Flight Test Results for Video-Aided Navigation

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**Problem Statement**

- A key issue for small UAVs is their inability to operate during periods of GPS denial.
- Current flight regulations require that UAVs land following loss of navigation.
- Larger UAVs carry inertial navigation systems that can provide back-up navigation during GPS drop-out.
- Smaller tactical UAVs generally have low quality IMUs that are unable to continue navigation solutions following GPS drops-out.
- A back-up navigation solution to GPS is needed for use on these smaller, lower cost UAV platforms.
GI-Eye Sensor Registration

- GI-Eye Product
  - GPS gives position
  - Inertial gives attitude

- GRIM Enterprise Server
  - Manages registered sensor imagery
  - Auto-mosaic generation

\[
\text{los}(N) = C_c^N \begin{bmatrix} P_x & P_y & f \end{bmatrix}^T \sqrt{P_x^2 + P_y^2 + f^2}
\]
GI-Eye Systems

NGA Tactical Surveying and Targeting System (TS2)

FLIR StarSAFIRE III

Dual GI-Eye System Flown at USAFA

Micro-Camera (Dual Camera)
GI-Eye Payload

<table>
<thead>
<tr>
<th>Component</th>
<th>Size</th>
<th>Weight</th>
<th>Power</th>
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<tbody>
<tr>
<td>As shown above</td>
<td>~ 300 Cubic Inches</td>
<td>~ 9 lbs</td>
<td>~ 175 Watts</td>
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Overall Web-based Georeferenced Image Manager (WebGRIM) Architecture

WebGRIM Client
- 100% Web Browser based
- No local software installation required
- Users can easily collaborate and share data

GI-Eye Payload
- LandmarkUAV.exe
- NIM RS-232
- GPS RS-232
- Internav
- Camera USB
- Oracle Interface Object
- File Storage

GI-Eye Architecture
- HTTP over TCP/IP
- FTP over TCP/IP

GRIM Server
- PCI Pluggable Functions
  - APM, MOSAIC, ETL, GDB, AGCP, AUTODEM
- MATLAB Services
  - Targeting
  - OrthoMosaicing
  - WUPT
  - Flight Plan/Monitor
  - Bathymetry
  - AutoDEM
- Oracle 11g AS
  - MATLAB Marshaller
  - NAVSYS WebGRIM J2EE Application

Oracle 11g Spatial Database
- Platform Collected Imagery
- Pre-designated Targets
- Pre-loaded Maps
- Pre-loaded Imagery
- Calibration Data

WebGRIM Server
- Internav.exe
- Internav (DGPS Reprocessing)
- WebGRIM J2EE Application

Base Station
- Novatel
- Base Station.exe
- Differential Calibrator

11g Spatial Database
- GEOREGMESSAGE
- IMAGES
- MOSAICS
- SENSORS
- CALIBS
- SETTINGS

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MATLAB Services
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Overall Web-based Georeferenced Image Manager (WebGRIM) Architecture
- Imagery and georegistration data is initially collected by the sensor and stored in Oracle database.
- Covariance is monitored to indicate a potential issue with GPS data.
- GRIM starts the WUPT process by pulling imagery and georegistration information from database.
- WUPT library compares images to reference images to determine Ground Control Points (GCPs).
- Lsreltgt Software uses GCPs to generate position and attitude corrections.
- Position/attitude updates sent to InterNav to assist navigation.
WUPT Work Flow

- pci.crproj
  - Creates Orthoengine project
- pci.camimport
  - Imports camera calibration data from XML data extracted from database
- pci.eoimport
  - Import Exterior Orientation Data from GI-Eye Inertial position/attitude meta data
- pci.autogcp
  - Collects ground control points for an input image from a reference image
- Lsreltgt
  - Uses inertial aiding and GCP points to calculate position/attitude errors in inertial solution
Landmark Flight Test - 11 July 09

- Rocky Mountain Aerial Surveys, Inc
  - Cessna 206G
    - Based in Denver
- Collection Area
  - Northeast section of USAFA
  - 25 NGA surveyed Ground Control Points
- Landmark Payload
  - 1 Hz images, looking Nadir
- Micro-Camera Payload
  - 2 Hz images, 30 degrees off Nadir
- Post processed images used to:
  - Test single and multi-shot targeting through WebGRIM
  - Collect imagery for AutoDEM processing
  - Validate WUPT navigation algorithms
WebGRIM Ground Station Software

- Web Based
  - No new software to install
  - On-line collaboration between multiple users
- Quickly locate & manipulate collected imagery
  - Orthorectification & mosaicking
  - Point and click targeting
- User Customized Tools
  - Flight planning
  - Targeting
  - map generation
- Compliant with OGC
  - Display third party maps
  - Acts as Web Mapping Service
- Auto-DEM map generation from collected imagery
WebGRIM - Zooming in to AOI

- User can zoom in to Area of Interest to see footprints of collected imagery
Ground Control Points

- WUPT Library compares images against the reference image in the database to determine GCP
WUPT Results

- Ground Control Points are automatically generated and compared against a reference mosaic.
- Corrections are generated for the position and attitude of the sensor based on the difference between common points in the images.
- Red indicates an accepted GCP
- Yellow indicates a rejected GCP
Airborne Navigation Performance with Image Aiding

Navigation Error with Closed Loop Image Aiding

Steady-State Nav Error < 5 m with 2 updates per minute
Conclusion

- GPS/inertial registered video can provide mosaiced reference image
- WUPT updates from current images to previous mosaic can bound inertial errors during GPS drop-outs
- Video aiding provides a cost effective back-up navigation solution for small UAVs using their onboard avionics and sensor payloads
Back-Up
NGA Truth Data