Analysis of Compression Algorithm in Ground Collision Avoidance Systems

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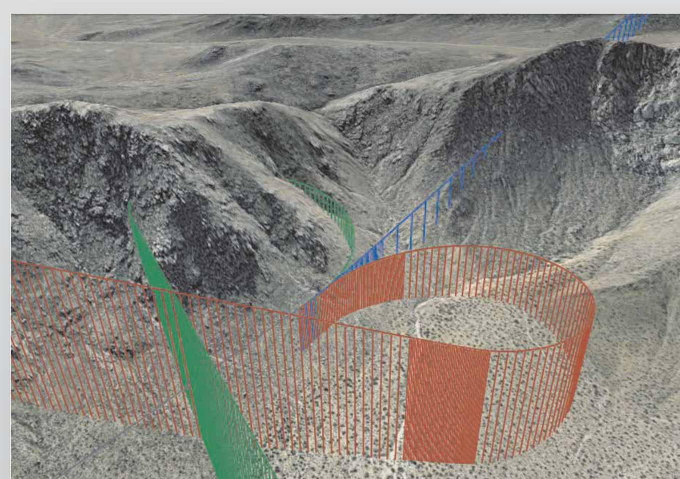
Background

Controlled Flight Into Terrain (CFIT) is the #1 cause of fighter pilot fatalities and accounts for 25% of destroyed fighter aircraft. To prevent CFIT, Automatic Ground Collision Avoidance Systems (Auto-GCAS) utilizes Digital Terrain Elevation Data (DTED) stored onboard a plane to determine potential recovery maneuvers. Auto-GCAS has been successfully tested on the F-16 in a small area at Edwards AFB/ Dryden Flight Research Center .

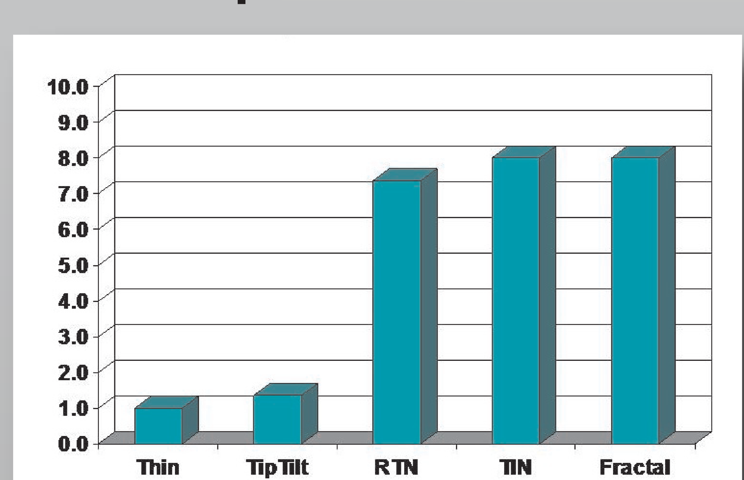
ACAT/FRRP F-16 during Auto-GCAS flight tests at Edwards AFB/ Dryden Flight Research Center



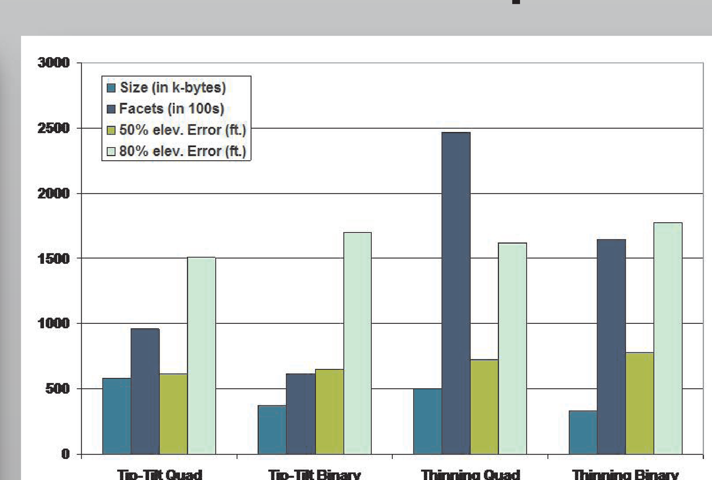
Computer simulations of vertical (blue) and lateral (left – green, right – red) recovery maneuvers.

The military is interested in worldwide Auto-GCAS for F-22 and F-35 to maximize fighter and pilot safety, but because of current computer hardware limitations, worldwide DTED must be compressed for storage. This lead to research of DTED compression algorithms such as: thinning of data, binary/quad-tree tip-tilt, regular and irregular triangle networks, and fractals.

