Image accuracy checkpoint collection guide

by Ashley Sedorovich, Charles O'Hara, Spatial Information Solutions, and Karen Schuckman, Penn State University

This guide is designed to help you perform a rigorous accuracy assessment while minimising the effort to do so, by providing an overview of how to collect high-quality ground checkpoints. In this white paper you will find information on what a photogrammetry target is, what one looks like, what the dimensions are based on scale, where to place them, and how to locate ground checkpoints if a photogrammetry target is not available.

Photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting images or photographs. The process itself consists of project planning, image acquisition, image processing, image orientation from reference data, data compilation, and finally the presentation of an end product. Photogrammetry is a complex process, involving the management of systematic and random errors from a variety of sources. As in any complex process, some errors may be actual mistakes or blunders, which can be detected and corrected. However, any model representation of reality will never be "exact": there will always be some difference between the end product of any surveying or photogrammetric project and "the truth". Quantifying the error, accuracy, and uncertainty of georeferenced images is the primary function of Accuracy Analyst.

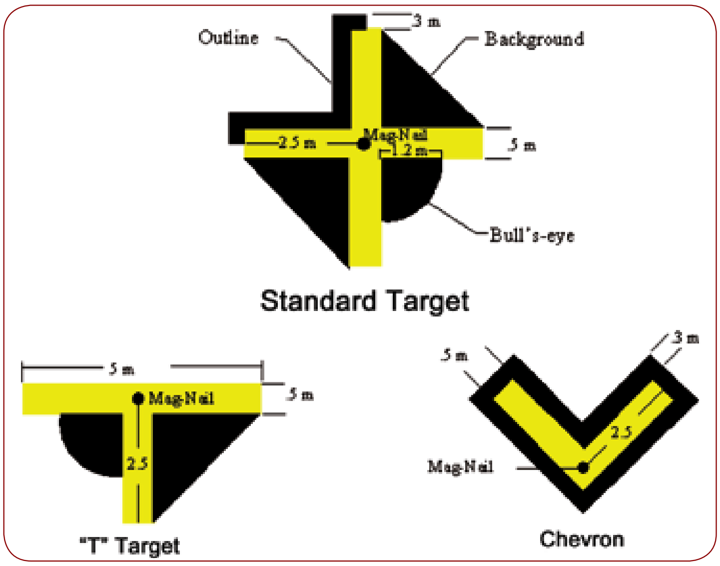

Fig. 1: Standard photogrammetry targets. Modified from the Survey Engineering Department at Ferris State University.

Ground control points and ground checkpoints

Before going into detail about photogrammetry targets, we begin by discussing the concept of ground control points versus ground checkpoints and how each is used in the photogrammetric process. Ground control points are identifiable points in real space (on the ground), whose locations are known, and they are used to verify positioning of map features, aerial images, or remotely sensed images. That is, they are used for initial georeferencing. Ground control points are often called GCPs in the literature, but some authors also use GCPs to refer to checkpoints, and therefore to be quite clear, this paper will not use the term. Ground checkpoints are used to perform an independent, quantitative assessment of image location error. Ground checkpoints are also commonly referred to as validation points, checkpoints, survey points, reference points etc.

Typically photogrammetry targets are used as ground control points; it is possible to use the photogrammetry targets as ground checkpoints if and only if they are not used in the initial georeferencing process. Photogrammetry targets to be used as checkpoints can be collected in one of two ways: i) the targets may be placed on the ground for use as survey checkpoint locations prior to an aerial imaging flight or ii) targets may be placed on the ground for use as control points and some may be omitted from the georeferencing process specifically to be used as checkpoint locations. Targets used as control for georeferencing should not be used also as checkpoint locations.

The terms "ground control point" and "ground checkpoint" will both be used throughout this document. Regardless of whether photogrammetry targets are being used as ground control points or ground checkpoints, the characteristics and criteria for collection discussed in this document will be the same. The difference between control points versus checkpoints is only in their use, not in their collection: control points are used in the initial georeferencing process and checkpoints are used only in the assessment check.

Photogrammetric targets

What is a photogrammetry target?

A photogrammetry target is something that can be easily identified on the aerial photos and that is preferably placed on the ground before taking aerial photos of a given area. These targets can assist in the processes of georeferencing, surveying, location analysis, assessment checks, and other mapping tasks. The use of targets increases the accuracy, precision, and efficiency of the photogrammetric process. Photogrammetry targets come in three levels: low-level, standard, and high-level. The target level required depends on the altitude of the airplane, focal length and sensor/camera system characteristics, and the resultant scale of photography designed for acquisition during the aerial photo flight.

