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Using orthorectification for cross-platform image fusion

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Abstract. Change detection and motion detection is theoretically possible using image fusion—imagery of a common area from multiple sensor platforms, however perspective differences represent a significant obstacle both to human and machine correlation, particularly in the case of side oblique imagery. Orthorectification provides a common perspective and thus a practical first step for follow-on correlation algorithms.

Keywords: image fusion, orthorectification, orthophotos, image correlation.
Palavras-chave: fusão de imagens, ortoimagens, orto-retificação ,correlação.

1. Image "Fusion"

The popular term "image fusion" often refers to combing two images to form a single image containing elements from both and hoped to somehow be of more value. While combining two images into one may have merit in certain applications, this paper will focus the combining of the information in two images of a common location taken from different sensors and/or different platforms and demonstrate the utility of correlation by simply overlaying one image on the other.

Sensors types may be electro-optical (EO), synthetic aperture radar (SAR), multispectral and hyperspectral. Platform types may be satellite or aircraft, both nadir-looking and side oblique. Much of the "image-fusion" literature focuses on the problem of combining imagery from mutliple sensors on a common platform. The more difficult problem of combining imagery from different platforms will be examined here. But first an example: Figure 1 shows two images that were set before the whole world at a Centcom briefing on April 4, 2003. The first image is a so-called pre-strike view showing several targeted buildings before an airstrike. The post-strike image on the right shows the bomb damage.

Figure 1. Pre- and Post-Strike Images from Centcom Briefing, April 4 2003

Note the arrows inserted on both images. These were added because the two views were taken from different vantage points. Consequently such visual aids are necessary to help the viewer mentally correlate objects between images. The image analyst who added these arrows was in effect doing a mental correlation on one or both of these images to locate the common points, but such correlation is both mentally taxing and time consuming. One example of the time and effort required is that on closer inspection the post-strike image may be seen to contain structures that were not present in the pre-strike image (See Figure 2.)—a phenomenon that begs for explanation, but about which none of the press at the briefing where these images were presented inquired, most likely because no one saw it. It just took too much mental effort.

Figure 2. Overlooked Construction in Post-Strike Image

2. Perspective Distortion & Orthorectification

Why can't such images be shown in the same perspective? Correlation (by human eye or machine) would be so much easier if they were. Of course in a tactical environonment, putting sensors in a precise location and pointing angle in order to match a previous image is not practical. But performing perspective correction on an image is not a trivial process either. Figure 3 illustrates the problem. If a sensor points to nadir over a flat and level terrain, relative distances in the image will match the same relative distances on the ground.

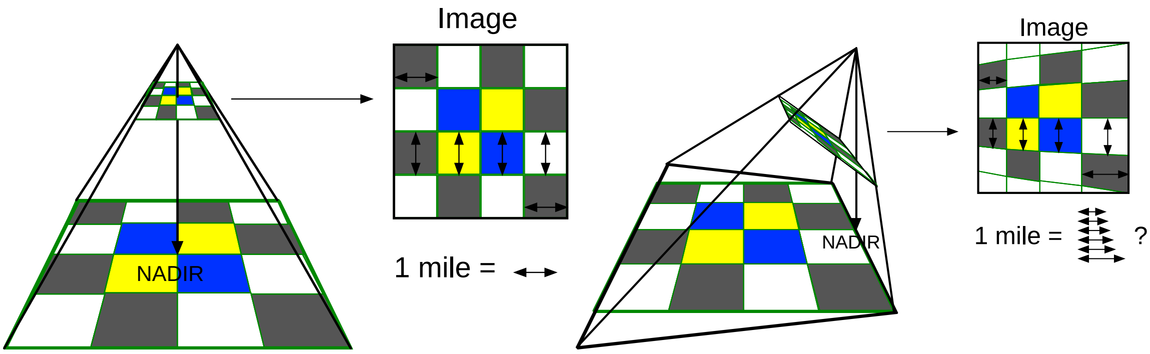

Figure 3. Perspective Distortion

However if the camera is not pointing straight down, relative distances in the image are not uniform due to the off-nadir angle and the image is distorted as shown.

