Practical Paper

Use of Aerial Photographs to Identify Suitable GPS Survey Stations

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ABSTRACT: Aerial photos can be valuable in planning a GPS survey. They can be used to find the most feasible sites for GPS stations and to inspect the usefulness of vertical control benchmarks for the survey. As an example, an area around Gauley Bridge in West Virginia was inspected using aerial photos. Suitable sites for GPS stations were identified and the most feasible benchmarks to occupy during the survey were selected.

The method seemed to be very useful as determined by field evaluations, and was easy to perform. Proper planning of a GPS survey is critical to making the survey run smoothly, but should take up a minimum amount of time in the total survey procedure. Aerial photos can potentially make the process of locating survey station sites much easier by helping to identify suitable station locations before field work.

INTRODUCTION

THE APPROACH USED FOR PLANNING a Global Positioning System (GPS) survey is substantially different from that of a conventional, terrestrial survey. While GPS stations do not have to be intervisible, they do require a relatively unobstructed view of the sky above 15 to 20 degrees elevation from the horizon. This "open sky" view is required to supply the maximum satellite tracking time, and to minimize GPS signal blockage of interference (King *et al.*, 1985). Another major concern is station accessibility. Because the location of stations is predicated on a clear view of the sky and not interstation visibility, the stations should be set so that they have a desireable view as well as easy access, preferably by vehicle.

Aerial photographs can help to expedite the planning and reconnaissance of a GPS survey. Photo strips or photo mosaics covering the area to be surveyed can be inspected to find possible station locations that have the properties discussed above. The approximate positions of benchmarks found on U.S. Geological Survey (USGS) and National Geodetic Survey (NGS) maps can also be checked on the photographs to see if they would be feasible to use in the survey for vertical control.

An experiment was needed to test the utility of aerial photographs for this purpose. Here, photographs, maps, and geodetic control data were evaluated to identify suitable station locations. Each of the proposed survey stations was visited and field checked to confirm its usefulness in a GPS survey.

The photographs also make it possible to identify unsuitable locations quickly and without much effort. Interpretation of photographs helps to identify obstructions and general terrain characteristics that may be a hindrance. Also, aerial photographs are often more current than maps, and supply new and different information, particularly in urban areas. This method could potentially save time and money that might be wasted by a field crew physically searching the area for station locations and suitable benchmarks.

METHODS

The project addressed the planning of a GPS survey in the upper Kanawha River valley in Fayette County, West Virginia. Specifically the Charlton Heights – Gauley Bridge – Brownsville area was evaluated (Gauley Bridge, West Virginia, USGS 7.5-minute quadrangle, Latitude = N 38°08′ Longitude = W 81° 12′).

The area is very rugged, and local surveys would be enhanced by GPS technology. The GPS survey would provide better network control which would help in cadastral surveys and mapping. Areas such as this will probably require control densification in the future, and GPS will most likely be used for this densification process as the system becomes fully operational.

In planning the survey, the location and relative position of new control points coordinated using GPS do not depend significantly on network shape, geometry, or station intervisibility. Rather, the optimal layout of the points is dictated by the intent of the survey and for later uses (FGCC, 1986). Thus, in the extremely rugged and steep mountains characteristic of the Gauley Bridge area, the points will need to be set in or near small towns, roads, and railroad grades.

Once the area has been studied using maps, photographs, and other information, and the typical station location has been identified, the station markers or monuments need to be chosen. Several factors need to be considered in selecting a marker type for a given terrain or structure. They include local conditions, transportation, materials available, equipment available for setting marks, and cost.

The markers utilized for most GPS surveys are corrosion-resistant metal disks that could be set in large masses of concrete such as bridge abutments or in rock outcrops. When abutments or rock are not available, a 1.43 cm (9/16 inch) stainless steel rod can be driven to refusal and capped with a brass or stainless steel disk with datum point (FGCC, 1986). The new marker sites should, whenever possible, be located on public property such as road rights-of-way, public building grounds, or school yards (FGCC, 1986).

In this experiment, the quality of the control needed in the Gauley Bridge area was for cadastral surveys, and mapping and network connections. The Federal Geodetic Control Commission (FGCC) Preliminary GPS Survey Specifications call for a survey of order 2, class I (20 parts per million or 1:50,000). This order and class of survey should utilize two first-order horizontal network control points and three vertical network control points.

