Preserving Dinosaur Tracks on Dinosaur Ridge, Morrison, Colorado

By Harold C. Schuch

To what extent can terrestrial photogrammetry be used for displays and/or engineering purposes? What is the state-of-the-art of the technology? What were the difficulties encountered, and how were they circumvented? These are the questions we asked as we set out to determine how best to photograph and preserve the dinosaur tracks on Dinosaur Ridge in Morrison, Colorado.

The "Friends of Dinosaur Ridge" group that manages the site for the town of Morrison, Colorado, was interested in finding a way to measure site deterioration due to climate, and the reduction of the number of footprints due to theft. Figure 1 shows holes in the surface (shored up with metal strips held by rebar) where important footprints have already been removed by thieves. In addition, the group is considering the installation of a roof that covers the site so that tracks can be better protected from the elements. Winds at the site can exceed 160 Km/hr., and snowfalls can exceed 2 m. This means that the roof has to be well engineered.

Significant aspects of the project included:

- A comprehensive approach, as in the case of conventional aerial projects.
- A stepwise block-building approach that included highly convergent photography, even to the point of using opposite directions.
- The photos used large object angles (due to lack of perpendicularity between lens axis and object plane).
- Widely varying object distances, ranging from less than three meters to more than 50 meters.

This project was completed successfully in all respects (content, usability, and accuracy). Keep in mind that product aesthetics were not the top priority.

The size of the area containing the dinosaur tracks on Dinosaur Ridge is about 33 m wide, 29 m deep (slope distance), and has a change in elevation of 17 m. A paved road crosses in front of the site (just below the photograph in Figure 1 – not shown). The track surface is firm, but covered in a fine sandy dust that makes walking over it very difficult, especially when there is moisture in the air.

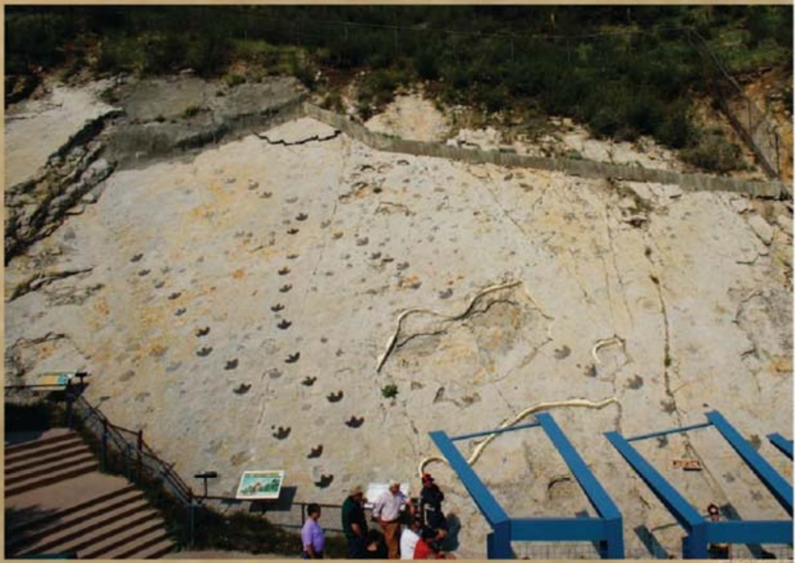

Figure 1. A general view of the site. It consists of a sloped surface (inclined about 36° from the horizon) that contains dinosaur footprints imbedded in sandstone, a layer that is about 150 million years old. Over a dozen different animals left tracks there. Some of the larger tracks appear black because they were rubbed in with charcoal for the tourists.

The camera used was placed on a tall tripod or lofted higher with the help of a 6 m telescopic pole (as in Figure 1). The 14.2 Mpixel sensor has a format of 23.4 mm x 15.6 mm (4,592 x 3,056 pixels) for the selected 3:2 aspect ratio. This makes the image plane resolution about 5.1 µm/pixel. Images were collected in JPEG format, leaving them at 23.8 Mbytes each. The corresponding GSD (ground spacing distance or pixel footprint) at 50 m therefore was about 16 mm.