Computational Burden



File size and Error Comparison

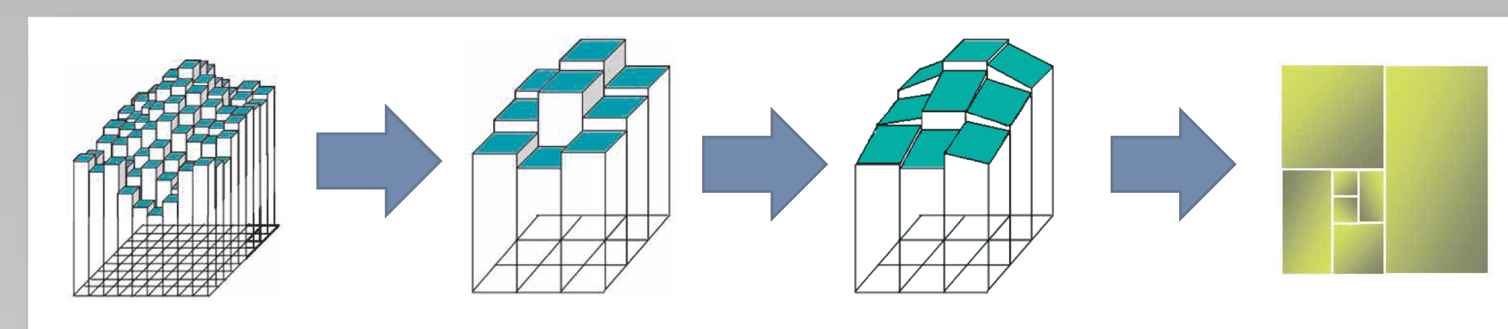


Previous research, as indicated in the graphs above, found that binary-tree tip-tilt offered one of the least computer intensive compression algorithms while also providing one of the smallest file sizes and facet counts. Both of these are crucial when it comes to compression, storage, and decompression

Some research has been done on the accuracy of binary-tree tip-tilt compression, but only global statistics have been looked at. To improve the accuracy of the compression algorithm, we shall investigate the spatial distribution of the errors with respect to the original DTED as well as the proportion of and distribution of underestimation of elevation.

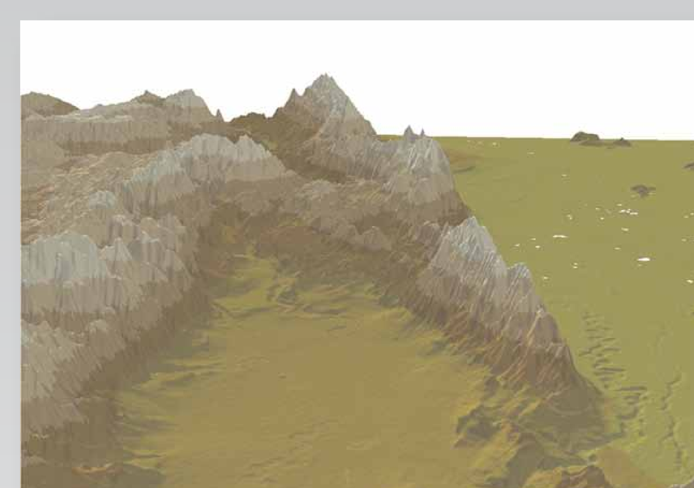
Materials and Methods

Binary-tree tip-tilt compression sub-samples DTED to a lower resolution and constructs regular rectangular slopes arranged in a regular pattern. Then the error is calculated by checking against the original DTED. Where the error is above a given tolerance, rectangular divisions are made and the process is repeated.

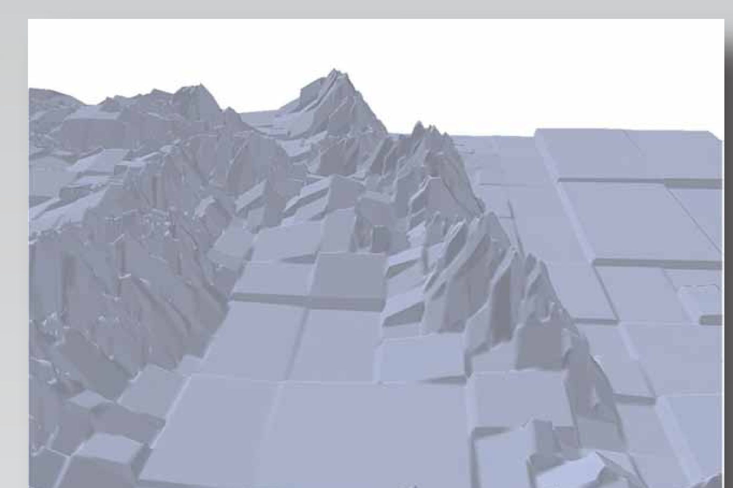


The truth data is 1 Arc Second National Elevation Data (from 35.1652°N to 35.2228°N and from -117.499°W to -117.306°W) and comes in a matrix of elevation posts.

