Hidden Point Offset

Vertical structures like trees, power poles, fence corner posts or building corners can quickly make for a bad day if your last shot of the day ends up being obstructed. But there may be an alternative to setting a new point, using an imprecise offsetting method or forcibly removing the obstruction.

>> By Shawn Billings, LS

Let's say it's 5:30 Friday afternoon and you're past ready to call it a week. You've just calculated the angle and distance to look for one of the last monuments you need to tie in. You turn the instrument to the angle and shoot a distance that measures just behind a tall tree. After a few minutes' search you find the monument intact and, sure enough, it is behind the tree. You're glad the point exists, but irked because you can't see it from the instrument.

Your brain begins to click through a mental toolbox of offset techniques. There are still two more setups and a delay like this is not on the agenda. But wait! Before you add another traverse point (or cut the tree down), there is another alternative–the hidden point offset.

For me, the hidden point offset has always brought to mind an old instrument ad that showed a pole with two prisms on it. The idea was to shoot the two prisms, after which a special software routine would calculate the coordinates at the base of the pole. It seemed like a nice idea, but I was skeptical about the accuracy. Add to that the cost of special hardware and software, as well as the rare occasion that would necessitate such a tool, and such a method just seemed beyond the reach of practicality.

One of my favorite aspects of surveying is problem solving. Like many surveyors, I enjoy unique situations that require creative uses of mathematics and mechanics. A couple of years ago I began to ponder whether I could do an offset with normal tools. As I thought about the mathematics involved and formulated a method, I was pleased to discover that the math could all be worked out with a simple, nonscientific calculator, like one on a cell phone. No special equipment was necessary, either. As long as a rodman can set up the prism pole on a point without the pole shifting or slipping, the technique can be performed with a common prism and prism pole.

Try This!

Here's how it works. Standing behind the tree that is blocking the view, the rodman centers the pole on the apex or center of the point and leans the pole over such that the prism can be seen from the instrument. The pole will need to be locked firmly in place during the procedure, which will likely require a solid bipod. Next, the instrument operator shoots the prism with the pole lowered as low as possible. If a data collector is being used, the rod height should be set to zero and the actual rod height should be carefully noted in a field book or in the description of the shot. Next the pole should be raised as high as is practical and a second shot made. Again, if the shot is being recorded in a data collector, the rod height should be set to zero and the actual rod height should be recorded in a field book or in the shot description. The pole should be calibrated to read true rod heights from pole point to prism.

Once the coordinates of the two shots (low and high) have been determined, a simple formula can be used to determine the coordinates of prism pole point:

Northing
Nl - [(Nl - Nh)/(HRl - HRh) * HRl] = Np

Easting
El - [(El - Eh)/(HRl - HRh) * HRl] = Ep

Elevation
Zl - [(Zl - Zh)/(HRl - HRh) * HRl] = Zp

Nl Northing coordinate of the short pole shot
Nh Northing coordinate of the long pole shot
Np Northing coordinate of the actual point

El Easting coordinate of the short pole shot
Eh Easting coordinate of the long pole shot
Ep Easting coordinate of the actual point

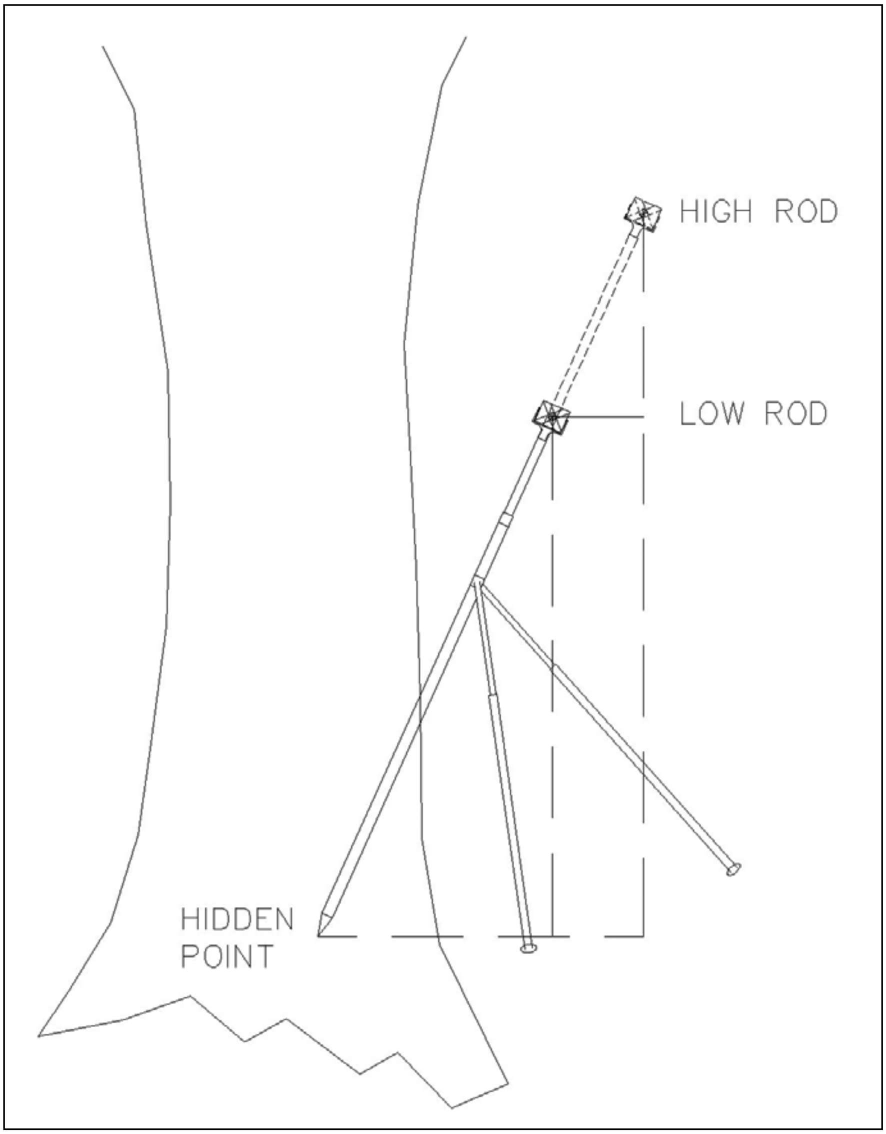
Zl Elevation of the short pole shot
Zh Elevation of the long pole shot
Zp Elevation of the actual point