Prior to the photo shoot, the f-stop was set to 8, and the lens was focused to infinity (actual through-the-lens focusing, not the end of lens travel). Everything in the camera was frozen, including autofocus, auto-exposure, aperture, blur detection, face detection, and smile detection, essentially converting the camera into something like a pinhole camera. In other words, everything was done to make sure that all subsequent photography (calibration and site shots) used the same lens portion and parameters. The focusing ring on the camera was clamped with the help of a tight plastic ring against the lens housing so that it didn't move (see Figure 2). The camera was then calibrated with the help of 16 panels holding five target points each (a calibration field of 80 target points) which were placed on the ground in a tight formation (filling the lens field-of-view). Twelve photos were then taken of the target panels (three camera positions from four directions).

During the photo shoot, the only setting that was activated manually was the exposure time, which most of the time was left at 1/600 second. As a result, the only problem introduced by this inflexibility was that images were sometimes too dark, and sometimes too bright (something that can be adjusted with software without affecting accuracy). Part of the reason was that the sandstone was very light in color and had the tendency of washing out detail in the images. In addition, any atmospheric moisture created more marked color differences.

Figure 2 shows one of the ground control targets (blue strip #7). These targets were built so that the center of the target (white circle) was exactly above the small yellow arrow at the bottom of the target, and 0.20 feet above the ground. The vertical shift (+0.20') in the control elevation was taken into account during computations.

The Technical Approach to the Project Was Comprehensive and Consisted of Four Phases.

Phase 1 — Establishment of the Ground Control

Ground Control was completed by planting six nails into the edge of the pavement of the access road (three points each side of the road), measuring the distances between them with a steel surveyors' tape and then using an automatic level and rod to obtain elevation differences for each nail. One easily recoverable point of the site received the arbitrary 6,000 foot elevation (1,828.80 m). Then, one target (like #7 below) was placed on each nail (the small yellow triangle at the bottom of the target was placed on the nail head). This resulted in a control field that was about 33 meters long and eight meters wide, and X, Y and Z coordinates were calculated for the six points, resulting in a scaled and leveled reference field.

Phase 2 — Creating Basic Controlled Block

A total of eight photos (four uphill and four downhill) were collected. Enough of the track site was also covered to be able to perform a good control transfer upslope. This phase resulted in a solid horizontal

Figure 2. The camera in front of its case. Note the yellow lens clamp. Also note the small mirror that allows shutter actuation from below via infrared remote. Behind the camera is one of the 16 white calibration panels.

continued on page 1190

continued from page 1189

and vertical control space for the project, and the resulting adjusted photogrammetric block (for Phase 2) having an overall RMS of 0.01 pixels, and a largest ground control residual of 0.9 cm. Since this block included pass points up the side of the hill (utilizing natural features), block residuals were somewhat larger than expected. (Figure 3)

Phase 3 – Transferring Control up the Slope

Transferring control up the slope consisted of taking shots upslope from various points along the road (from the road straight up the hill), essentially to transfer and extend the control field along the road all across the track site (See Figure 4). Phase 3 photography lens axes were approximately parallel to each other and approximately horizontal.

Figure 3. Collecting the control space photography. This consisted of taking photographs up and down the road (this Figure shows two of the shots) to create a controlled photogrammetric space along the road.

