Near Real-Time Geo-Referenced UAV Imagery Collection and Web-Based Processing on a Server for Targeting and Mapping

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BIOGRAPHY

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ABSTRACT

This paper discusses new capabilities designed and tested by NAVSYS to provide near real-time support of targeting and mapping applications by incorporating advanced software and database techniques for collecting, distributing, and organizing geo-referenced imagery. In this paper, we describe the design of the WebGRIM Enterprise Server and its employment of the Oracle tool suite for spatial processing. We present a demonstration of the type of imagery products that they provide for targeting and mapping applications. We also describe a concept of operations for further use of this technology for real-time precision targeting.

INTRODUCTION

Many aircraft and unmanned air vehicles now carry sensors to support battlespace awareness. By downlinking real-time video to the battlefield through systems such as Rover (Figure 1), these can provide real-time situational awareness for ground forces. Ground Based Observers (GBOs) have a need for near real-time mensurated imagery to support their call-for-fire operations. The current video downlinks do not include the high precision metadata needed for registration of the sensor imagery to allow it to be used for targeting. NAVSYS has developed an autonomous sensor registration and mosaicking capability that can provide access in near real-time to precision registered imagery. An example of an auto-mosaicked image is shown in Figure 2.

Figure 1 Rover Real-Time Video Display

Using auto mosaicked images instead of video images has a number of advantages. With a video downlink, the ground user is viewing an unstabilized image with a "birds-eye" view of the ground. This generally requires training to be able to interpret what is being viewed geospatially; for example, to interpret "is that truck coming towards me or away from me". The mosaicked images are stabilized in the georectification process and are oriented in geographic coordinates when viewed. This simplifies interpretation by any operator familiar with using maps or overhead images.

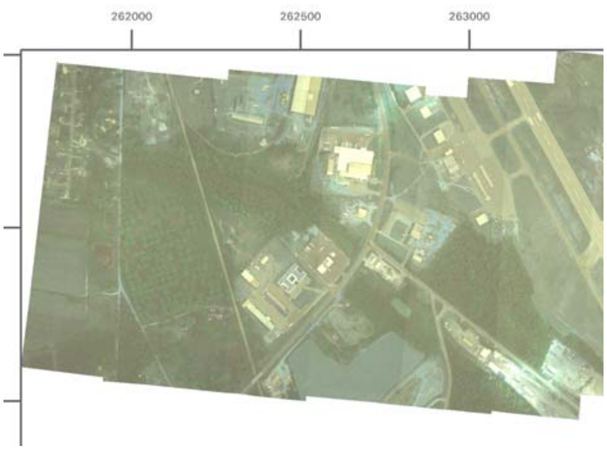


Figure 2 Auto-Mosaicked Image View

Video downlinks generally compress the sensor imagery due to limited bandwidth. This results in the image quality being degraded. Even with JPEG2000 compression the downlink still requires significant bandwidth (~5 Mbps). The auto mosaicking process results in a much lower overall bandwidth for the downlink of georectified and registered imagery even though the full-quality images are available. This is achieved since "redundant" pixels, including the same geospatial information, are removed. While in the video many of the pixels in a 30 fps downlink are viewing the same geospatial points.

With the downlinked video, sophisticated ground stations are needed to mensurate the imagery against ground truth before the sensor data could be used for targeting. These ground stations are not suitable for man-portable applications in the field. With the auto mosaicking approach, the views of the battlespace are already mensurated allowing them to be used for targeting by a Ground Based Observer using simple Web viewing tools. Registration also allows for spatial data management. Viewing registered data also simplifies access to multiple sensor feeds when available, as the data from each sensor feed can be overlaid on a common view facilitating target identification or can be compared with historic views for applications such as change detection.

This paper describes the architecture of an unmanned aerial vehicle (UAV) imagery collection and web-based server system that is designed to provide access to near real-time registered imagery for use by Ground Based Observers.