Vertical control network benchmarks were located on the USGS 7.5-minute quadrangles for Gauley Bridge and Beckwith, West Virginia. The locations of benchmarks were evaluated as to their applicability to the survey/experiment. The maps were also ex-

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amined for information that might indicate whether the benchmarks and survey stations were suitable.

Relatively large-scale aerial photographs were obtained for the area. The position of each benchmark shown on the USGS quadrangles was transferred to the aerial photos. Each benchmark area was checked stereoscopically for proximity of trees, buildings, or hills that could obstruct a clear view of the sky. These areas were also evaluated for ease of access.

As a further evaluation, vertical angles from the horizon were calculated for each potential site obstruction. This was accomplished through parallax observations for height difference and horizontal distance measurements taken from the quad maps. These relevant facts about each benchmark site were recorded and evaluated. Three benchmarks in the area were selected based on the fact that they would be usable by GPS survey receivers and that they would give the best elevation control coverage for the area.

Next, the stereopairs were used to check for the best and most suitable locations to set new monuments. The type of site selected was one that was easily accessible, that had a clear view of the sky, and that was, if possible, on public land. Because GPS stations require an unobstructed horizon above about 15 degrees vertical angle, obstructions at the new station locations were analyzed with parallax measurements in the same manner as the benchmarks were checked. As an example, calculations for potential obstructions at station 8 (Figure 1) are presented.

The values needed for height difference calculations were obtained. The flying height above the ground was determined using the scale of the photographs (1:9600) and the focal length

Fig. 1. Aerial photograph of Charlton Heights. Station 8 is located at A.

of the camera (0.1524 m). The scale of the photographs was calculated by comparison of well defined points on the photographs and on the quadrangle maps. The scale is a point scale valid along the river or other areas with the same elevation.

$$FH = 9600 \times 0.1524 \text{ m} = 1463 \text{ m}$$

The photograph base for the stereo pair was found to be 74.5 mm. At station 8 a building up the hill to the northeast looked high when preliminary photograph reconnaissance was performed with the photographs and was checked for horizon blockage. A parallax measurement for station 8 was taken and was found to be 13.75 mm. The parallax at the building was observed as 12.54 mm. This gives a difference in parallax for the two objects of 1.21 mm. Once this value was found the data was entered into the elevation difference equation (Moffitt and Bouchard, 1982):

$$dh = \frac{dp\,H}{dp + b}$$

$$dh = \frac{1.21 \text{ mm } (1463 \text{ m})}{1.21 \text{ mm} + 74.5 \text{ mm}}$$

$$dh = 23 \text{ m}$$

Then the horizontal distance between station 8 and the building was scaled from the 7.5-minute quad and was found to be 86 m. From this, the vertical angle to the building at station 8 could be calculated using the tangent function:

$$VA = \arctan (23 \text{ m} / 86 \text{ m})$$

$$VA = 15 \text{ degrees}$$

The same type of calculation was performed for buildings close to station 8, but none of these objects were higher than 13 degrees.

In summary, the building met the criteria for horizon blockage at a GPS survey station, as did all the other potential obstructions at station 8. Thus, station 8 would be acceptable for use in a GPS survey. Figure 2 shows a view of station 8 from the ground.

Many good sites were located using the photographs, but eight locations were found to be the most suitable for the survey. It was determined that they would give adequate coverage of the area with minimal signal interference: potential obstructions at these stations were calculated to be equal to or less than 14 degrees above the horizon.

