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Note About Resolution

Appendix D

Experiment Assessing Influence of Tilted Detail Pole

D.1 Purpose

The purpose of this appendix is to report the method and results of a set of simple experiments that were conducted to assess the influence of on DEM uncertainty of a surveyor inadvertently tilting a detail pole during a topographic survey.

D.2 Background

Whereas historically the limiting factor controlling the acquisition time of individual topographic survey points with GPS or total station was the technology, now rtk-GPS and auto-tracking total stations can acquire accurate fixes in a fraction of a second. Thus, now the time it takes the operator to physically move between one point and the next and accurately position the pole approximately plumb is the primary control on acquisition time (at best 2 to 3 seconds). While an accurate solution for the GPS antennae or total station prism centre may be easy to acquire rapidly, the topographic point (determined by assuming the pole is vertical and subtracting the rod height) accuracy is only as true as the detail pole was held plumb (e.g. Figure D.1). As the figure shows, the highest elevation value it is possible to attain is only when the pole is perfectly plumb. Thus, this component of elevation uncertainty ($\delta(z)$) can only systematically introduce negative errors. When working in a rapid topographic survey acquisition mode (e.g. 2-6 seconds between shots), it is very easy and quite common for the detail pole to be tilted slightly off vertical.

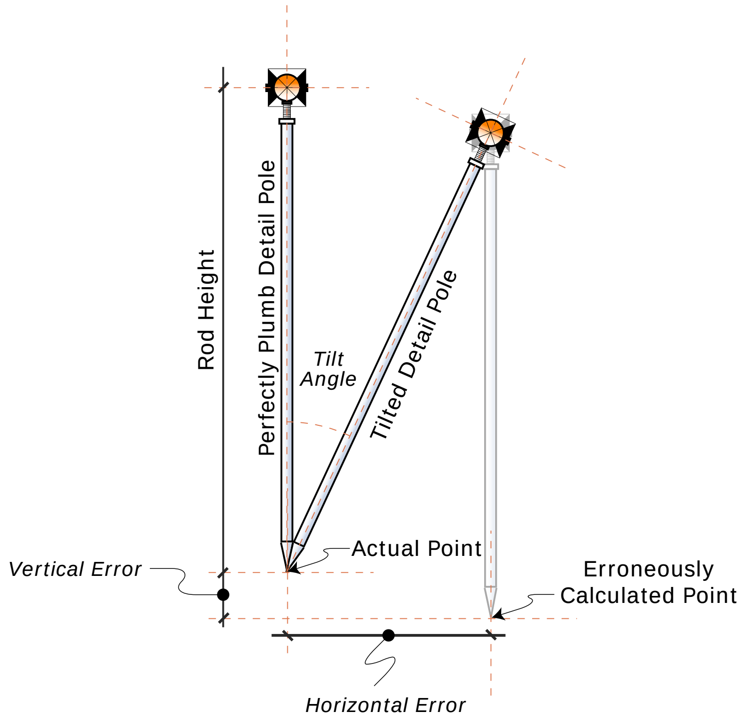

FIGURE D.1: Illustration of horizontal and vertical position errors due to a tilted detail pole.

D.3 Methods

A simple experiment to assess the influence of a titled detail pole on topographic point accuracy was conducted. The experiment consisted of four parts:

1. independently determine 'true' coordinates of a control point;
2. determine the variation in point accuracy when the operator attempts to hold the detail pole perfectly plumb without the assistance of a bipod or tripod;
3. determine the variation in point accuracy when the operator makes little attempt to hold the detail pole perfectly plumb ($\leq 5^{\circ}$ off vertical; thought to emulate actual survey conditions) ;
4. determine the variation in point accuracy when the operator records an exceptionally sloppy shot, (with detail pole between 5° to 15° of vertical; used as an end-member)

For part 1, the coordinates of a control point were determined by averaging 41 independent reoccupation control measurements (15 epoch observation time, average of 10 observations per epoch) of the point (Table D.1). For the remaining steps, roughly 25 regular topographic points were recorded. In between observations, the detail pole was removed completely from the point and the operator then reoccupied the point. However, the low standard deviation between measurements (even on parts 3 and 4; see Table D.1) and the strong bias in the