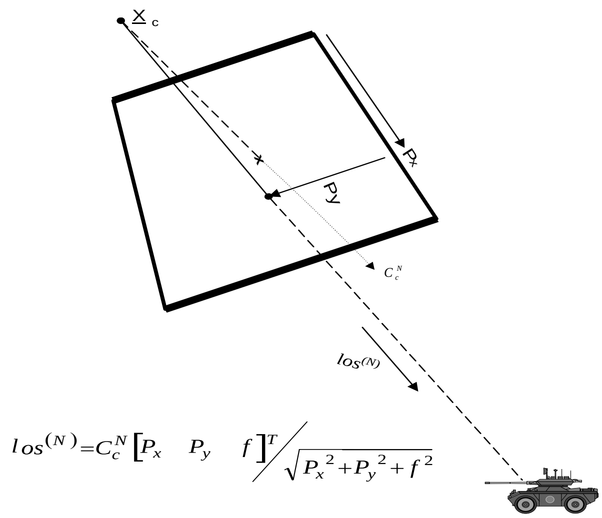
UAV SENSOR REGISTRATION SYSTEM

NAVSYS has designed and tested a GPS/inertial/video sensor (GI-Eye) [1] that provides precision georegistration data for collected imagery directly at the sensor. This has been packaged into a UAV payload that generates and delivers precision mensurated imagery directly from the airborne UAV. The payload is connected through a network link to a ground based server that can process the georegistered data in near real-time using our Web GeoReferenced Information Manager (WebGRIM) Enterprise Server. The WebGRIM server employs advanced spatial database modeling, storage, retrieval, and display techniques to accelerate imagery processing. This has been made possible by exploiting Oracle's Database 11*g* and MapViewer tools.

The UAV sensor's (EO camera) images are collected for indexing and storage by the WebGRIM Enterprise Server. The spatial database provides sophisticated tools that allow for the searching and retrieval of sensor images that cover a common coordinate or a common point in a particular sensor image. These images can also be processed in near real-time to generate an automatic mosaic as the aircraft flies. By employing Oracle's MapViewer technology, ground-based users can access imagery, maps and mosaics directly from the server over a wireless data link using a web browser. Historical map data is immediately updated with real-time imagery collected from the UAV's ground path. By adding the dimension of time, the user is provided with dynamic 4D imagery, allowing easy change detection. The GI-Eye and WebGRIM systems can be used to provide near real-time access to imagery products for targeting and mapping applications

GI-EYE AUTO-REGISTRATION

The GI-Eye product provides the capability to precisely time mark each camera image and uses NAVSYS' proprietary InterNav kinematic alignment algorithm[3] to measure the precise position and attitude of the camera using the GPS and inertial sensor data. The GI-Eye system auto-registration capability provides the location and pointing angle of the sensor with each image and sensor calibration data from which the coordinates of each pixel in the image can be derived. This information can be used with a Digital Surface Model (DSM) to extract the individual pixel coordinates of each image (Figure 3).



$$los^{(N)} = C_c^N \left[P_x \quad P_y \quad f\right]^T \Big/ \sqrt{P_x^{\,2} + P_y^{\,2} + f^{\,2}}$$

Figure 3 GI-Eye Sensor Registration

GI-Eye is designed as a modular product that can couple together data from a variety of different GPS, inertial and sensor sources to generate the precision metadata. In Figure 4, the GI-Eye sensor payload that was configured for testing in an Unmanned Airborne System (UAS) is shown. It includes a PixeLINK PL-B776U commercial camera, HG1900 IMU, a NovAtel OEMV commercial GPS receiver, and a Kontron computer that hosts the Kalman filter and processes the data. Figure 5 shows a commercial product manufactured by FLIR Government Systems in Portland, Oregon, that also includes the GI-Eye sensor registration capability. FLIR has adapted their product to use the precision metadata to allow for geopointing the gimbal at a particular target coordinate on the ground.