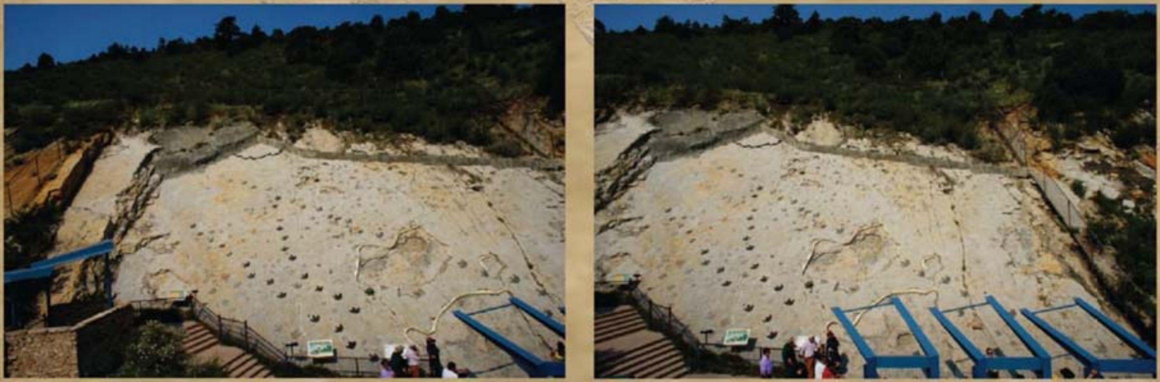

Figure 4. Transferring the control space up the slope.

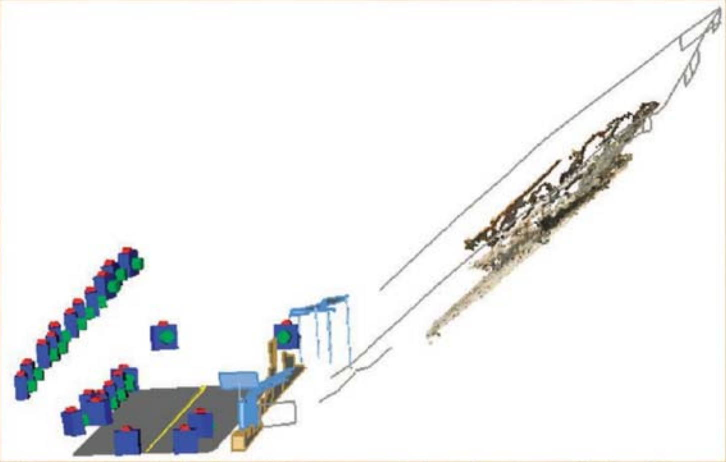

Figure 5. The distribution of the camera stations for phases 1, 2 and 3. Note that some of the shots were highly convergent, or even in opposite directions (up and down the road). The grey line to the right represents the top of the fence around the site.

Phase 4 - Collecting Detailed Photography

Collecting detailed photography consisted of taking quite a few detail photos closer to the track surface and gradually incorporating them into the photogrammetric block. Given that limited computing power was used for this, it is estimated that about a hundred block adjustments were executed (See Figure 6).

Figure 6. Taking detailed photography at various scales and overlaps.

