High Speed Stabilization and Geo-Registration of Drone Imagery based on GPU Optimization

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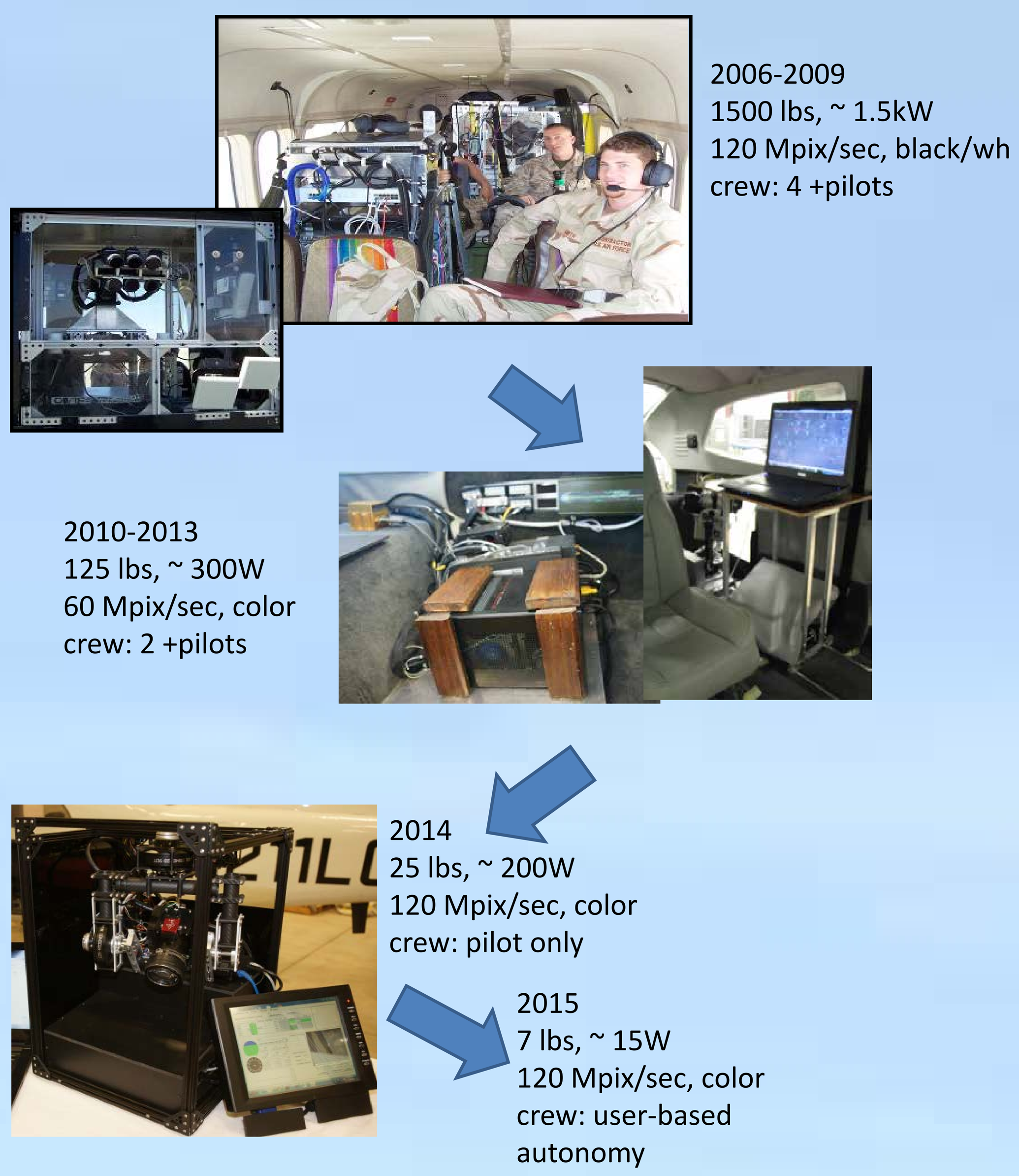
See the video at the above Website for a view of the system in motion and description in detail

Geo-Registration for WAMI

Wide Area Motion Imaging (WAMI), that create "Magic Maps", or 3D maps in motion from high resolution imagery captured from aircraft or drones flying overhead. These maps can be critical for both military and civil applications such as law enforcement and emergency responders. Processor improvements, and GPU technology in particular, have played a key role in increasing capability while reducing Size, Weight, Power and Cost (SWAP-C).



Transparent Sky Real-Time WAMI

Transparent Sky took WAMI systems to their next level of affordability and practicality through the use of CPU-GPU processing. Users see imagery draped over terrain that is updated at 4 frames/second in near real-time (with a lag of about 5 seconds). Images are distributed via client-server networks and viewed on computers, tablets, phones, etc.