HRl rod height of short pole shot
HRh rod height of long pole shot

This procedure requires no special equipment or special poles and is actually more adaptable than using the special double-prism pole because you have the flexibility to fine-tune a specific height for your particular needs (such as using 5.2 for the low shot to get over the wood fence or 7.8 for the high shot to stay under a tree limb).

Perhaps most pleasantly surprising is the accuracy I've been able to achieve with this technique. However, it must be pointed out that this isn't a panacea and care should be taken when performing a hidden point offset. Error sources beyond the normal surveying sideshot error sources are: 1) movement of the pole alignment between shots, which causes you to unknowingly lose your vector along the pole; 2) incorrect rod heights; 3) relatively low ratio of distance between high and low shots and the low shot and point–you don't want to project a half foot out five feet; 4) misalignment of the prism leading to parallax.

Regarding the calculation, most companies probably don't want their field crews doing algebra in the field. Fortunately, both AutoCAD and IntelliCAD have a routine called LENGTHEN which can perform this operation graphically back in the office.



This schematic shows the basic principle of similar triangles, which makes this method work. Notice the right triangle being formed by the hidden point, the low prism and the offset at the ground, as well as the the triangle formed by the hidden point, the high prism and the offset at the ground. These two triangles are said to be similar (the angles are the same). This is the foundation of the Hidden Point Offset.

Simply draw the 3D line between the high rod shot and the low rod shot and lengthen by the low rod height. It can be done in just a couple of seconds. Also, for surveyors who are also programmers, if your data collector will allow it, it would take little effort to write a small program that could perform this in the field. Additionally, it isn't too difficult to perform the calculations manually using paper, pencil and a basic calculator.

As to the issue of parallax, our friends at SECO sent us a true nodal prism to try out for this article, but you don't *need* a true nodal prism. If you are careful to point the prism to the instrument, parallax should not be an issue. However, at a rod height of eight feet or more, it becomes difficult to assure accurate alignment of the prism to the instrument. A true nodal prism places the apex of the prism directly over the center of the rod, meaning that regardless of orientation, vertically and horizontally, the apex, or nodal point, represents the actual center of the rod. With the pole leaning, the normal aids for collimating the prism (center of the pole and prism targets) don't really work. Having a precise, accurate target point will significantly improve the accuracy of the method.

> **"...this method offers verticals that are as precise as the horizontal. And you can amaze your friends at your next outdoor barbeque and say, 'Hold my beer and watch this!'"**

Setting the pole up, your rodman must be diligent to firmly place the bipod legs in the ground and do everything possible to keep the pole point from slipping. The alignment of the pole must remain the same as the two shots are being made or the method will yield inaccurate results.

Here are a few examples I observed in the field. For these examples, the instrument was set up at:

N: 5000.0000
E: 5000.0000
Elevation: 100.0000

It was zeroed at a backsight azimuth of 351°12'35". The instrument height was 5.44 feet. For this first example, I set the pole up leaning to the right from the perspective of the pole. I observed at a rod height of 5.00 feet for the low shot and 8.00 feet for the high shot.

At 5.00 feet I observed:
AR: 122°41'18"
ZE: 88°56'51"
SD: 184.962'

This yielded rectangular coordinates of:
N: 4925.0826
E: 5169.0762
Elevation: 108.8382
(Remember to zero the rod height for determining the coordinates.)