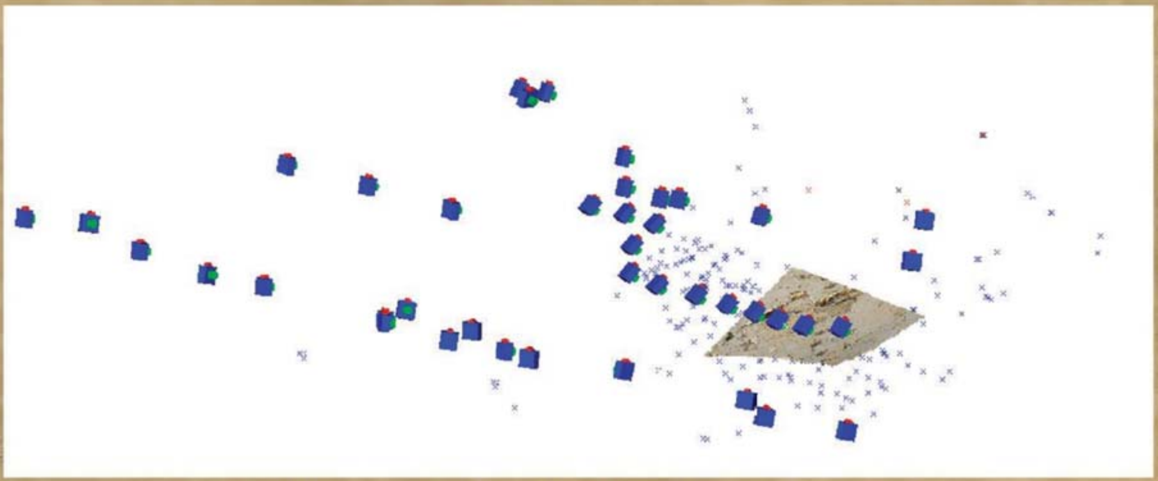

Figure 7. Camera station distribution for parts of Phases 1, 2 and especially 3. The blue crosses represent some of the pass points used for the close-up photos.

Blocks were adjusted progressively, so that block 1 covered Phase 1, block 2 combined Phases 1 and 2, and block 3 included the rest of the photography progressively (all Phases). In point cloud space for block 3, the largest adjustment residual was 2.81 pixels for the worst point, and block RMS error was 0.61 pixels. Within the ground control field, the residuals were 45 mm (X, Y and Z combined) for the worst pass point, and a block RMS error of less than 1 cm. This accuracy satisfies the nature of the project, which sought to be within 5 to 10 cm.

One reason that there is opportunity to improve adjustment results is the fact that the pass points used were unmarked ground features. Since this approach used a mix of general site photography (longer object distances), detailed photos (shorter object distances), and convergent shots in between, detail has the tendency to look different in each image. A better selection of pass points and locations of photos can improve the results.

3D Products

One byproduct of the creation of a draped point cloud was the ability to visualize and perform measurements on objects in 3D space. Figure 8 shows a stereogram of the footprints of a dinosaur. The large footprint corresponds to the right rear foot, and the smaller indentation above it would have been created by the animal resting one of its right hand knuckles. This stereogram covers an area of about 1 square meter.

The animal that left the footprints in Figure 8 is depicted in Figure 9. This dinosaur is a "duck-billed" Ornithpod (an animal about 5m tall and 15m long).