GPU-Based Feature Point Categorization

Rapidly segregate tracked features into 4 categories:

1. Points stable in terrain model
   (use unmodified)
2. Points exhibiting parallax motion
   (correct terrain – then use)
3. Moving content points (e.g. cars, people)
   (reject but feed to other algo's)
4. Noisy, poorly detected points
   (reject outright, eventually prune)

Feature points can be efficiently computed using integral histogram algorithms and GPU parallelization for detection and matching.

Preparation & Initial alignment

All points calculated from geo-projection:

$$\langle u, v\rangle = \langle \frac{x_t}{z_t}, \frac{y_t}{z_t} \rangle \ where\ X_t = M^T(X_s - X_p)$$

Points are then matched using normalized cross-correlation (below) and RANSAC.

$$v = \underset{i,j}{\operatorname{argmax}} \frac{1}{(n-1)} \frac{\sum_{x,y}(r(x,y)-\bar{r})(m(x-i,y-j)-\bar{m})}{\sigma_r \sigma_{m_{i,j}}}$$

Where r(x,y) is the reference template and m(x,y) the is the same template neighborhood around the feature point in the "matched" image.

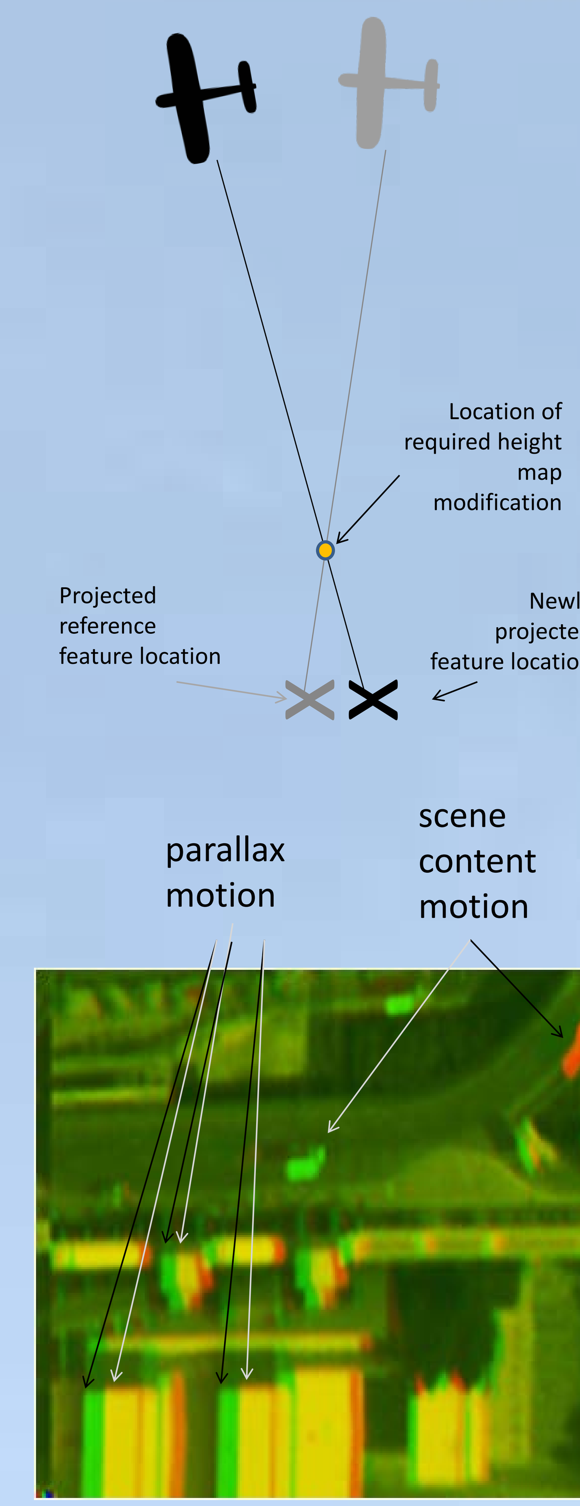
Category 1 Points::

$$\Delta x_{n_p} \in C_1 \text{ if } \left|\Delta x_{n_p}\right| < \varepsilon$$

Category 2 Points:

Elevation errors cause false motion along a vector parallel to aircraft motion:

$$\Delta x_{n_p} \in C_2 \text{ if } \frac{\left(\Delta p_n \cdot \Delta x_{n_p}\right)^2}{\Delta p_n \Delta x_{n_p}} > 1 - \sin^2\phi$$



Category 3 Points:

Points that follow frame-to-frame motion limited by reasonable acceleration. Passed to LOFT real time tracking of moving object points.

Category 4 Points:

Points not categorized above

Initial Results:

Real-time (acquire, geo-project, correct & other processing at 4 Hz) demonstrated with CUDA-based system on i7 6-core + nVidia 660ti

Results shown at right:

Green: confirmed Cat 1

Blue: confirmed Cat 2

Gray: Cat 3 or 4

(Algorithm to segregate Categories 3 & 4 under development)

LOFT long tracks shown in inset.