Not shown here is the additional complication of uneven terrain.

The process of correcting for both perspective and terrain distortion is called orthorectification and is illustrated in Figure 4.

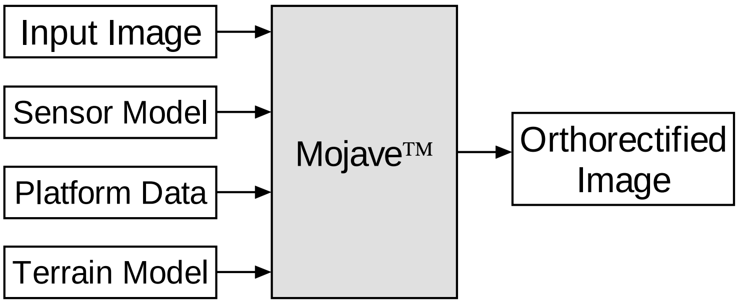

Figure 4. The Orthorectification Process

The distorted image is combined with knowledge of the sensor geometery, the platform location and pointing angle, and a digital model of the terrain in an orthorectification package such as Cardio Logic's Mojave to produce an undistorted and geolocated orthophoto. When two images of a common area are orthorectified it is then possible to overlay one on the other and readily spot differences.

3. Airborne Image & Satellite Image Correlation

In Figure 5 shows an airborne image orthorectified along with a corresponding satellite image also orthrectified. The airborne image was taken at an altitude of 3700 meters. The satellite image was taken from 450 km. Yet thanks to orthorectification both images align precisely to each other. Of course, overlay alignment is easier to show onscreen than on paper, yet even here on paper the changes are much easier to spot than they were in Figure 1. Not only is that important for human eye analysis, but any computer based changed detection algorithm would have to first do the same thing.

Figure 5. Airborne & Satellite Image Correlation

The building in the upper right has expanded and two other buildings erected to the left of that. Also the two foundations on the lower right have become completed buildings.

4. Multispectral Correlation

In addition to cross-platform alignment, orthorectification also helps in cross-sensor alignment. Figure 6 shows two images from the same platform, the one on the left a multispectral image, on the right a high resolution panchromatic image of the same location. Multi and hyperspectral imagery is useful for the radiometric information, to distinguish active vehicles from inactive for example. But such imagery may not have sufficient resolution to determine what exactly a hot object is. The image on the right shows clearly that the light dots are airplanes.

Now while it might be expected that two images from a common sensor would have perfect alignment, such is not the case—at least not with arrays as large as those used in the

QuickBird satellite from which these images were taken. So orthorectification again is necessary to achieve precise alignment.

