Polar Alignment by Iterating on One Star and Polaris

Michael A. Covington
Artificial Intelligence Center
The University of Georgia

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The Meade LX200 manual describes the following technique for improving the polar alignment of a computerized telescope:

(1) With the telescope roughly polar-aligned, go to one star high in the sky and sync on it, or do a one-star initialization.

(One-star initialization is the only kind offered by the LX200; it is also available on the ETX. The following technique is not usable on a telescope that has been initialized on two stars in order to compensate for polar alignment errors, such as the Celestron NexStar.)

(2) Tell the telescope to go to Polaris. Then adjust the mount (without slewing the telescope) so that Polaris is actually centered. (Or move part of this distance; see below.)

(3) Tell the telescope to go back to the alignment star, center it in the telescope by slewing (without adjusting the mount), and sync on it again.

Repeat steps (2) and (3) until you can go from each star to the other without further adjustment.

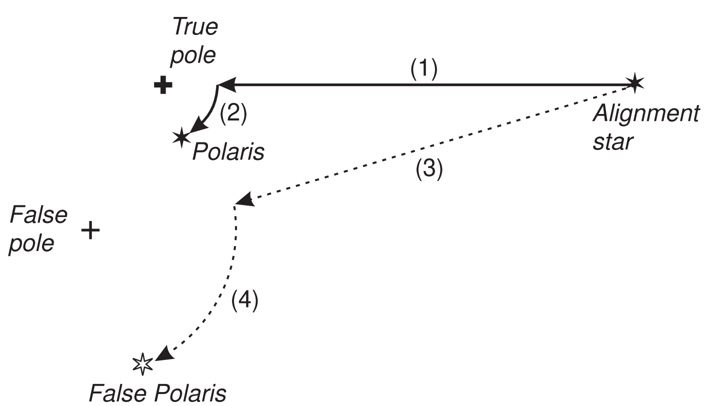
There is some controversy among telescope users as to whether this procedure always works and whether, in step (2), one should eliminate all the error or only half of it. In this paper I will analyze the technique in detail and answer these questions.

> **Brief recommendations: Choose an alignment star whose R.A. is well away from that of Polaris ($2^{\rm h}30^{\rm m}$) and correct about 2/3 of the error, not the whole error, when recentering Polaris by adjusting the mount each time. Contrary to Meade's instructions, there is no need to wait 15 minutes between iterations.**

Case A: Polaris, the alignment star, and the false pole in no special relationship

By "false pole" I mean the point on the celestial sphere to which the telescope's polar axis is actually directed. By "false Polaris" I mean the position to which the telescope slews when told to go to Polaris.

Here is a typical situation:

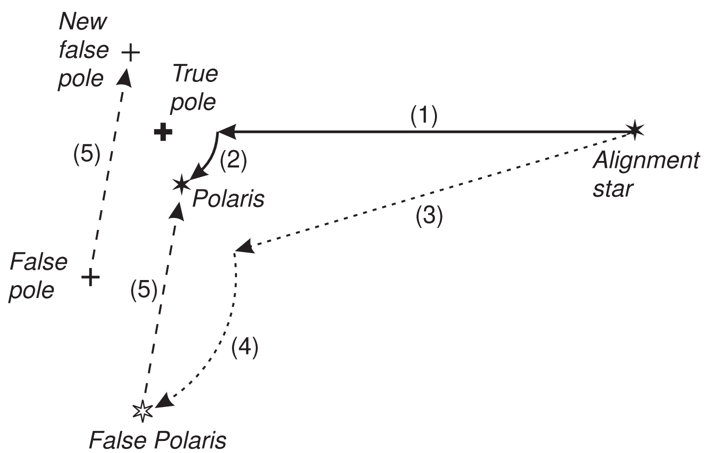


When synced on the alignment star and then told to go to Polaris, the telescope should perform movements (1) and (2), first slewing in declination and then revolving in right ascension about the true pole.

But in fact, because the polar alignment is incorrect, the telescope performs movements (3) and (4) instead. Note that movement (3) is exactly the same length as movement (1); that is, the distance of movement in declination is the same. That is because the rotary encoders in the telescope measure relative movement, not absolute position.

Note also that movement (4) is the correct *angular* revolution, but it is part of a circle around the false pole instead of the true pole.