What does a photogrammetry target look like?

Photogrammetry targets should be clear and easily identifiable on aerial photos. Most often targets are either painted onto hard surfaces at ground level, or a scheduled field paneling operation is conducted as close as possible to the anticipated flight. Targets should be a symmetrical shape, adequate size based on the scale, and outlined by a contrasting colour. Most targets are either white with a black background or yellow with a black background. They are typically in the shape of a crosshair, a "T", or a chevron and targets are highlighted with an outline, a bull's-eye target, or a complete background.

The one exception to the rule is that low-level targets are always shaped liked a crosshair while the highlighting is a complete square background. Figs. 1, 2 and 3 show examples of standard, low-level, and high-level aerial targets.

What are the dimensions of photogrammetry targets?

Photogrammetry targets are scale-dependent meaning they vary with the size of the scale being used.

See Table 1 for recommended target dimensions as a function of photo scale.

Where should survey points be placed?

Before placement of survey points begins, a sample design should be created. Creating a sample design will help minimise errors that can occur during the process. For all sample designs, 20 sample points are considered the minimum necessary, but for statistical rigor, more than 20

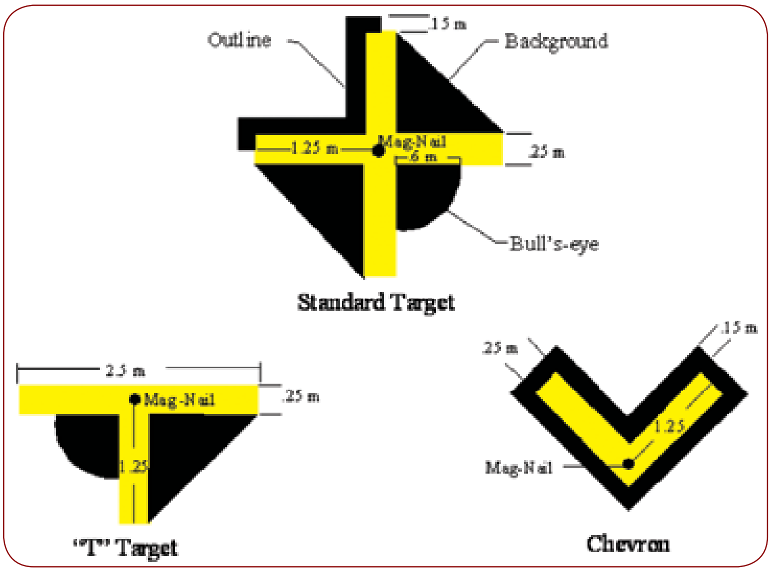

Fig. 2: High-level photogrammetry targets. Note that the dimensions are different, even though the general appearance is the same. Modified from the Survey Engineering Department at Ferris State University.

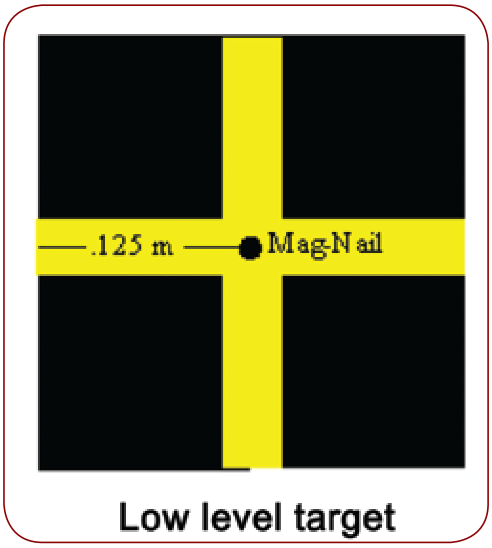

Fig. 3: Low-level photogrammetry targets. Modified from the Survey Engineering Department at Ferris State University.

