An Evaluation of Photographic Resolution at Various Acquisition Altitudes

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Background

During field exercises conducted in Marion county, Kansas on November 9, 2014, numerous images were acquired of a pasture approximately 4 miles north of the town of Lehigh. This particular pasture was of interest because the Santa Fe Trail passed through it. This is also the likely site of a roadhouse called Cottonwood Hole Ranche built in 1861 by Claude Francis Lalogue (AKA French Frank) and Peter Martin (www.santafetrailresearch.com). No obvious signs of the roadhouse were seen, but the ruts, or more precisely, swales left by the thousands of oxen and pack animals that plodded the trail, are still clearly visible today.

Image Acquisition

Three separate platforms were used in these exercises: a single engine fixed wing Cessna 188A airplane, a Rokkakku type kite, and an unmanned quad-rotor “drone”. The first images of the day were acquired from the airplane at approximately 0845 CDT. The low sun angle greatly accentuated the swales which cross the pasture in a NE to SW direction nearly perpendicular to the solar azimuth. The airplane images were made at an altitude of 3000 feet (~900m) above ground level (AGL) and 2000 feet (~600m) AGL. Additional images were made later in the afternoon at approximately 1515 CDT from an altitude of 1000 feet (~300m) AGL. Images from the kite were made in the early afternoon around 1330 CDT from an altitude of approximately 500 feet (~150m). Numerous oblique and nadir images were made from the kite, but only the nadir images were used for this report. After the kite images were acquired, a small unmanned drone was tested. While the images were interesting, (fig. 1) they were of limited usefulness for this report due to the lens distortion, and the fact that the GoPro camera which it used was quite different than the Nikon AW120 and AW110 cameras used on the airplane and kite.

Figure 1 GoPro image taken from small drone.

Image Processing

Three kite images were selected for evaluation and comparison along with one airplane image from each of the three altitudes flown. The three kite images were stitched together into one panorama using PTGui software. Attempts to stitch the airplane images proved unsatisfactory as there was insufficient overlap in the images to provide adequate control points. Fortunately, the airplane images had a large enough field of view that even at the lowest altitude, stitching multiple images was not necessary. After selecting the images for evaluation, each image was oriented with north to the top.

Interpretation/Evaluation

A composite image of the three kite aerial photographs is shown in figure 2. Resolution of this image was determined by zooming in on the 1m x 4m ground marker and counting pixels. The resolution of this image was found to be 28 pixels/m or about 3.6 cm/pixel. The road was found to be about 92 pixels across giving it a width of 3.3 m. A cow seen at the bottom of the image was about 60 pixels long. This may be used as an additional data point, but is subject to high uncertainty. While most of the cows were of similar size, their apparent length when viewed from above can change significantly as the cow moves her head up and down, plus the objects near the edges of the image are subject to more parallax error. Nonetheless, the size of the cows might be useful as a second order check on our data in the absence of anything better.

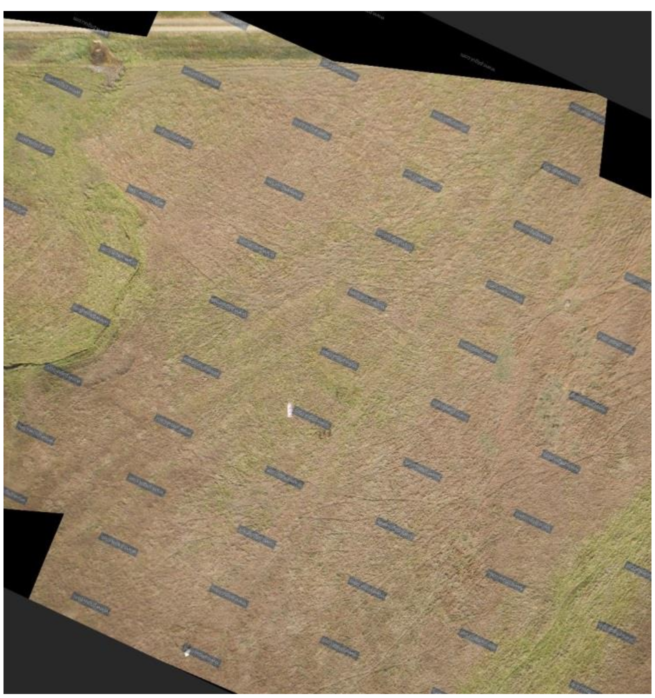

Figure 2 KAP of probable site of French Frank's roadhouse on the Santa Fe trail (altitude ~500 ft.) Several swales trending from NE to SW can be seen on either side of the marker. North is to the top of the image.

A series of aerial photographs taken from the airplane show the effect of increasing altitude and varying sun angle. Figure 3 was taken from an altitude of 1000 feet (300 m) at 1518 CDT. The high sun angle make the swales difficult to see. With no ground marker available, the resolution was estimated from the width of the road and double checked by measuring the length of a cow. The road in this image was found to be 36 pixels wide making the resolution about 11 pixels per meter or about 9 cm per pixel. The length of a cow in figure 3 was inconsistent with the size measured in figure 2, so this method was not pursued any further, as the road provided a more reliable means of correlating the image resolutions. The aerial view in figure 3 was centered about 100 m west of the kite image in figure 2. A culvert that runs under the road appears in both images, in the upper left in figure 2 and in the upper right of figure 3. This culvert appeared in each image that was analyzed, and proved to be very helpful in assessing the relative resolutions of the images.

