THE ADVANTAGES OF POLARIS OBSERVATIONS IN LAND SURVEYING

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ABSTRACT

The use of Polaris for azimuth observation has not been popular in land surveying applications due to myths about the difficulty and inconvenience of its use, and the popular belief that it is necessary to observe it at odd hours of the night or evening. In fact the Polaris observation can be made quickly and easily over a broader range of conditions than can Solar observations, and is well known to be more accurate. This paper presents a description of the Polaris observation, the underlying theory, and a discussion of it's advantages as a simple, accurate and easy azimuth determination method for use by the Land Surveyor. The paper provides procedures for computing, finding, observing and reducing Polaris at any time of day or night.

GENERAL

Imagine a method to quickly establish astronomic azimuth to check a traverse line. A method that does not require an expensive Roeloffs prism or an objective filter to protect the electronics in your Total station, that does not require you to fiddle around trying to project the image of the sun on a piece of paper, and a method that can be used at any time of day or night. Such a method exists but seems to be used little these days by the average surveyor. That method is the Polaris observation. With Polaris there is no need to race out to the job site fearing the sun may be too high to observe and the answer can be had within seconds with a simple 41C calculator program.

Many textbooks and tutorials on obtaining astronomic azimuth represent the Polaris observation as accurate but difficult to use due to the requirement that it be observed at elongation which frequently occurred at odd hours of the night. This seems to be a residual myth from the old days when observation of Polaris at elongation was a common method used to verify azimuth. The elongation observation was used because it was very accurate non time critical and could be computed with tables. Before the days of electronic computation, this was a big plus. And of course how could you do a polaris observation in the daytime.

Another factor which has changed a bit is the increased availability of high quality optics in our survey instruments. The ability to see stars during daylight is somewhat enhanced, however many of us have heard stories from not so long ago `old timers' who took polaris observations in the day time with such as Gurley Transits.

How many surveyors are familiar with reducing Polaris observations to azimuths? Probably not too many, and we are talking about not just studying Polaris observations for LS exams but actually using them in the field to run and check bearings, and even basing the entire survey on them. We hope to spark some interest in the profession in learning to use Polaris. In terms of accuracy, ease of use, simplicity of reduction, under many circumstances it can be considered superior to making solar observations.

The Bureau of Land Management Cadastral Survey Offices are the descendants of the old contract and GLO surveys responsible for the survey of the public lands. The azimuth control for these surveys has traditionally been by means of astronomic observations. That factor has made surveyors in the BLM common users of various astronomic methods. As most of us came into the BLM from school or from the private sector we may never have imagined that anyone would be using the stars for azimuth, let alone working in the daylight. But it's true.

Historical Insights. Those who peruse the records of early PLSS surveys the Polaris observation in prominent as an accurate means to check azimuth, to calibrate solar instruments and the like. Mention of the method is primarily noted for checking compass declination or to establish a meridian used to perform daily or weekly checks of solar instruments. The method used was the observation at elongation primarily because it was easy to produce tables to allow reduction. In those days, as now, the easier the procedure the more likely it would be used and the results correct.

Since those days and the dominance of the urban surveying profession many have not had opportunity to perform a Polaris observation. Perhaps it was a class in school, or when studying for the LS exam. The method has fallen into general disuse. This is unfortunate, as the field use of Polaris is fun, as well as an accurate and valuable tool.

Now days when the programmable calculator is in universal use by surveyors, the preferable method to use is the Polaris hour angle method. Because Polaris is a near polar star, it's relative motion is fairly small and thus the observation is very non critical for time, latitude or longitude. Polaris does move, however, so that a search position must be computed.

PRO'S and CON'S

ADVANTAGES

- Easier to observe with no note keeper. Because the stars apparent motion is so slow, it is easier to make an observation without a notekeeper. Now days this can also be achieved with a good 41C program, but the process is much simplified with a Polaris sight.
- No expensive filters. Because we are not sighting the sun or even near it, we do not require any filter. Some have experimented with common photographic polarizing filters to increase contrast, but it seems to provide insignificant help.
- No problems projecting on paper. Polaris is sighted directly, the limitation is the altitude of the sight and can be assisted with a right angle eye piece.
- Available at all times of day. With the hour angle Polaris method it can be sighted at any time of the day or night with about the same degree of accuracy. The star is totally non critical for time near East and West elongation but the errors at all times are fairly small when compared to a solar or equatorial star observation.
- Easy to compute and reduce. The computation for polaris is by means of 2 simple hour angle formula. A program can easily be written to compute the star's azimuth and vertical angle for the given geographic point and time, this is used to find the star. The same program is then used to reduce the observation. Because polaris is a close circumpolar star it is possible to compute it with even simpler formula than conventional astronomic objects.
- High accuracy. Because the star presents a pin point target and the stars small apparent motion it can provide highly accurate azimuth. The most critical element of error seems to be the ability to level the instrument and keep it that way. (see the analysis following)
- Minimal accuracy needed in time, latitude and longitude.

