need for ground control points
    - Relative accuracy of points sampled at same time in different ground images should be +/- 1 meter
  - Time over target for Bathymetry SW to estimate wave number
    - ~240 consecutive images of area of interest
  - Tier I UAV Payload size
    - Most UAVs are battery powered w/limited power available for the payload
    - Payload weight limited to ~ 2 lbs
NAVSYS Micro-Camera

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Operator designates AOI using WebGRIM Interface on Micro-Camera Ground Station Laptop
Micro-Camera CONOPS

Operator launches the UAV
• Micro-Camera payload measures winds aloft en route to AOI
• Micro-Camera Ground Station flight planning module calculates flight path waypoints over AOI based on sun angle and wind direction and sends updated flight plan to UAV
Micro-Camera CONOPS

UAV captures images over AOI
• Imagery and GPS/INS data logged in payload for post processing
• Thumbnails sent to Micro-Camera Ground Station during flight so operator can monitor image quality
Micro-Camera CONOPS

Ground Station Post Processing

- Operators retrieve UAV
- GPS/IMU and imagery data transferred from payload compact flash to ground station
- DGPS data collected from on-site reference station
- InterNav processing
- Image Processing (Ortho)
- Image Selection/Stacking
- DepthWizard
- WMS Publishing
Micro-Camera CONOPS

Under NESI guidance data is made available to other applications via a WMS data feed.
Cross-Shore Bathymetry Profile

Errors using mean depth in subpatch:

- Bias = 0.12 m
- RMS error = 0.48 m
- Average % error = 5%

FRF bathy lines -
(LARC 27 Oct 99)
tide level of 0.2 m
accounted for

Courtesy of
Z. Williams

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Micro-Camera Payload

Features
- Operation: In-flight, fully autonomous flight planning

Interface
- Command: Serial over UAV platform wireless link
- Video Out: Serial over UAV platform wireless link

Electrical
- Supply Voltage: 12 Volts
- Power: 10 W (typical)

Mechanical
- Size: 3.25” x 4” x 7”
- Weight: 900 grams / 2 lbs

Video
- Payload Camera: Dual side looking 3.1 megapixel color machine vision imaging modules

Operating Envelope
- Range: Limited by UAV platform and available memory
- Speed: Up to 60 mph
- Operating Altitude: 500 – 1500 ft AGL

Data Processing
- Bathymetry: Post process data collected over littoral region
- Mapping: Mapping capability from mosaicked imagery
WebGRIM Ground Station Software

- Single, integrated SW environment
- Web Based
  - No new software to install
  - On-line collaboration between multiple users
- Quickly locate and manipulate collected imagery
  - Orthorectification and mosaicking
  - Point and click targeting
- Bathymetry tools
  - UAV Flight planning → Bathymetry map generation
- Compliant with OGC
  - Display third party maps
  - Acts as Web Mapping Service
- Auto-DEM map generation from collected imagery
DepthWizard Software

• Software for estimating water depth in shallow regions (0.5 - 30 m) from time series of airborne imagery
• Uses spectral (FFT) inversion techniques based on the physics of surface gravity waves
• Presently MATLAB code; Transitioning to C-coded GUI
• Versatile adaptation to variety of image data
Auto-Mosaicking Results

- Transforms imagery into usable targeting information to facilitate decision making and mission planning
Duck NC Bathymetry Test Range

• Flight Test & Data Collection w/ Cessna at Duck NC
  • U.S. Army Corps of Engineers Field Research Facility
  • Supports coastal engineering research
  • 1000 m of frontage along the Atlantic Ocean
  • 1,840 ft research pier
    • 20 ft wide
    • Extends to depth of 20 ft
  • (35-ft) tall Coastal Research Amphibious Buggy (CRAB) survey vehicle
**Bathymetric Inversion Field Tests**  
*(Duck, NC; USACE Field Research Facility)*

- 27 m above MSL
- High oblique camera view
- 1 MB, 8-bit digital camera
- 3 @ 4 min ensembles
Example Ortho-normalized Snap Shot

- 8 bit deep camera
- 1 m pixel resolution
- Pier structure in center region of image
- Decreasing resolution in the far field owing to high oblique camera view
Profile Comparisons

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Conclusion

- Micro-Camera payload can provide high accuracy metadata from which we can extract feature coordinates
  - Bathymetry
  - Targeting
  - Mapping
- WebGRIM software can display mosaiced imagery and WMS overlays from Oracle GeoRaster database
  - Geospatial database management provides powerful capability for managing UAS imagery and for search, retrieval and viewing of multi-source data
- Bathymetric inversion methods works reasonably well
  - TOP shore-based techniques, O(0.5 m) RMS errors in 1-6 m water depths for the 12 days examined
- Validation under variety of conditions not fully completed
  - Small waves only as no ground truth under large waves
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