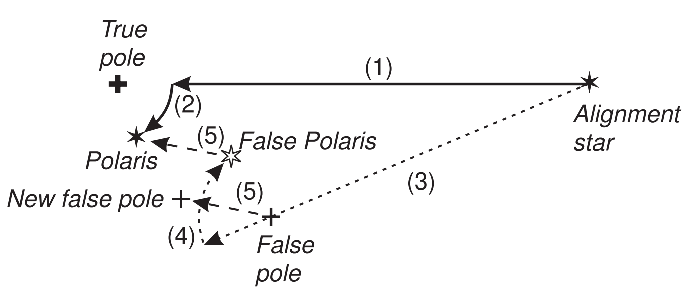
Then the user adjusts the mount, performing movement (5):



This movement superimposes the false Polaris on the true Polaris. It also moves the false pole closer to the true pole, *which is the object of the game.*

Case B: Same, but alignment star nearer false pole than true pole

What if the false pole is closer to the alignment star, so that instead of being too short, movement (1) is too long? In that case, here's what happens:

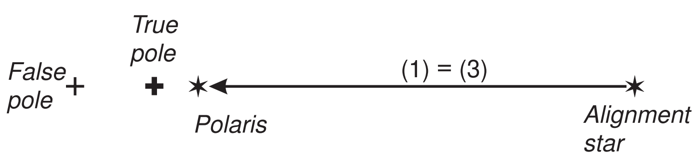


Although the diagram is cluttered, the key point is that movement (3) is again the same length as movement (1), and movement (4) again covers the same angle as movement (2) (in the diagram, about 75° clockwise), even though it's on the opposite side of the false pole.

Again, movement (5) moves the false pole closer to the true pole, as it should.

Case C: Polaris and alignment star have the same R.A.

The right ascension of Polaris is about 2^h30^m, the same as Hamal (α Arietis). When you use Hamal as an alignment star, the iterative technique does not work. Here's why:



If the false pole is anywhere on the line joining the alignment star, Polaris, and the true pole, then movement (3) will be identical to movement (1) – that is, the telescope will slew only in declination and, slewing the correct distance, will land on Polaris, regardless of the remaining polar alignment error.

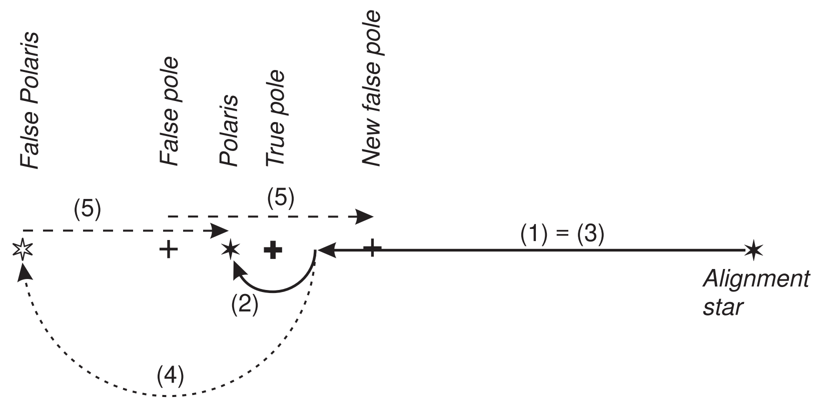
Note that if the false pole is initially *not* on this line, the iterative method will move it somewhere onto that line, and then you're stuck – you'll have a bad polar alignment error without knowing it.

Fortunately, Hamal is the only star of right ascension 2^h30^m that is bright enough to align on.

Case D: Polaris and alignment star differ in R.A. by 12 hours

What if your alignment star is Arcturus or Spica, each of which is on the opposite side of the pole from Polaris? In that case, something happens that has been noticed by telescope users but not adequately explained. The telescope tends to oscillate between two equal and opposite polar alignment errors.

Here is a somewhat cluttered diagram explaining what happens:



Crucially, movement (5), superimposing the false Polaris on the true one, moves the false pole over to the opposite side of the true pole, but does not bring it any closer.

If, however, you make only *half* of movement (5), all is well; you get perfect polar alignment. And in fact if you make any part of movement (5), less than its full length, the procedure quickly converges toward correct polar alignment.

This, I think, is what led to the recommendation to correct only half the visible error each time. That guarantees convergence in this situation.

Further notes

By working out a number of other cases by hand, I determined that:

1. If the alignment star is within about 3^h of the R.A. of Polaris (i.e., if it's anywhere from 0^h to 6^h), the process converges very slowly. This means you should avoid using Hamal, Aldebaran, Capella, Betelgeuse, or Rigel. However, if those are the only convenient alignment stars available, you might use δ Ursae Minoris rather than Polaris as the pole star.

2. In general, it is best to remove only about 2/3 of the visible error when recentering Polaris. That is, make movement (5) only 2/3 as long as shown in the diagram. That leads to fast convergence most of the time.

3. Contrary to Meade's instructions, there is no need to wait 15 minutes between iterations.

The ETX-90

This same technique should be applicable to the ETX-90 (on which it is called 1-star polar alignment). In fact, though, I have had some difficulties working out how to apply it and am still experimenting. Unlike the LX200, the ETX-90 cannot slew past the false pole (as shown in the diagram for Case B), but that is not the whole explanation for the problems I'm encountering.