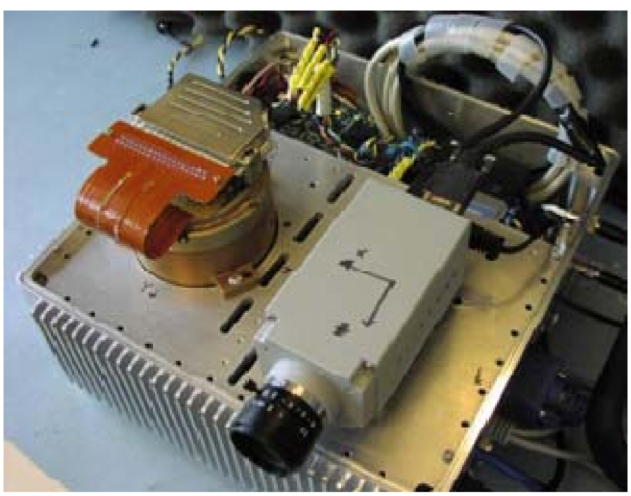


Figure 4 UAS GI-Eye Sensor Payload

The GI-Eye/WebGRIM system is designed to be capable of supporting ten meter target location errors (TLEs) at distances of up to five km. This is accomplished through a combination of the following capabilities:

- **Precision GPS Positioning**. The GI-Eye can calculate the coordinate of the sensor focal point to an accuracy of one meter through high accuracy GPS positioning. This is accomplished through differential GPS corrections from a ground station or by using Zero-Age Ephemeris received from NAVSYS' Precision GPS Ephemeris Tactical Control Stations (PGE TCS) located at Schriever and Vandenberg AFBs[2].
- **Precision Attitude Determination**. Using our proprietary InterNav[3] GPS/inertial integration software we are able to achieve high accuracy alignment of the sensor attitude using a kinematic alignment technique to calibrate the inertial errors. This has been demonstrated to achieve < 1 mrad accuracy even when using tactical grade (~10 deg/hr) inertial measurement units.
- **Camera Calibration**. We have designed a camera calibration procedure that allows us to precisely estimate the camera parameters needed to compute a target's location or accurately georectify an image. This includes estimation of the camera misalignment from the inertial axes, the focal length and radial distortion caused by the camera lens.
- **Precision Digital Surface Model (P-DSM).** The targeting or georegistration accuracy is also dependent on the precision of the DSM used to estimate the range to a ground location viewed in the image. To achieve high accuracy targeting, we have the capability of loading into our system a precision DSM (P-DSM) generated from precisely registered stereo images collected from a previous flight.

Figure 5 FLIR Star SAFIRE III with GI-Eye[4]

The combination of these precision techniques allows the GI-Eye system and Web-based GeoReferenced Image Manager server onboard the aircraft to produce high-quality georegistered mosaics in near real-time with accuracy sufficient to be used for targeting and mapping applications. During initial development, the WebGRIM software is hosted on an Alien Area 51 computer. Later, it will be hosted on an airborne server. A user will be able to browse into the server via a Wi-Fi connection to request information and products.

WEBGRIM ARCHITECTURE

At the heart of the WebGRIM architecture is the Oracle Database 11g Enterprise Edition and Applications Server. Metadata from the sensor(s) and imagery is stored in the database using Oracle's Spatial and GeoRaster technology. This allows for the storage of virtually unlimited amounts of data while still achieving very fast geographic searches. The database can also be preloaded with maps, satellite imagery, and elevation models to provide the user with a geo-context for identifying targets and planning missions.

WebGRIM provides a web-based interface for the user. Using wireless technology a ground-based observer can bring up WebGRIM web pages on their PDA or laptop. By making use of Ajax and the qooxdoo JavaScript framework WebGRIM provides users with a web application that behaves more like sophisticated desktop program than simple web pages. Users can plan collection missions, observe current and archived imagery (displayed as either seamlessly mosaicked maps or raw images), generate targeting coordinates from observed ground features, measure distances, etc. Potential targets can be compared to older images and maps for verification or for battle-damage assessment.

By integrating MATLAB into the WebGRIM architecture we are able to make rapid changes to mathematical algorithms during development and testing. MATLAB routines can pull data directly from the Oracle database and send results to the client web applications. WebGRIM makes use of PCI Geomatics "pluggable functions" to perform advanced image manipulation, such as rapid orthorectification.