DISADVANTAGES

- Not effective at high latitudes, such as Alaska where the high vertical angle makes polaris not only hard to see but increases the error due to mislevel dramatically.
- Weather. Of course you can't see polaris on a cloudy day, but neither can you see the Sun usually. The Sun is a little less susceptible to clouds and haze. Polaris can be observed in light haze even at sea-level, but is more likely to be obscured and difficult to find.
- Requires some skill. Part of the fun of using Polaris is obtaining the skill to find it in daylight.
- Requires some form of rough azimuth to find it in daylight, thus is less practical for isolated observations and more practical in an ongoing job where the lines themselves can be used for azimuth and the observation is a

check and refinement.

OBSERVATION FACTORS

Time Is the most critical element in an hour angle solar observation, but is much less critical in the polaris observation. For solars, time better than half a second, use of time signals, reaction time, fine correction to UT, poor radio reception, sighting on a fast moving and large object, etc. are all factors which make accuracy in the solar observation difficult. In summer the sun cannot be observed midday due to its high vertical angle overhead. The Altitude Solar while not time critical also cannot be observed near mid day due to lack of vertical motion and vertical angle.

Polaris is much less critical for time as long as you are at a viable observing latitude (between 25 and 55 degrees). See Figure 1. In general the maximum error for Polaris is in the range of 1/3 second in azimuth for 1 second error in time. Much of the day it is less than this. The primary reason for this is the small radius of its apparent motion around the pole.