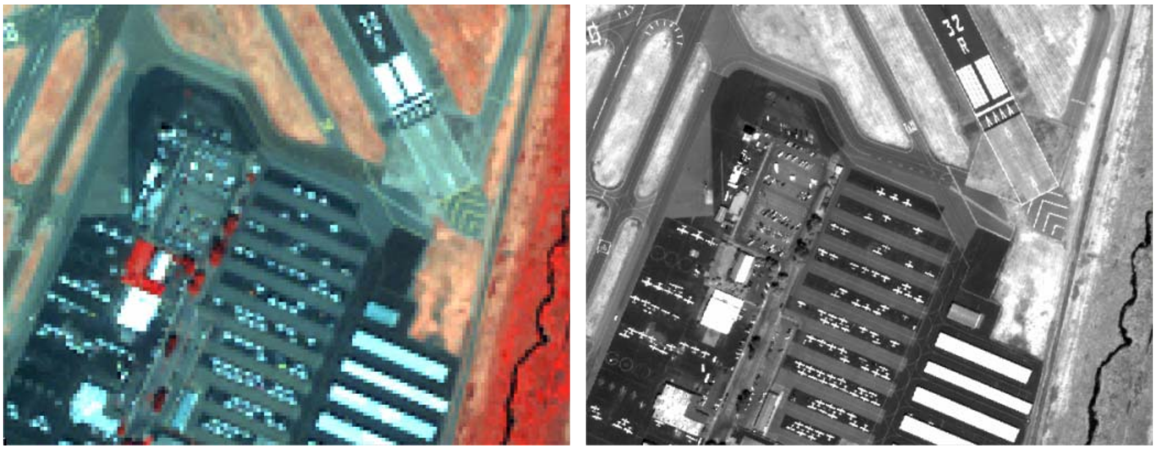

Figure 6. Multispectral & Panchromatic Correlation

5. SAR Correlation

What is done with optical imagery can also be applied to SAR imagery as shown in Figure 7. SAR has the advantage of being able to see in the dark and through clouds. However, it can be difficult to interpret as the image on the left shows. But when orthorectified and overlaid on an archived EO image the interpretation is much easier. By combining the two images the following can be deduced:

The row of white objects in the lower left is a row of planes, probably fighter planes.

The two rows of fighter planes above that in the EO image have been removed.

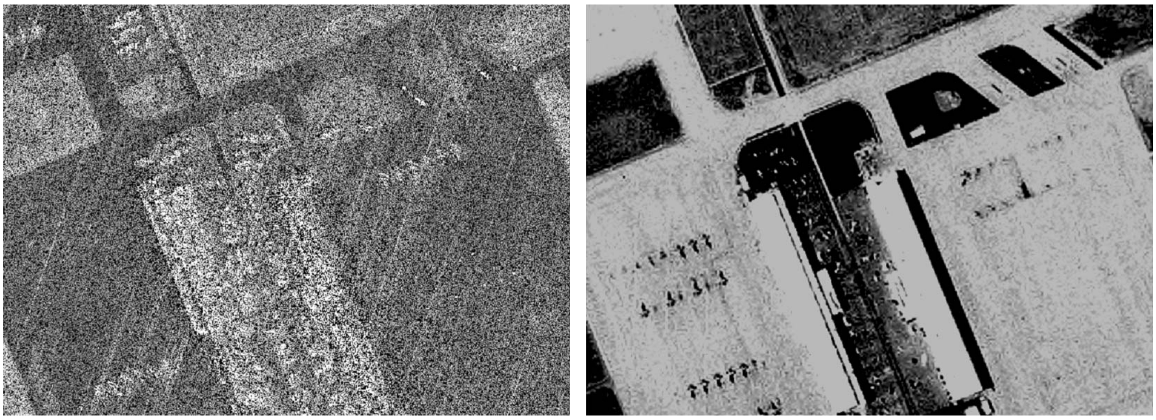

Figure 7. Correlation of SAR Image With Aerial Orthophoto

6. Side-Oblique Correlation

The most ambitious use of orthorectification, though, is in the case of side-oblique imagery. Figure 8 shows an image[1] taken at a side-oblique angle of approximately 62° along with a corresponding USGS orthophoto. We wish to compare the two and look for changes. But without orthorectification this is a mentally intensive task to say the least. In fact, it is not immediately obvious that the two images even cover the same area.

[1] Taken with BAE 9K x 9K EO framing camera.

Figure 8. Side-Oblique and Archive Orthophoto

Careful inspection might uncover the X-shaped apartment complex common to both images. (See Figure 9.) Of course, such nice landmarks cannot be assumed to always be present. But even focusing on the detailed area shown, a non-trivial amount of mental effort is required to identify common objects.