Stat:	Easting	Northing	Elevation	3D Point Quality
CP1 - Independent Establishment of Point (n = 44)				
Mean	792950.020	284285.473	352.753	0.015
CP1 - Plumb ($\angle \cong 0°$; n = 25)				
Range	0.018	0.018	0.017	0.004
Std Dev	0.004	0.004	0.005	0.001
Error	0.007	0.005	0.002	
CP1 - Slight Slant ($\angle \leq 5°$; n= 25)				
Range	0.030	0.126	0.024	0.004
Std Dev	0.008	0.040	0.007	0.001
Error	0.017	0.109	0.010	
CP1 - Major Slant ($\angle 5°$ to $15°$; n = 25)				
Range	0.041	0.142	0.031	0.004
Std Dev	0.009	0.030	0.007	0.001
Error	0.002	0.540	0.073	

TABLE D.1: Influence of a titled detail pole on x-y-z coordinate accuracy.

easting are a reflection that the operator was still returning to roughly the same tilt position that happened to be oriented in an east-west axis for each reoccupation. A Leica System 1200 GPS was used operating in RTK mode.

D.4 Results

Table D.1 shows summary statistics of the experiment. When the operator was attempting to hold the pole perfectly plumb, the horizontal error was on the order of 5 to 7 mm and the vertical error was on the order of 2 mm. When the operator was a little less careful (as they would during the course of a regular topographic survey), horizontal error increased to between 1 and 10 centimeters and vertical error increased to about 1 cm. When the detail pole was blatantly held at an angle off vertical, horizontal errors grew up to circa 50 cm, whereas vertical errors grew to circa 7 cm.

D.5 Discussion

It is noted that GPS 3D Point Quality remained extremely consistent throughout the experiments. This is partly due to the short time window over which the experiment was conducted in which satellite geometry did not change appreciably. Moreover, this is a reflection of how steady the operator held the pole during the acquisition of individual points, which again did not vary appreciably between points. This also highlights that 3D point quality is not a good discriminator of points that may have been collected with the detail pole tilted. Of course, if the tilt angle is known (which in practise it is not), the horizontal and vertical errors shown

Tilt ∠	Horiz. ϵ_{XY} (m)	Vert. ϵ_z (m)
0°	0.000	0.000
0° 30'	0.017	0.000
1°	0.035	0.001
2°	0.070	0.002
3°	0.105	0.005
4°	0.139	0.010
5°	0.174	0.015
6°	0.208	0.022
7°	0.242	0.030
8°	0.276	0.039
9°	0.309	0.049
10°	0.342	0.060
15°	0.500	0.134
20°	0.643	0.234
25°	0.766	0.357
30°	0.866	0.500
45°	1.000	1.000

TABLE D.2: Influence of a tilt angle of a detail pole on x-y-z coordinate accuracy for a 2 m rod height.

in Figure D.1 can be calculated directly with simple trigonometry given a specific rod height. This is illustrated in Table D.2 over a range of tilt angles.

While this simple experiment provides some empirical evidence as to the magnitude of influence of a non-plumb survey pole on point accuracy, it does not give a direct indication of the role of this error in DEM surface representation and ultimately elevation uncertainty. In terms of the contribution of the horizontal error components, this experiment suggests that under normal topographic surveying conditions (i.e. plumb to slight slant) the horizontal errors tend to be a fraction of the typical resolutions that DEMs for DEM-differencing are modelled at. Particularly with 1 m resolution DEMs, as used in this chapter, a positional error on the order of 1 to 10 cm is going to place a negligible role in elevation uncertainty in relationship to other components. The vertical errors under normal topographic surveying conditions (on the order of 5-10 mm) are less than the magnitude of surface grain-roughness for a gravel bed river. Thus, given that most of the time the tip is not placed in voids between grains when surveying gravel bed surfaces,[1] the systematic error introduced by a tilted pole will result in a slightly lower elevation value, but one that is still well within the range of sufrace grain roughness. In comparison to other error components that contribute to overall surface representation uncertainty (see § 4.3.1), the influence of a tilted detail pole on elevation uncertainty ($\delta(z)$) will probably vary between 5% and 50% of the total mangnitude $\delta(z)$. However, in the context of monitoring gravel beds like the Feshie, the influence of tilt can

[1]Elevations sampled in voids represents the lower range of true elevation values due to surface grain roughness. See Table 4.5 and Figure 4.5 A and B, which suggest that 84% of the time the detail pole tip is placed on the 'tops' of grains as opposed to in the voids between grains.

probably be considered negligble.[2]

[2] Beds comprised primarily of fines will obviously be different.