The test data is the compressed version of our truth data covering roughly the same geographical area. It is recorded in rows that contain the corners of the planes.



Example of 1 Arc Second National Elevation Data (DTED)



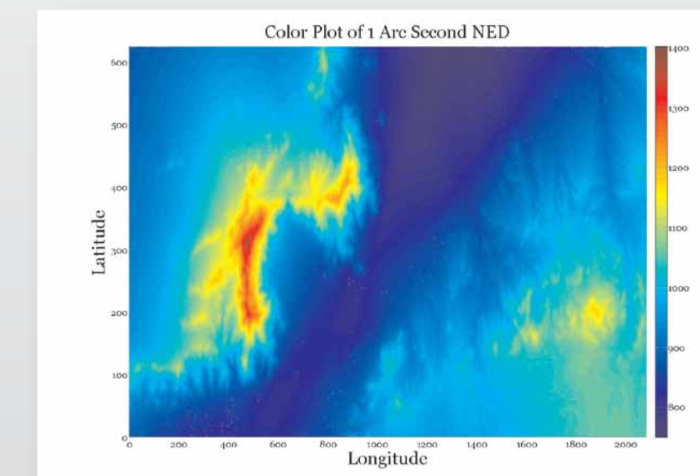
Example of DTED after Tip-Tilt Compression

Since the data sets come in different formats, it must be determined which plane contains each elevation post. Once this is determined, the difference or error is found by subtracting the height of the plane from the height of the elevation post. This will result in a matrix of error values that is the same size as the original DTED.

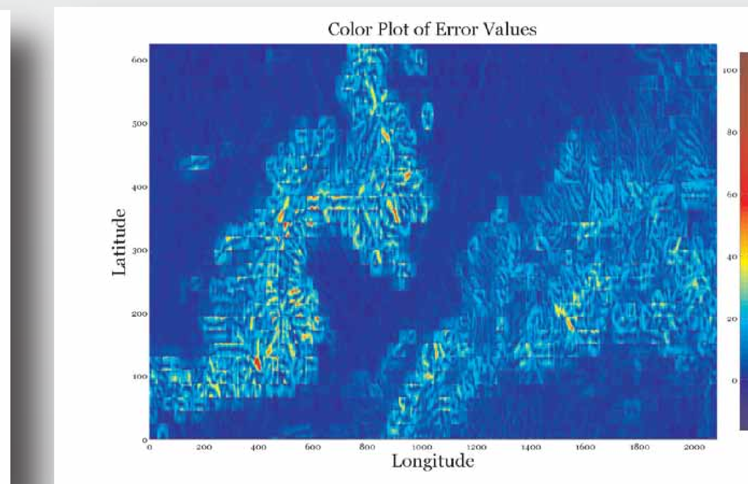
Preliminary Results

Descriptive Statistics of Error Values	
Mean Error	6.658 meters
Absolute Mean Error	6.684 meters
Standard Error	9.803 meters
Percentage of Points Underestimated	1.096%

Preliminary Results (Continued)



MATLAB color plot of truth data.



MATLAB color plot of error data

Discussion

The error values are largely dependent on the shape of the terrain as can be seen by comparing the two color plots. Wherever there is a quick change in elevation, the errors are high.

1% of the terrain is being underestimated. Compression algorithm is not supposed to be underestimating so this raises concerns. Requires further investigation of spatial distribution to see if certain areas are causing issue.

Future Areas of Interest

The following are research ideas to provide further information and improvements to Binary-Tree Tip-Tilt compression:

- Assess the horizontal accuracy of the DTED after compression
- Explore different sub-sampling techniques and determine the most efficient/most accurate
- Analyze how the error of the original DTED propagates through compression and decompression

References

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2. Miliaresis, George Ch, and Charalampos V.E Paraschou. "Vertical Accuracy of the SRTM DTED Level 1 of Crete." International Journal of Applied Earth Observation and Geoinformation: 49-59. Web.

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