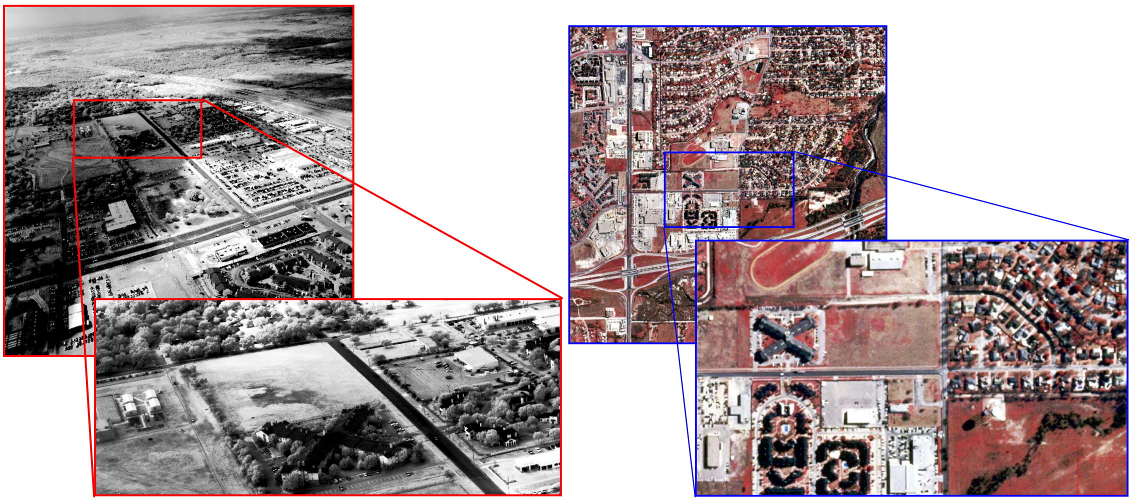

Figure 9. Detail Of X-Shaped Apartment Complex

At best, one might observe that the four trailers on the left of Figure 10 are new, but that only after mentally rotating and warping it.

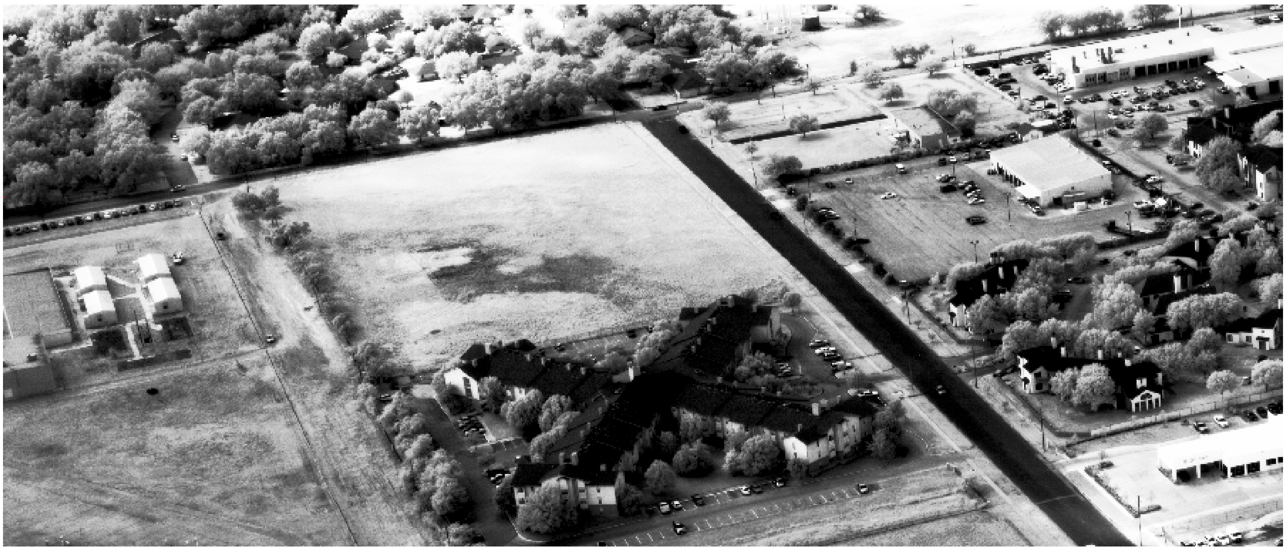

Figure 10. Side-Oblique Sub-Image Enlarged

Figure 11. Archive Orthophoto Sub-Image Enlarged

If, however, the side-oblique sub-image is orthorectified, then the trailers and several other changes jump right out. (Again, this is even more evident when overlaying the two on a computer screen, but demonstrating that is beyond the limits of paper media.)

Four trailers have replaced one trailer (top, left of center).

Trees have grown (residential area on right and elsewhere).

