Repeatability of a Theodolite

September 27, 2011

1 Goals

- Learn how to properly care for a theodolite.
- Learn how to properly use a theodolite.
- Determine the repeatability of a theodolite measurement.
- Attempt measurements of a star from Berkeley.

2 Measurements

2.1 Determining the repeatability.

Set up the theodolite in the HFA courtyard. Either mark a point or select a recognizable point to measure. This point should be high enough so that its elevation angle is noticeably different from zero. Make repeated, and *independent*, measurements of the vertical angle of the point with respect to gravity.

Each student in the group should make at least four sets of measurements for the point. That is, to measure an angle you must make both a forward and a reverse measurement: a single "set of measurements" is the combination of these two forward and reverse measurements.

The largest source of error in such measurements is—quite simply—writing down the wrong numbers. Humans have developed a time-tested procedure for avoiding this embarrassment:

(1) The written record of the data should be done in tabular form and should be in a common format that people agree on before beginning.

(2) The person who reads the theodolite must *not* be the same person who records the numbers.

(3) The person taking the data states the numbers *clearly and loudly* to the person recording the data.

(4) The person recording the data writes the numbers down *neatly* and **boldly**.

(5) A third person looks at the written numbers and reads them back to the data-taker in a *clear and loud* voice.

(6) The data-taker confirms that the written numbers are indeed correct in a *clear and loud* voice.

Finally, during this beginning stage when you are learning how to use the instrument, the person who reads the theodolite should ask a different person (not the one who records the numbers) to make an independent determination of the reading; then the two people can compare their independent readings. The very act of reading the theodolite is a complicated business and this will help to (but will not definitively) ensure that everyone is following the correct procedure!

2.2 The effects of misalignments.

When using any piece of instrumentation whose operation is complicated, it is always wise to determine the consequences of operating it improperly. Each student should take *one* set of measurements, with the student introducing a deliberate misalignment of a size that differs from that of the other students.

Introduce *deliberate misalignments* to see how they affect your results; this tells you how finicky you must be. The misalignments should be large enough so that their effect is easily noticeable, and you should estimate the amount of misalignment. For example, when misaligning the split bubble, misaligning it by a known fraction, say half of the total visible range, is a reasonable choice.

For altitude measurements you need to align the split bubble after pointing the telescope and before making the reading; if you deliberately misalign it by a known amount, what is the resulting error in the altitude angle?

If the plate level is not perfectly aligned, what is the resulting error in the altitude angle?

2.3 Measurement of stellar position.

We suggest that you attempt observations of Polaris, the North Star, as this will be the target of our observations next week. You may have to choose a different, i.e., brighter, star depending on conditions. Some familiarity with how to detect the star and make measurements on it will be very helpful.

The technique for measuring the star's position are the same as for a fixed object with *one exception:* you must note the exact time of your measurement. An accuracy of 10 seconds or better is required for good results. Mark the time when you acquire the star at the center of the field; you can take your time measuring the angle afterwards, even though the star will have moved out of the center.

3 Data Analysis

First, transfer your measurements from the written piece of paper to a computer file using a text editor. Create a table of data that you can share with others in your lab group.

Use the data on the fixed object to estimate the uncertainty in your measurements. How accurately can you measure the position? Are some observers more accurate than others? What should you do with discrepant points?

Combine the forward and reverse measurements such that each person's average result and uncertainty are available; this allows you to spot people with problems. Combine all people's results and get the best possible result for the angle.

In addition to the *statistical* uncertainty there are also *systematic errors* in your result. These occur because you have made certain assumptions about your measurement that may not be true. In this measurement you may not think there are any systematic errors except for inaccuracies in the theodolite. However, later we will learn about a most important error in measuring vertical angles; it has nothing to do with the instrument. Anyone who comes up with the answer now gets the proverbial "gold star".

For the star data, if we obtain it, plot the altitude and azimuth angles as a function of time. How well can you measure the declination and latitude of Polaris? Make an attempt at a linear least square solution to this data. This will prepare you for the measurements we make on the field trip next week.