continued on page 1192

continued from page 1191

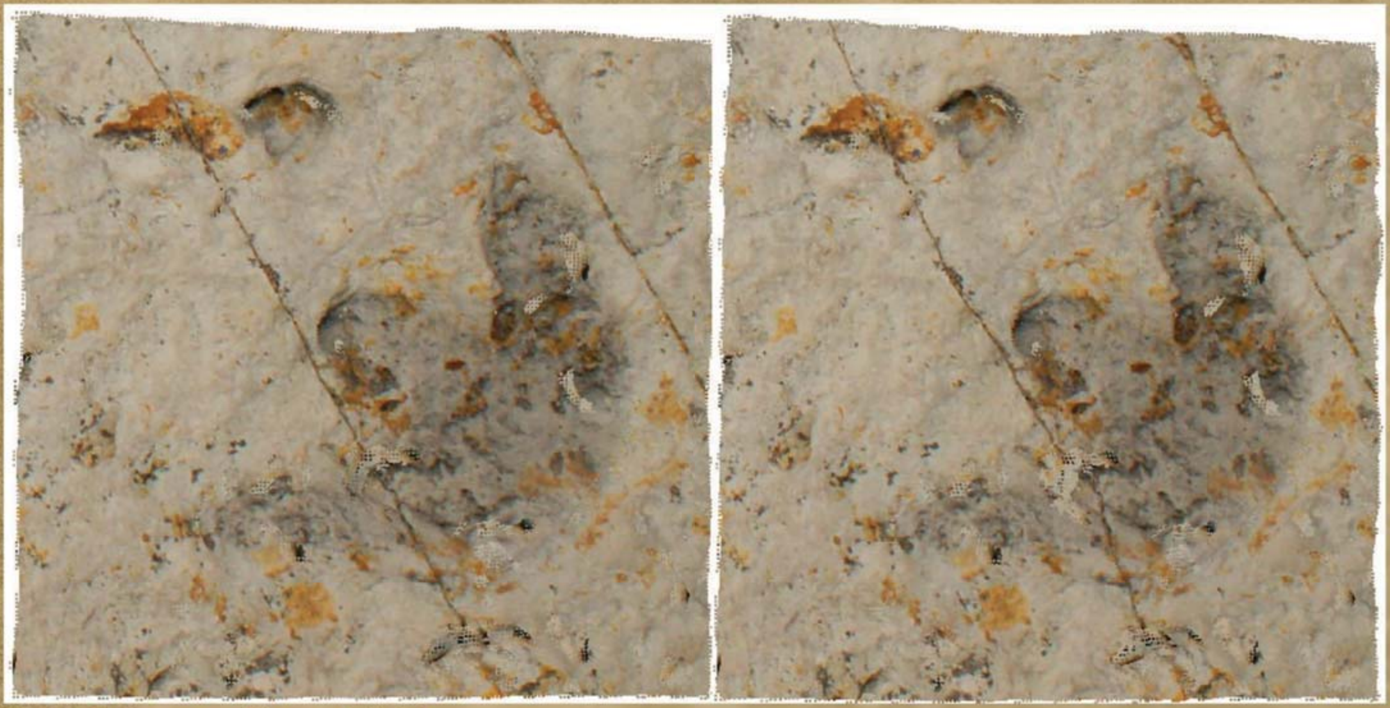

Figure 8. A stereogram of dinosaur footprints.

Deliverables

Two deliverable products were prepared. One was an ortho map of the track site, prepared so that the inclined track site became a scalable image (relief distortions were removed as if the incline were level). The second was an engineering drawing that provided enough scaled contour information for an engineering design of the planned roof. Both products were delivered as shown below (see Figures 11 and 12).

This map satisfies the needs of Dinosaur Ridge. However, it could benefit from the application of better photography brightness and gamma adjustments, plus radiometric corrections. Even the smallest cloud or the smallest change in ambient humidity could change photo characteristics considerably. In addition, many image areas were obscured by the structure in front of the site, fences and signs, forcing the collection of a denser patchwork of orthoimages along the bottom edge.

Figure 9. An Ornithopod, one of the many animals that transited the site long ago.

Figure 10. An unexplained indentation in the track site, also showing lines used to measure its depth (10.8 cm). Some think that this indentation is a "wallow" for a large animal.

The principal technical concern was the fact that the surfaces in the photos were not perpendicular to the lens axis. As a matter of fact, in some cases they were as much as 60° from being perpendicular (as in Figure 5). This raised questions about the software's ability to create draped point clouds at such a shallow angle. However, the software proved to be rather resilient when it came to creating dense point clouds, triangulation meshes, and draping photographic detail over them under those conditions.

Figure 11. A sample image of the orthomap that was prepared in an A0-format, resulting in a map scale of 1" = 2' (1:24). The image quality of this map (which was printed, coated, and mounted) is as shown in Figure 8 (stereogram).

Engineering Drawings

The following figures relate to the engineering product delivered.