Photo scale	Width of leg	Length of leg
1:1800	6 inches (150 mm)	3 feet (0,9 m)
1:2400	6 inches (150 mm)	3 feet (0,9 m)
1:3000	6 inches (150 mm)	4 feet (1,2 m)
1:3600	6 inches (150 mm)	4 feet (1,2 m)
1:4200	6 inches (150 mm)	5 feet (1,5 m)
1:4800	8 inches (200 mm)	6 feet (1,8 m)
1:6000	8 inches (200 mm)	6 feet (1,8 m)
1:8400	12 inches (300 mm)	7 feet (2,1 m)
1:9600	15 inches (375 mm)	8 feet (2,4 m)
1:12000	18 inches (400 mm)	10 feet (3,0 m)
1:19200	24 inches (600 mm)	15 feet (4,5 m)
1:24000	30 inches (750 mm)	20 feet (6,0 m)

Table 1. Target dimensions as a function of photo scale. (Modified from the New Jersey DOT Survey Manual.)

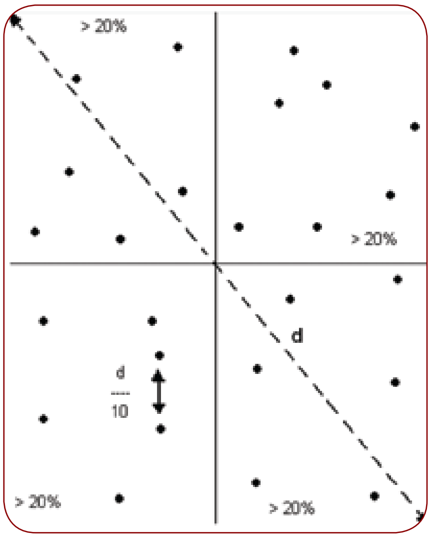

Fig. 4: Hypothetical distribution of sample points. (Modified from Congalton and Green, 2009.)

Fig. 6: Optimal checkpoint location 307. The survey checkpoint (green) and photo identified locations (red) are shown.

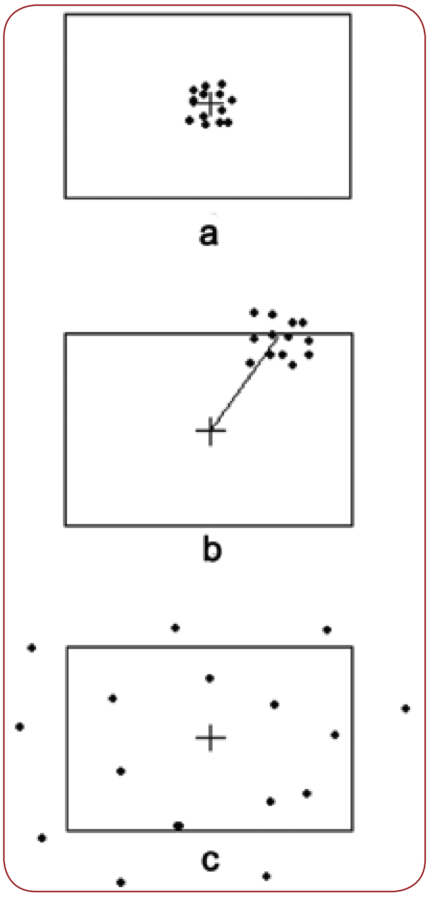

Fig. 5: Precision and accuracy.

Fig. 7: Optimal checkpoint location 311. The survey checkpoint (green) and photo identified locations (red) are shown.

sample points should be chosen. The optimal sample design is obtained by first deciding the number of survey points needed for the area. The second step is to divide the area of interest into four quadrants and to determine the number of survey points in each quadrant, making sure that no more than 20% of the survey points come from one quadrant. After deciding on the number of survey points per quadrant, the next step is to select optimal sample sites with all points spaced at an appropriate distance from each other (see Fig. 4).

The samples may be distributed more densely in the vicinity of important topographic features and more sparsely in the areas of little or no interest. Keeping this in mind, no two points should be closer than the diagonal of the area of interest divided by ten. Points should be located where shadows will not adversely affect the visibility of the panel.

Furthermore, they should only be located at ground level and not on the rooftops of buildings.

What if photogrammetric targets are not available?

If targets are unavailable and/or conducting an aerial survey using targets is not an option then it is possible to identify points on pre-existing aerial photos. This method is less accurate than using standard photogrammetric targets; however, it is used because it is less expensive. Nonetheless, utilising photogrammetric targets is the most accurate and precise method.

There are several factors that need to be considered when collecting quality ground checkpoints without using photogrammetric targets. First of all, the points must be well-defined and represent a specific feature. Secondly,

Fig. 8: Optimal checkpoint location 315. The survey checkpoint (green) and photo identified locations (red) are shown.