Interoperability was a prime concern when designing WebGRIM. By leveraging the Oracle Application Server MapViewer product WebGRIM can both ingest and publish Open Geospatial Consortium (OGC) Web Map Services (WMS). Users can display third party maps and features in WebGRIM right alongside their real-time sensor imagery. And if desired, third-party display tools like Google Earth or ESRI's ArcGIS can easily make use of WebGRIM data.

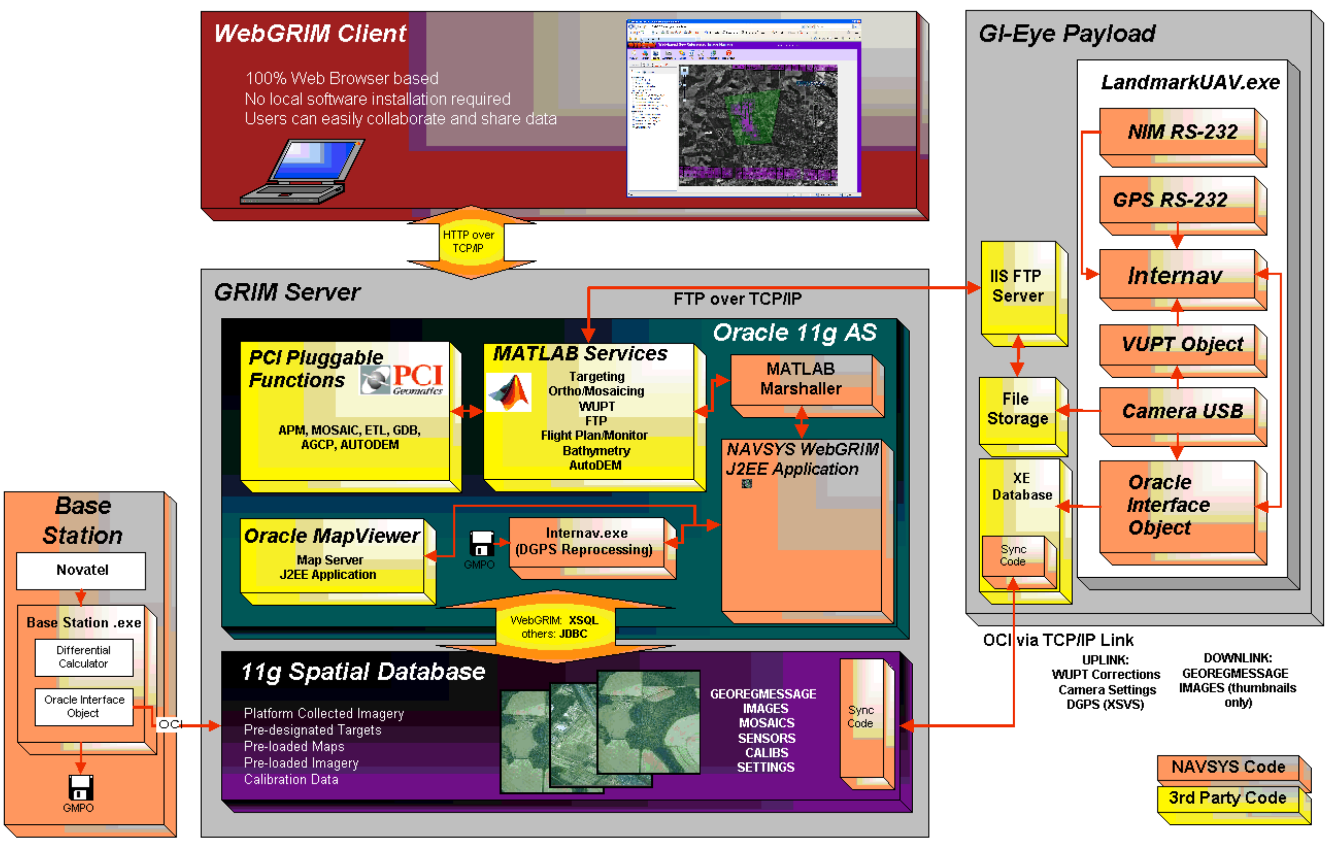


Figure 6 Overall Web-based GeoReferenced Image (WebGRIM) Architecture

UAS CONCEPT OF OPERATIONS (CONOPS)