Building on the bottom left has been torn down and replaced.

Building in the low center has a slanted roof.

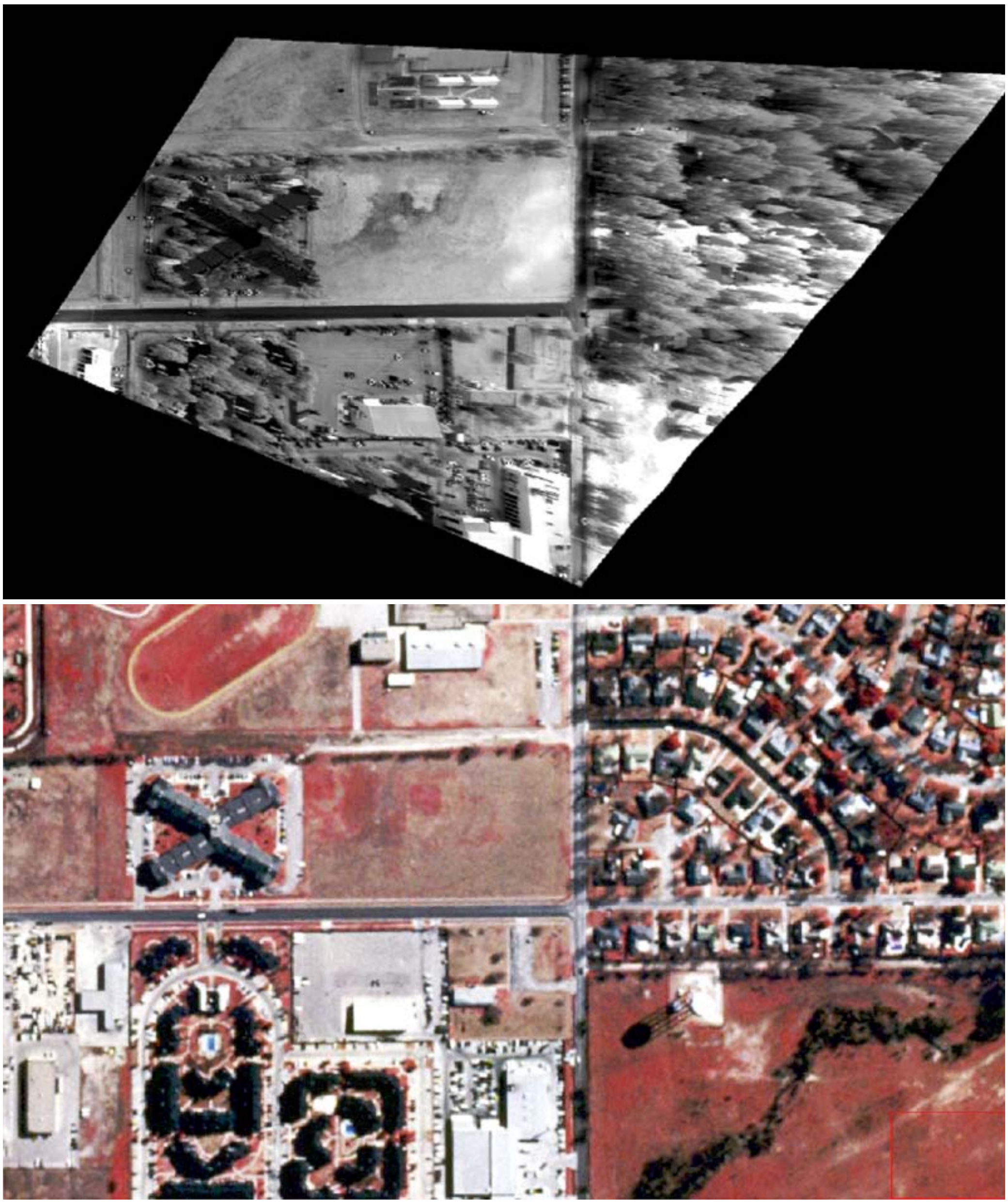

Figure 12. Side-Oblique Sub-Image, Orthorectified & Compared With Archive Orthophoto

Actually, the slanted roof is not a change, but it is something that becomes apparent only in the side-oblique image.