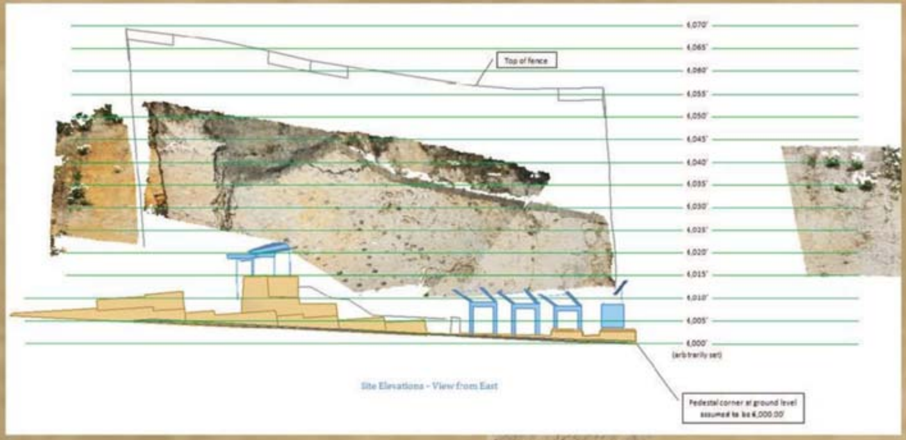

Figure 12. A reduced image of an A3 map that was delivered and that provides an orthometric (not perspective) view from East of the road, the structures at the front of the site showing contour lines (green) in profile overlaid to a general image.

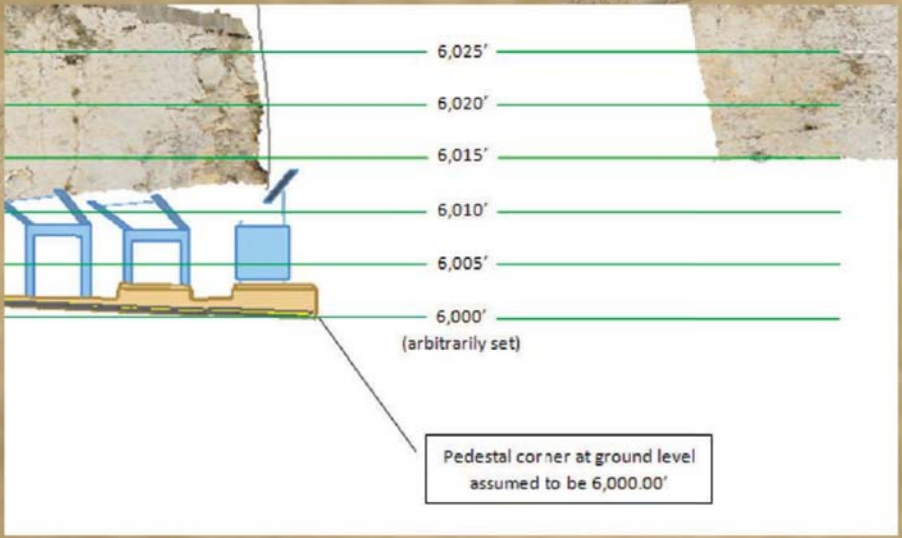

Figure 13. A detail of the image in Figure 12. Note that the elevation was assumed to be 6,000.00 feet for one of the physical points on the site.

