Transparent Sky

GPU-Optimized Real-Time Processing of Wide-Area Motion Imagery (WAMI)

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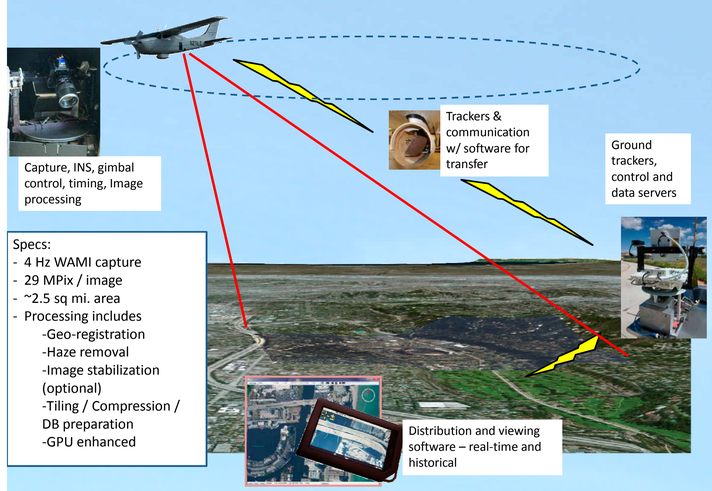
See the video at the above Website for a view of the system in motion and description in detail

What is WAMI?

Wide-Area Motion Imaging creates a "Magic Map" in which sequences of rapidly-captured high-resolution images are registered to a terrain model and stored in a database that can be browsed by geography. The resulting "maps" create a virtual view of reality in motion.

The first WAMI systems were built by the U.S. military to get enhanced situational awareness and to study threats in Middle East conflicts. Civil uses could include security, traffic study and management, sports casting and many other uses.



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/sec (approximately 120 Mpix/sec) in near real-time (about 5 seconds behind reality). Images are distributed via client-server networks and viewed on computers, tablets, phones, etc.

WAMI GPU Challenges

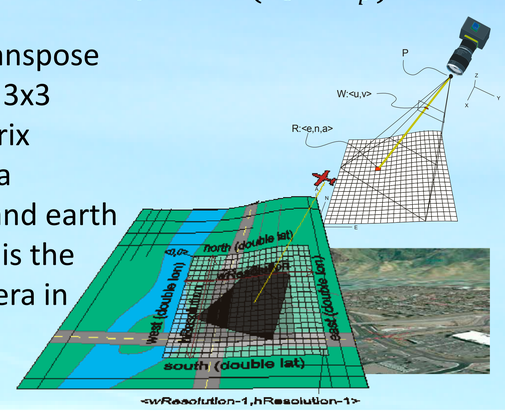
Optimized GPU code has allowed the real-time processors to be reduced from a small cluster to a single gaming-class computer, with great gains for airborne processing. Three specific tasks addressed include geo-projection, image-image registration, and enhancement (e.g. haze reduction).

Geo-Projection

The algorithm follows subtle terrain through CUDA code free of branching logic. Projected pixels are kept with threads, while input imagery flows through global memory. The key calculation maps terrain points $X_s = \langle x_s, y_s, z_s \rangle$ to a color vector in the image (belonging to a coordinate <u,v> in camera space) as follows:

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

Where M^T is the transpose (and inverse) of the 3x3 transformation matrix between the camera coordinate system and earth coordinates, and X_p is the location of the camera in earth coordinates.



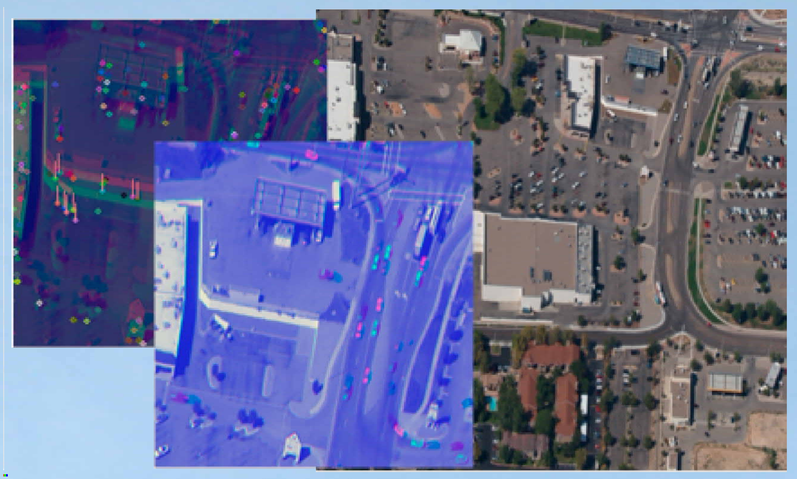


Image-Image Registration

To improve jitter reduction:

1. An image section is projected using uncorrected metadata
2. Normalized cross-correlation finds a matching reference image neighborhood.

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

3. A displacement vector at each point.
4. A RANSAC algorithm finds the most plausible match of points within the sets.

The matched images can be further used for tasks such as vehicle tracking downstream.

Haze Removal

By pre-calculating global estimates of air light and dark channel data, the algorithm can perform haze correction on the CUDA device during geo-projection