The concept of operations for providing Ground Based Observer support for situational awareness and targeting is shown in Figure 7. Currently, only the video feed from a UAS sensor payload can be viewed in real-time by GBOs. There is no real-time access to mensurated imagery for targeting by GBOs. By installing the both the GI-Eye payload and the WebGRIM server on a UAS, it will be possible to provide near real-time access to mensurated imagery directly to the GBOs through a wireless network interface from the UAS. Using WebGRIM Tools, GBOs will be able to view imagery at any coordinate they provide; for example, using their existing Target Location, Designation and Hand-Off System (TLDHS). They will also be able to extract target coordinates from the WebGRIM views with the estimated target location error to input into a Call for Fire message.

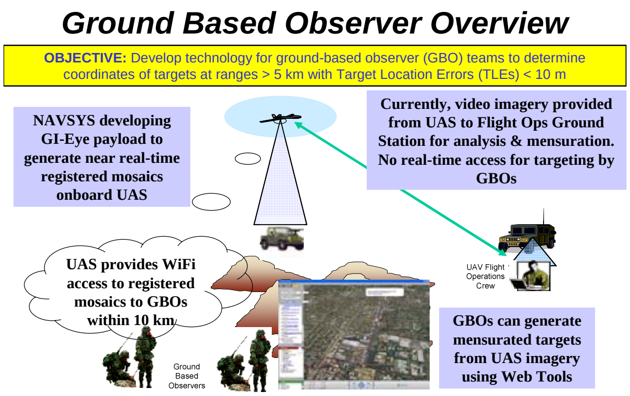


Figure 7 Ground Based Observer Support CONOPS

Figure 8 shows a WebGRIM page displaying the targeting icon (red open cross) on the background map with the most recent image from GI-Eye that has been mosaicked into a GeoRaster overlaid on top. The GBO can use WebGRIM tools to zoom in and refine the target location.

Figure 8 Orthorectified Image in GeoRaster

Figure 9 shows that the GBO has sent the LLA, CE & LE to another application for input into the Call-for-Fire message.

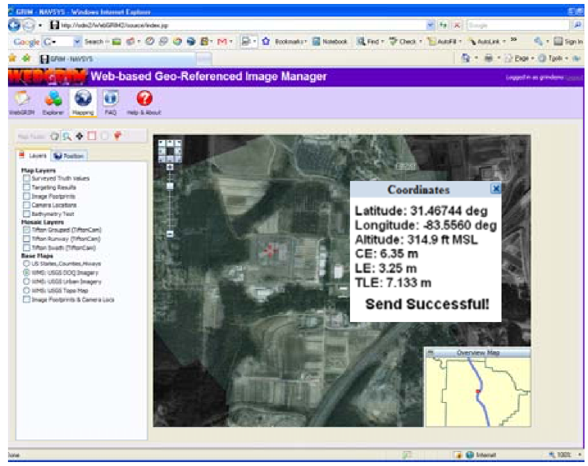


Figure 9 Target Coordinate Generation

Figure 10 shows another WebGRIM page that provides the GBO a listing of images covering a specified location or area of interest.

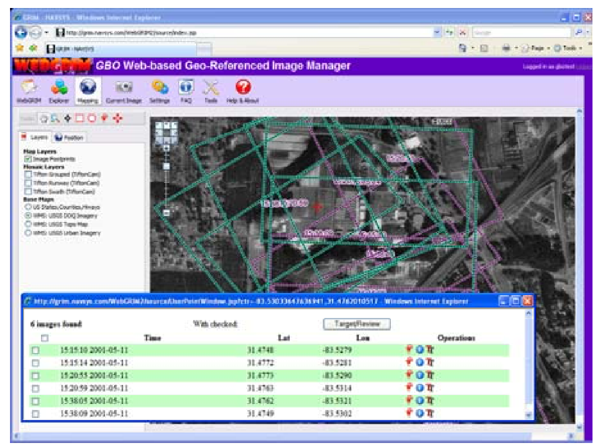


Figure 10 Spatial Inquiry and Imagery Listing

Figure 11 presents the results of single shot targeting after the GBO has reviewed the available images and selected the exact target location.