Fig. 9: Optimal checkpoint location 336. The survey checkpoint (green) and photo identified locations (red) are shown.

the points must be of a high degree of horizontal accuracy and precision (Fig. 5). *Precision* refers to the closeness with which repeated measurements made under similar conditions are grouped together. *Accuracy* refers to the closeness of the best estimated value obtained by the measurements to the "true" value for the quantity measured.

Fig. 5 illustrates the difference between accuracy and precision. In Fig. 5a, the points are grouped closely together and the measurement is said to be "precise". Fig. 5a is also accurate because the centre of the group coincides with the centre of the square.

In Fig. 5b, the grouping is still precise but not accurate because it is not centred on the middle of the square. The points in Fig. 5c do not exhibit close grouping or nearness to the centre. They are, therefore, neither accurate nor precise.

Finally, each point must be clearly identifiable on the spatial dataset being assessed as well as in the reference dataset. Right-angle intersections of roads, railroads, or other linear mapped features work well as reference points when using graphic maps and/or vector data. When using orthoimagery, these same right-angle intersections of linear features work well, but small isolated shrubs or brushes can also be used. Ideal features to use should be permanent, not subject to erosion, and easily identified on an image or map. When using maps or images with scales larger than 1:5000 additional features such as utility access covers and intersections of sidewalks, curbs, or gutters can also be used

Photo-identified points

What are some examples of photo-identified quality ground checkpoints?

Figs. 6, 7, 8 and 9 provide examples of optimal ground checkpoints if photogrammetric targets are not available. In each set of photos, the first two images represent the specific location and survey set-up at ground level. The last image represents the same location as above but from an aerial view rather than a ground view.

References

[1] P Bresnahan: *Geolocation Accuracy Evaluations of OrbView-3, EROS-A, and SPOT-5 Imagery.* National Geospatial-Intelligence Agency, 2006 http://calval.cr.usgs.gov/JACIE_files/JACIE06/Files/22Bresna.pdf.

[2] R Burtch: Undated. "Analytical Photogrammetry Instrumentation" www.pharmacy.ferris.edu/faculty/burtchr/sure440/notes/Corrections_to_photo_coordinates.htm>.

[3] RG Congalton, K Green: *Assessing the Accuracy of Remotely Sensed Data: Principles and Practices.* Boca Raton, Florida: CRC Press Taylor and Francis Group, , 183 pp, 2009.

[4] P H Dana: September 1994; revised May 2000. "Global Positioning System Overview." www.colorado.edu/geography/gcraft/notes/gps/gps.html>.

[5] GIS Development. Undated. "Global Positioning System- An Overview" www.gisdevelopment.net/technology/gps/techgp0038.htm>.

[6] R Knippers: "3. Reference surfaces for mapping." <http://kartoweb.itc.nl/geometrics/Reference%20surfaces/body.htm>.

[7] CG O'Hara, A Cheriyadat:: *Accuracy Analyst: A Horizontal Accuracy Assessment Tool.* Starkville, MS: SIS Internal Publication 2008. www.spatialis.com/pdf/Accuracy_Analyst_White_Paper_V1.1.pdf>.

[8] Riesterer: "*Introduction to Topographic Maps.*" 7 April 2008. Department of Geosciences at Idaho State University. <http://geology.isu.edu/geostac/Field_Exercise/topomaps/map_proj.htm>.

[9] CM Rose: *Error Theory as Applied to Mapping, Charting, and Geodesy*. DMA Tech. Rep. DMA TR 8400.1, 70 pp, 1991.

[10] State of New Jersey Department of Transportation. "Chapter 7: Photogrammetric Surveys", 2009. www.state.nj.us/transportation/eng/documents/survey/Chapter7.shtm>.

[11] The Aerospace Corporation. "GPS Primer." 29 April 2005. www.aero.org/education/primers/gps/index.html>.

[12] US Geological Survey. 2007. National Map Accuracy Standards. <http://rockyweb.cr.usgs.gov/nmpstds/nmas.html>.

[13] World Health Organisation. Guidelines for Data Collection in the Field using Global Positioning System (GPS) Technology 2003. www.who.int/entity/health_mapping/resources/GIS_guidelines_data_collection.pdf>.

Contact Charles O'Hara, Spatial Information Solutions, cgohara@spatialis.com