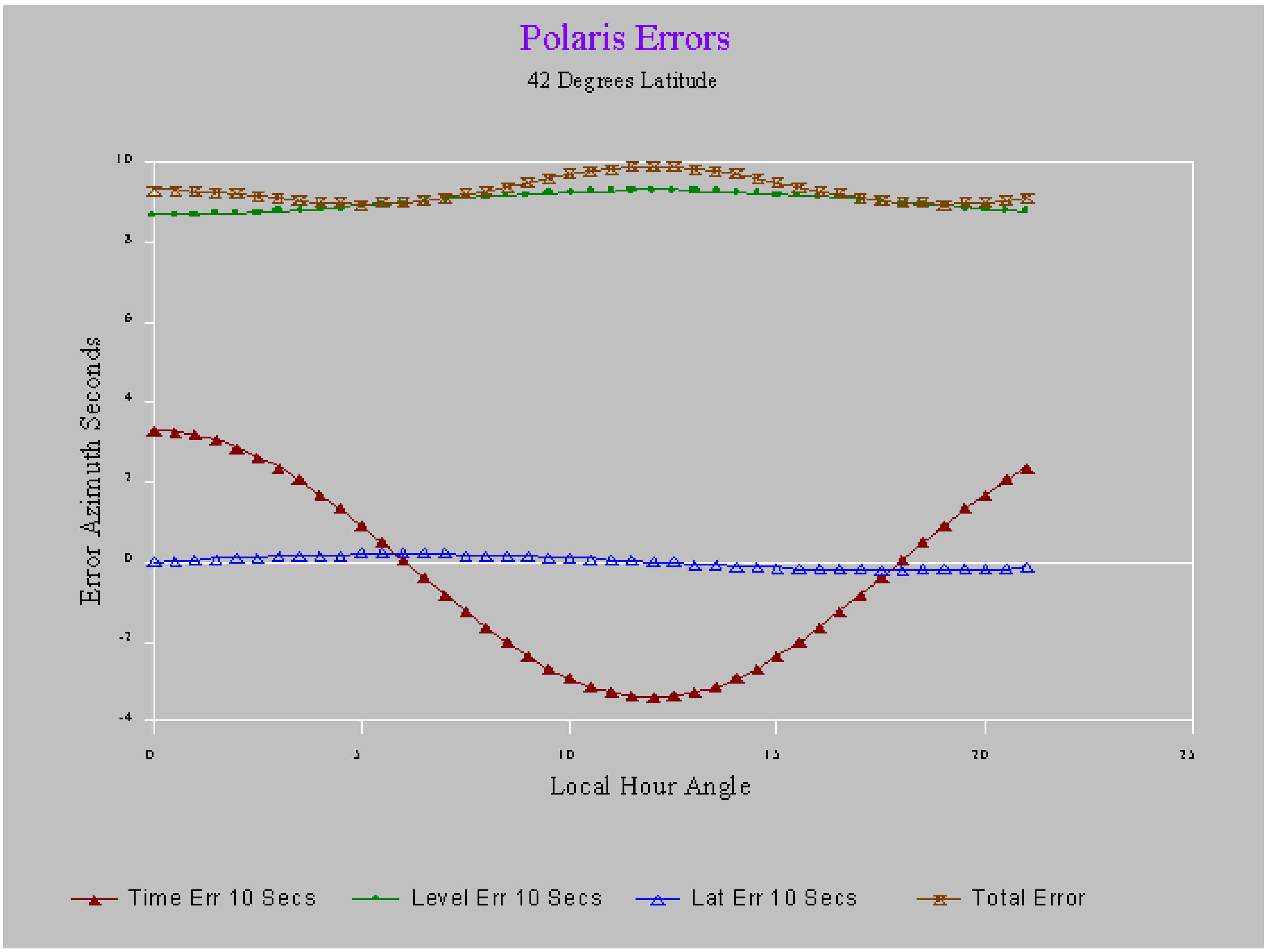

Figure 1 - Various Sources of Error (seconds @ 42 lat)

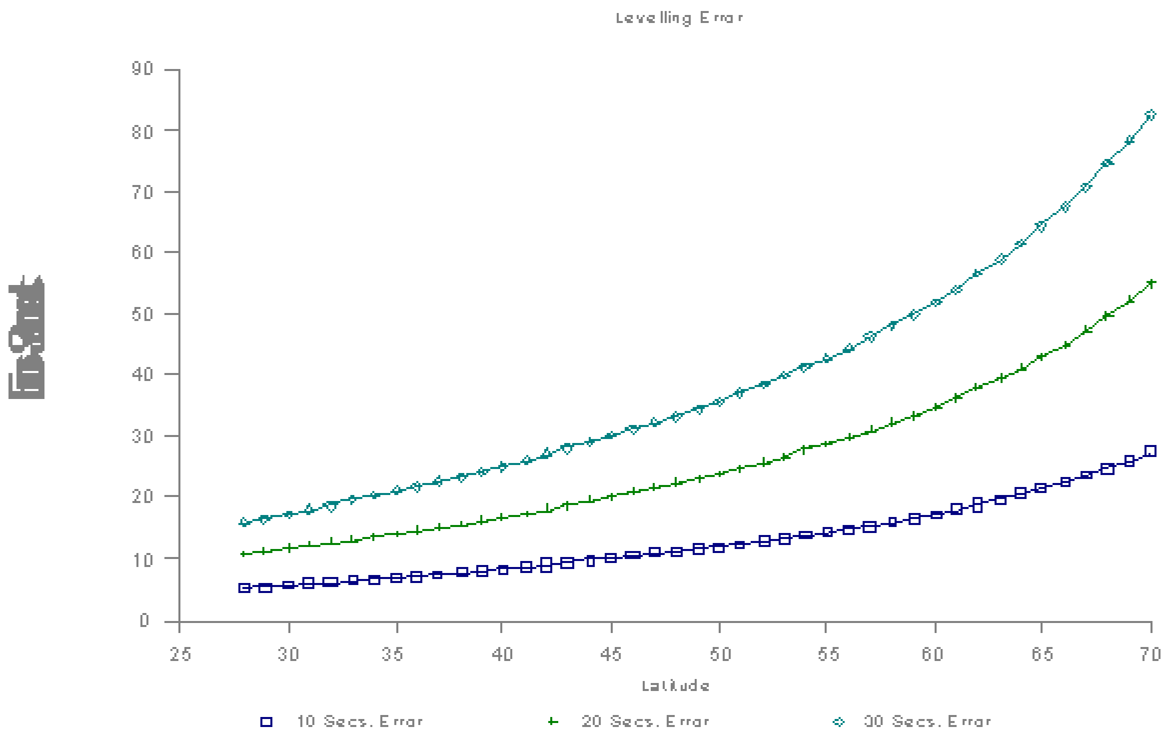

Figure 2 - Magnitude of Level Error - Seconds

Data from Ephemeris: Many programs now exist that eliminate the need for an ephemeris for Solar observations. If you do not have one of those making a Solar observation requires entering data from a published ephemeris. The data then requires interpolation of the GHA and Declination data to the time of observation, polaris only requires two entries, GHA and declination for the day. Because Polaris is a star it's relative data changes only very slowly, thus it is usually only necessary to enter the GHA and declination for the specific day. It is actually possible to compute the data over a longer period, however it is listed in most Ephemeris each day so there is no need.