continued on page 1194

continued from page 1193

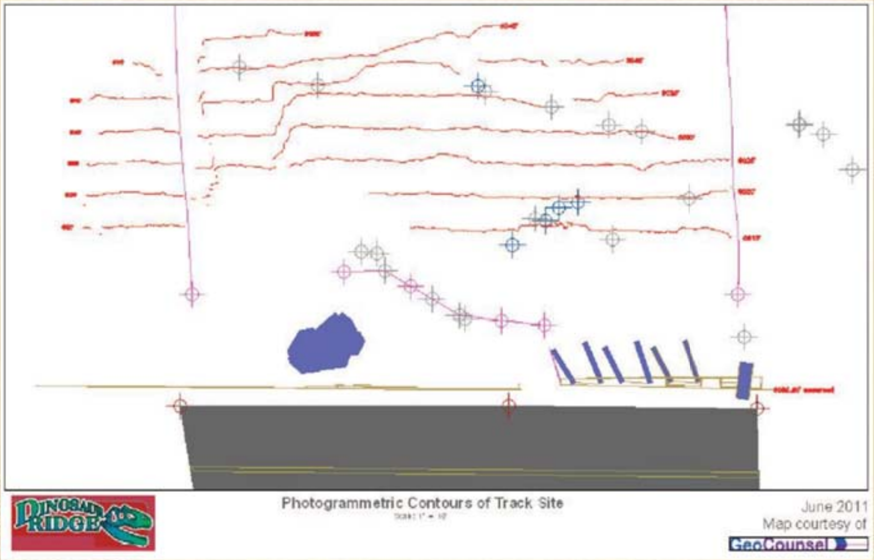

Figure 14. A reduced version of the A3-sized scaled plan (AutoCAD layout) of the data in Figure 12, which was also delivered.

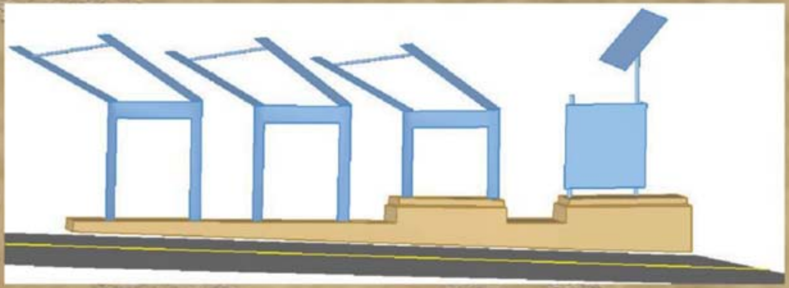

Figure 15. Some of the structural detail collected from the site. Note that this includes filled shapes and tubular elements. To the left of the figure are artistic rails, and to the right is a sign with a solar panel on top. All are imbedded in a concrete pedestal.

Conclusions

The results of this project indicate that terrestrial photogrammetry can be as important a tool for professionals as aerial methods have proven to be. The biggest credibility hurdles are two: (1) aerial photogrammetry is still too misunderstood to have achieved its real credibility potential in the private sector, and (2) the use of small-scale tools (as above) would raise eyebrows even further. However, the application of solid survey practices, the use of a documented professional approach, and careful consideration of accuracies, precisions, error propagation and analysis and testing can result in highly professional products that engineers can rely on.

The ability to calibrate the camera (complete interior orientation, including focal length) as frequently as necessary, and the application of technically unimpeachable block adjustments will result in a solidly controlled object space, whether aerial or terrestrial methods are used. As a matter of fact, nowadays it is much easier to calibrate a terrestrial camera than an aerial one.

Possible application areas include the creation of products that have eluded many for a long time. The first such application is in the area of as-builts, where pipes, conduits and machinery are located in space (when many users only have access to design documents). This is applicable to all the utilities, construction projects, highway inspection of over/under passes and tunnels, piping of utilities in residential sites (where developers may want to claim that they deliver the utilities and also provide as-builts together with the site documents). This technology is also applicable anytime when a site can be measured only remotely (due to heat, radiation, shock, etc.).

Acknowledgements

The camera used for this project was a Sony NEX-5 with a 16mm lens The photogrammetric software was a beta issue of the 64-bit PhotoModeler of EOS Systems. The computer used was a 64-bit Lenovo 4GByte, 2.66 MHz, laptop. PhotoShop was used to create images with transparent background for the orthos. AutoCAD was used to create the scaled product and to produce the maps. Large plots were plotted, coated and mounted by FedEx-Kinko's. With more computing power, better color balancing could have been achieved. This project was completed with thanks to Friends of Dinosaur Ridge, Morrison, Colorado that gave access to the site. Thanks to Erin Fair, a Dinoridge volunteer and instructor, who drew the Ornithopod in Figure 9.

Author

Harold C. Schuch, PE, Certifed Photogrammetrist, Land Survey Intern
President
GeoCounsel, Inc.
31 Manzanita, Littleton, CO 80127
303-979-7773, www.geocounsel.com