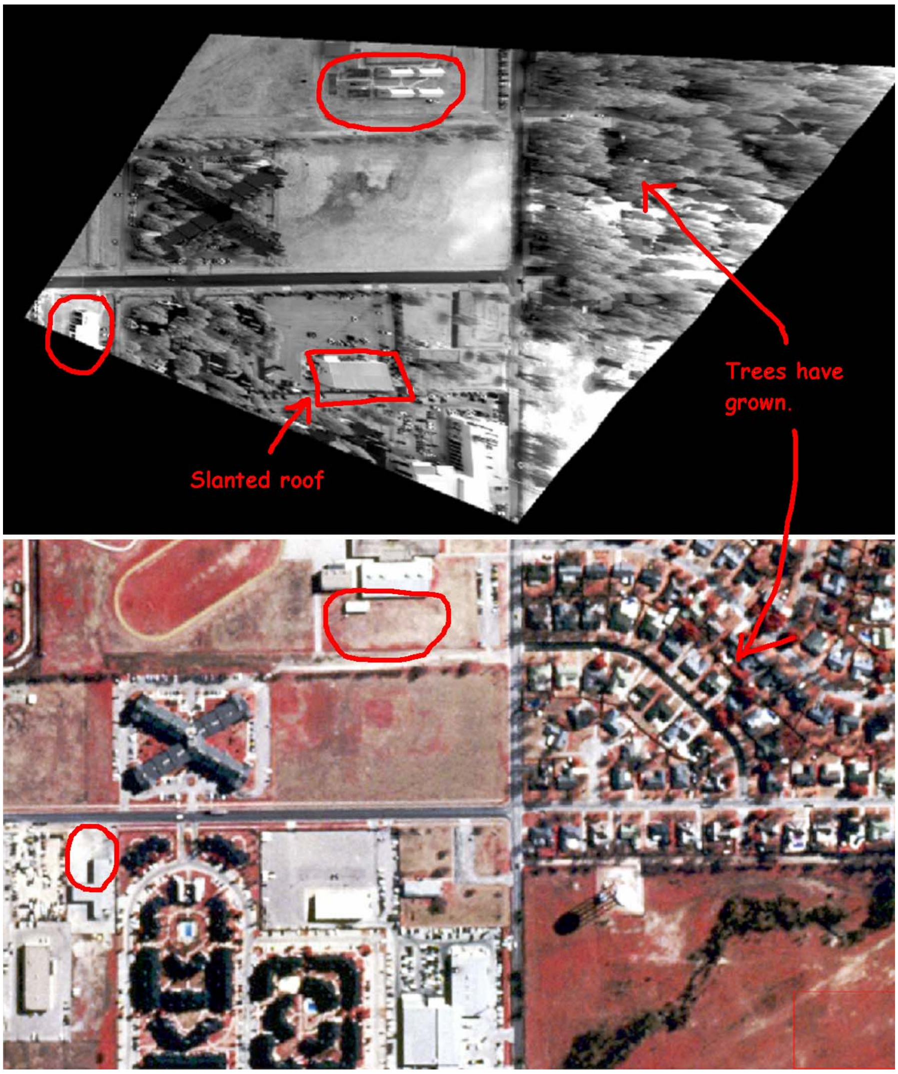

Figure 13. Orthorectified Comparison, Annotated

7. Conclusions

In conclusion there is significant value in cross-platform image fusion. Change detection is vastly simplified, and SAR and multispectral imagery can be more easily and accurately interpreted. The perspective and terrain distortion that presents a significant obstacle both to human and machine correlation can be overcome by orthorectification which provides a common perspective and thus both reduces mental labor and provides a practical first step for follow-on correlation algorithms.

Credits

Photos:

Satellite imagery courtesy DigitalGlobe.

Figure 5 airborne imagery courtesy Kodak.

Archive orthophotos courtesy USGS.

Side-oblique imagery courtesy BAE.