Latitude and Longitude In usual practice latitude and longitude is scaled from a USGS quad map, but may be determined by coordinates if you have tied into control. Latitude is critical in both the hour angle and altitude Solar observations because we are solving a large PZS triangle where the co-latitude is one of the sides. Longitude is also critical in the hour angle Solar computation where 15 seconds is equivalent to 1 second in time. For Polaris there can be an error of as much as 50 seconds in latitude (corresponding to about a mile on the ground) to introduce 1 second in azimuth error. Longitude contributes 1/15th the error as time.

Leveling Error: Levelling error is fairly critical in solar observations. The higher vertical angle to an object the more error is introduced by levelling error. This introduces larger errors for mid day solars. This factor is always present for polaris observation since it is always at a significant vertical angle. The levelling error is by far the most significant contributor to error in the Polaris Azimuth. The plate bubble on most theodolites have graduations representing 20 or 30 seconds. It takes some care to maintain an instrument within 10 seconds. Careful levelling with the vertical circle can minimize the problem.

Observation Point: Easily selected, ideally in shade to minimize levelling problems caused by solar heating, and with a clear sight to the north. Surprisingly it seems as though in moderate timber or vegetation this is easier than finding a clear sight for the sun which quickly moves out of any hole you thought you had.

OBSERVATION PROCEDURE

Preparation. For the daytime observation, it is often useful to prepare a listing or plot of the polaris position during the day. This can eliminate the need to have a calculator program in operation in the field. With a calculator it is only necessary to have a program, the approximate geographic position of your observation point, the ephemeris data for the day, a good watch and instrument.

Focus. A critical factor in being able to locate such a fine point of light in the daytime is proper focus. If you are in an open area, this can be obtained by first focussing on an object as far away as possible. If this is not possible, then preparation should be made at another location to make a mark on the focussing barrel of your theodolite at the distant focus position. Most scopes focus past infinity, so wrapping the focus all the way will not work. Chances are that this mark may depend a little on the particular observer. Focus on the star will be very near this point, but may vary slightly.

Catch 22. One of the catches involved in using Polaris in the daytime is that you have to have a rough bearing in order to find the star. This can be obtained from bearings you are carrying on your traverse, from control points, etc. It is possible in some areas to obtain an adequate azimuth to find Polaris with a compass. It must be in proper adjustment however, and today most theodolites do not come equipped with one. An instrument with an attachable trough compass may be a good match for polaris observations.

If you have no real idea of azimuth such as when starting a new job in the middle on nowhere, then one has to resort to luck or a `quick-solar' observation. This can be a quick and dirty single solar pointing that can be reduced by the method of your choice. As long as you can get within 5 minutes with the shot, you should have no trouble finding the star. Polaris is most effectively used when you are carrying true bearing in your traverse and can thus quickly observe Polaris to check and refine the line.

Setup. This involves setting up on your point assuring a potential clear north sight, taking your backsight and running the calculator program to obtain a polaris search position in azimuth and vertical angle for the approximate time. It is best if the program can accommodate input of the backsight coordinates or azimuth and gives you an angle to turn.

Focus. Set your predetermined focus with the mark on the focus barrel or focus on a distant point.

Search. Set the angles into the instrument turning to find the star. If your azimuth is within 5 minutes you will usually be able to find the star to one side or the other of the crosshair. It will nearly always appear above the cross hair a few minutes, offset due to atmospheric refraction.

Point. Once located a number of observing procedures are possible. It is often a good idea to lower the scope and pick or set a sight point that can be used to return to the proper horizontal position.

Level. Carefully relevel the instrument as this is the greatest source of error.

Observe. The observation can be made by reading the plates and taking time, returning to read the backsight and reversing. The sight is used to regain the star with the same vertical angles. It is even possible to do repetitions on the star taking the time of each Polaris pointing.

Reduce. After the observation is complete each time is entered into the program and the azimuth of polaris is computed. This is then added to or subtracted from the angles turned as appropriate to get the proper azimuth.

SUMMARY

Although it seems like a strange thing to do, the daylight Polaris azimuth observation provides a fun, accurate and easy to make azimuth determination method. With experience it can provide superior azimuth over a broad range of conditions, more so than solar observations. The azimuth determination has low dependence on time, latitude or longitude, but is critical for level error as are most astronomic observations. Experience has shown that in moderate vegetation it is frequently easier to sight Polaris than the Sun. We hope that more of you will consider giving Polaris a try and join the fun.

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