Figure 12 presents the results of multiple shot targeting after the GBO has reviewed the available images, noted the same feature in at least two images and requested the exact target location. Circular Error (CE), Linear Error (LE) and TLE (90% confidence interval) are also calculated and displayed with the latitude, longitude and elevation.

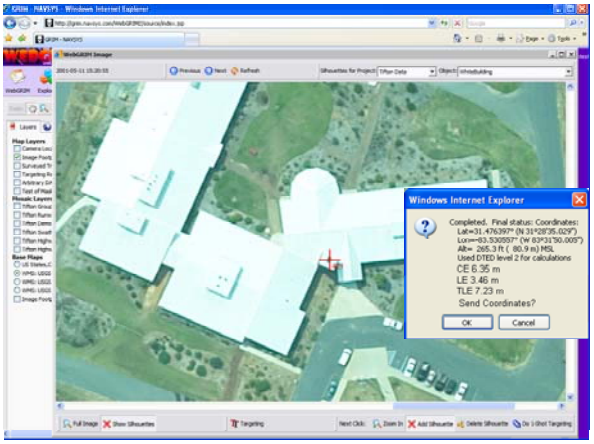


Figure 11 Single Shot Targeting Results

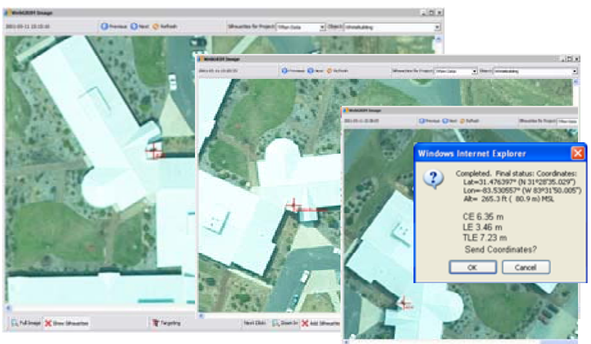


Figure 12 Multiple Shot Targeting Results

PLANNED UAS FLIGHT TEST

The USMC is funding a flight test of the UAS GBO payload described in this paper to demonstrate near real-time targeting using the georeferenced imagery and WebGRIM tools. Figure 13 shows the GI-Eye payload installed in a USFS Cessna 206 prior to test flights over the USAF Academy. Figure 14 shows a Tier II Class UAS that will also be used for flight testing the GI-Eye and WebGRIM systems in a later stage of this program.

Figure 13 GI-Eye Payload Installed

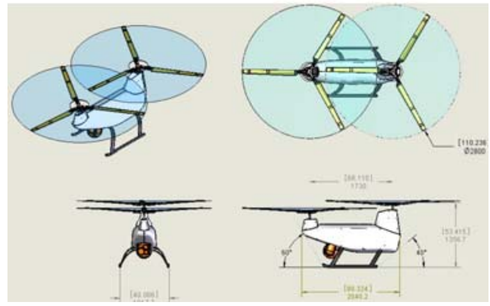


Figure 14 Dragonfly Pictures DP-12 UAS

CONCLUSION

The GI-Eye and WebGRIM products described in this paper have the capability to store georeferenced imagery in an Oracle GeoRaster database in near real-time. The high accuracy image meta-data provided by the GI-Eye system provides the capability for the user to extract feature coordinates using the WebGRIM tools with sufficient accuracy to be used for targeting. WebGRIM can display mosaicked imagery and WMS overlays from Oracle GeoRaster database. The geospatial database management also provides powerful capability for managing UAS imagery and for search, retrieval and viewing of multi-source data.

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