Figure 3 Aerial photo of the study area taken from the airplane at an altitude of 1000 ft. This image is centered about 100m west of figure 2. Note the culvert in the road in the upper right of this image can be seen in the upper left of figure 2.

Figures 4 and 5 show the images taken from the airplane at 2000 feet and 3000 feet respectively. The low sun angle of these images created long shadows that accentuated the texture of the pasture and made the swales much more obvious compared to images taken in the afternoon. The raw image in figure 5 had a larger field of view than figure 4; however, these images were cropped and resized so that they appear almost identical. The quality of the image in figure 5 is noticeably inferior to figure 4. When zoomed in to the pixel level, the road in figure 4 was found to be 18 pixels across giving a resolution of 5.5 pixels/m or about 18 cm/pixel. In figure 5, the road was 13 pixels across giving a resolution of about 4 pixels/m or about 25 cm/pixel.

Figure 4 Altitude 2000 feet

Figure 5 Altitude 3000 feet

Aerial photograph taken from the airplane at altitudes of 2000 feet and 3000 feet. Note the swales are accentuated by the low sun angle. North is to the bottom of this image, the culvert is seen in the bottom center of image.

As previously noted, a culvert crossing under the road to the north just west of the swales can be seen in each image. One can get a sense of the resolution of each of the images by cropping and expanding that section of the image for comparison. As seen from the kite (figure 6), one can clearly discern a fence line parallel to the road and detect what appears to be a pile of rocky material south of the fence. The fence line is also easily discernable in the airplane image taken from 1000 feet (figure 7); however, the different texture of the rocky material is more subdued and one would not likely be able to ascertain that the bottom of the ravine is filled with rocks.

Figure 6 Close up view of the culvert. Note fence line indicated by the vegetation differences and the rocky material on the south side of the fence. North is to the top.

Figure 7 Culvert from 1000 feet. The fence line is clearly visible, but the different texture of rocky material is not as obvious.

At higher altitudes, the details become more obscure as expected. Figure 8 shows the culvert from 2000 feet and figure 9 is the same area imaged from an altitude of 3000 feet.

Figure 8 Culvert from 2000 foot altitude image.

Figure 9 Culvert from 3000 foot altitude image.

The fence line is visible in figure 8, but not as obvious as in the previous figures. In figure 9, only the faintest vestige of the fence line can be discerned. It would be difficult to identify this dark spot on the image in figure 9 as a culvert unless one could correlate the object to higher resolution images. Objects on the image cannot be identified by a single pixel. Most objects require 4 to 9 pixels to be identified (Aber 2010). Based on pixel counts of known objects, the pixel size of images taken at 3000 feet were estimated to be about 25 cm. Therefore, it would be difficult to identify any object that is less than about 1 to 2 meters in size on this image. The culvert in this picture is near the lower limit based on this criterion. However, with some experience and logic, one could make an educated guess as to the identity of the fuzzy dark spot by considering the context of the object to the rest of the image. This point is illustrated in figure 10 which was taken from the same image as figure 9, but is cropped differently and covers a larger area to the north. In figure 10, one can clearly see that the dark spot near the road coincides with the drainage channel that runs across the road from the north at that point. A reasonable assumption would be that this must be a drainage culvert.

Figure 10 Wider view of the culvert showing the drainage channel.

Conclusion/Lessons learned

The altitudes from which aerial photographs are taken directly affect the resolution and field of view. No single platform can be considered optimal for all applications. Taken at lower altitudes, the drone and kite gave the highest resolution images in terms of pixels per meter; however the long swales that remain of the Santa Fe Trail were less obvious in some of those images due to the limited field of view. The swales in the higher altitude images were much easier to discern, in part because one's eyes are naturally drawn to long linear features. However, the greatest factor that made the swales easy to identify in these images was the low sun angle that existed at the time the 2000 and 3000 foot images were acquired. While resolution is crucial to the usability of images other factors such as sun angle and field of view are important as well. One drawback to the high altitude images is that as one climbs higher in the atmosphere, some of the light will be more diffuse resulting in the images having more subdued color and possessing a washed out appearance. This is clearly illustrated by comparing the contrast of figures 6, 7, and 8. Post processing the contrast of the image could alleviate this problem to some extent.

One way to get clear, high resolution, large field of view images, is to take numerous pictures at a low altitude, stitch them together and then reduce the image to the desired area. Attempts at stitching together side by side aerial images in this study proved unsuccessful due to insufficient overlap and difficulty in identifying good ground control points and to the low contrast of the target area. This could be corrected in future studies by careful flight planning and the inclusion of multiple artificial ground control points (GCP).

Logistical issues during this exercise made it impractical to deploy the ground reference marker or install GCPs prior to the airplane overflight. Determining the spatial resolution was complicated by the lack of objects of known dimensions for reference. However, the ground reference marker was available for the kite images. Other objects (most notably the road) were correlated between the kite photographs and the airplane images. This made it possible to determine a reasonable estimate of the pixel size for each of the airplane acquired images. The estimated resolution correlated well with subjective analysis of minimum identifiable object size of the images.

References:

http://www.santafetrailresearch.com/main-route/cottonwood-hole.html accessed November 2014

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