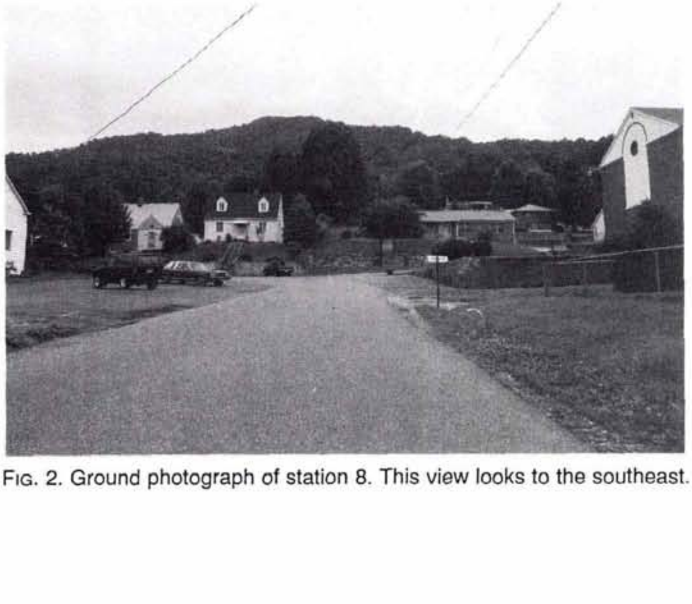

FIG. 2. Ground photograph of station 8. This view looks to the southeast.

A U.S. Coast and Geodetic Survey triangulation diagram for West Virginia was then inspected to find the horizontal control points (triangulation stations) that were close to the project area. Three stations were fairly close to the project: Station Elk was 10 km to the northeast, Station Grindstone was 17 km to the east, and Station Summerlee was 16 km to the south. Only two first-order horizontal stations were necessary for the accuracy required for this survey, so the two closest stations – Elk and Summerlee – were chosen.

Finally, the eight control points to be set and the three benchmarks that would be utilized for the survey were marked on the USGS quadrangle copies for use in the field and office. The eight selected stations, three benchmarks, and four rejected stations were visited to assess the accuracy of the horizon blockage determinations.

RESULTS

Analysis of the photographs, maps, and other information revealed that the three best benchmarks for use in this survey were benchmarks 685 (across from Brownsville), 672 (at K & M junction across from Gauley Bridge), and 666 (in Charlton Heights). These vertical control points would provide for accurate elevations in the network, and would be most usable by GPS survey equipment. Analysis of the photographs for new stations showed eight very probable locations for monuments.

To determine the quality of the stations, field checks were employed. All of the new stations were visited, and the true elevation angle to obstructions was measured with a inclinometer. The measured angles fell within ± 2 degrees of the calculated values. This difference can probably be attributed to scale difference due to relief.

All of the new control stations were found to be suitable for the job. Benchmark 672 was found to be the best vertical control point for GPS observations. Benchmarks 685 and 666 were also field checked, and were found to be suitable.

Other vertical control points that were excluded from the GPS survey were also visited. All of these sites were found unsuitable due to high obstructions as determined from aerial photograph analysis. In this example, aerial photographs successfully supplied information to exclude five vertical control sites, and field checks indicated that all of these choices were, in fact, good decisions.

CONCLUSIONS

The network geometry and relative location of survey stations is really of no value for most GPS surveys. Hence, the layout of points for a survey is determined solely by ease of access and minimum obstructions of the sky. In this example, the steep sides of river gorges and surrounding mountains in the Gauley Bridge area did cause some low angle sky obstruction problems, making this photographic method of locating observation sites especially valuable.

Planning of a GPS survey is usually more critical than for a regular terrestrial survey. This is especially true with the current limited constellation of 11 or 12 satellites, that provide a mutual observation window of only five to seven hours per day.

Aerial photos make the process of locating feasible control station sites and usable vertical control benchmarks much more rapid and prosperous than with maps. Photos provide a way to extract information about the heights of buildings and trees that is not given on standard maps. The procedure described here was easy to execute, and can be employed in other projects, as long as aerial photos can be found or procured.

Sites with the least amount of obstructions and easiest access can be quickly analyzed with aerial photos using stereoscopic viewing and parallax measurements, and then can be located and marked on a map of the area. Each prospective location would have to be field checked, and some sites excluded. Yet, the probability of locating suitable sites is increased.

This approach can potentially save a great deal of time and effort in GPS survey planning and reconnaissance. The current prices for GPS receivers make it costly to leave the equipment idle, redo a poorly executed survey, or take extra time to search out suitable monument locations (King *et al.*, 1985). Hence, this method along with other planning tools will potentially be useful in GPS surveys by possibly saving time in the reconnaissance step.

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