At 8.00 feet I observed:
AR: 122°30'57"
ZE: 88°02'08"
SD: 184.950'

This yielded rectangular coordinates of:
N: 4925.6280
E: 5169.2191
Elevation: 111.7807
(Again, remember to zero the rod height for determining the coordinates.)

Plugging these values into our above formulae, I got:

Northing
4925.0826 - [(4925.0826 - 4925.6280)/(5.00 - 8.00) * 5.00] = 4924.1736

Easting
5169.0762 - [(5169.0762 - 5169.2191)/(5.00 - 8.00) * 5.00] = 5168.8380

Elevation
108.8382 - [(108.8382 - 111.7807)/(5.00 - 8.00) * 5.00] = 103.9340

At the same time, I also observed the point with the pole plumbed at a rod height of 5.00 feet:

AR: 122°58'16"
ZE: 88°55'21"
SD: 185.116'

This yielded rectangular coordinates of:
N: 4924.1866
E: 5168.8435
Elevation: 103.9218

This would result in a difference between the standard observation method and the hidden point offset method of:

N: 0.013
E: 0.006
Elevation: -0.012

This, in turn, would be equivalent to a total 3D error of only 0.019 foot.

Here is another example:

HR 5.00'
AR: 96°23'35"
ZE: 91°38'44"
SD: 33.940'
N: 5001.4190
E: 5033.8963
Elevation: 104.4654

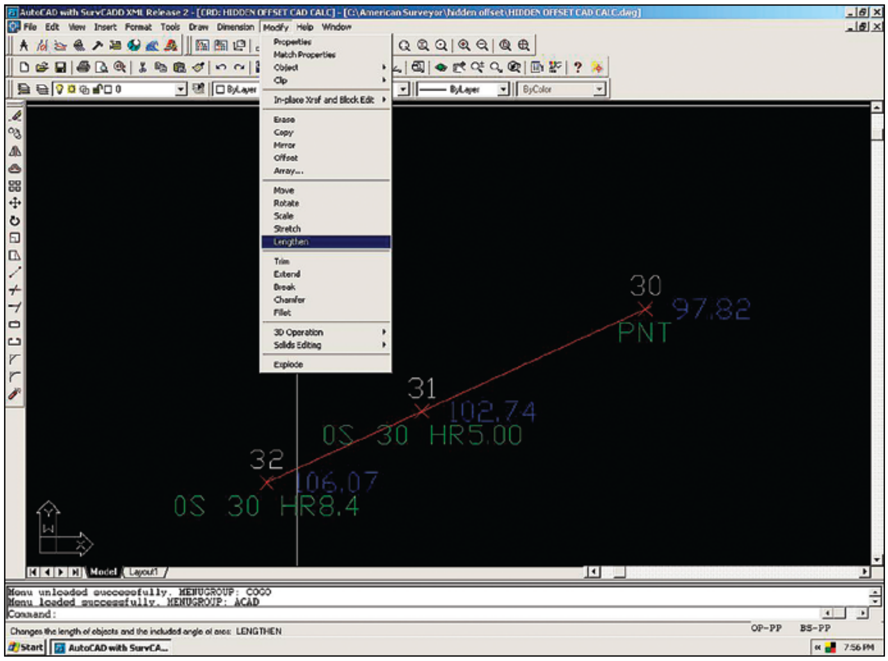
HR 7.6'
AR: 97°32'26"
ZE: 87°26'23"
SD: 33.503'
N: 5000.7300
E: 5033.4616
Elevation: 106.9366

Point by Hidden Offset:
N: 5002.7440
E: 5034.7323
Ele: 99.7131

Point by Standard Observation:
N: 5002.7325
E: 5034.7201
Ele: 99.7161

Difference:
N: -0.012
E: -0.012
Elevation: 0.003
3D: 0.017

I encourage you to go out and spend 15 minutes in a parking lot and see what you can do with this method. It is inexpensive to implement and works at times when there just aren't any alternatives. You also get reasonably accurate 3D coordinates from it. As this data set indicates, this method offers verticals that are as precise as the horizontal. And you can amaze your friends at your next outdoor barbeque and say, "Hold my beer and watch this!" In practice, I would encourage you to implement redundancy any time you use this technique. If you are reducing in the field, two separate observations should allow you to compare and make sure the rod didn't shift or you didn't mis-enter a rod height. If you are waiting to reduce it in the office, I would recommend three different observations. This will allow you to pick out the odd duck if you have any disagreement. Enjoy!



Not in for doing algebra in the sweltering heat or blistering cold? Let your CAD program do the lifting back at the office. Both IntelliCAD and AutoCAD provide a Lengthen routine that can determine the true coordinates in seconds.

As you can see in this photo, the reflection of the camera lens is at the center of the true nodal prism. Overlaying the horizontal axis and vertical axis, you will find that the apex, or nodal point of the prism, is precisely coincident with the intersection of the axis lines even though the prism is not directed toward the camera.