Innovations in Mapping

Short Term 2015

Triangulation Lab

5/5/16

Due Wednesday, May 11 at 10am

Imagine that Bates campus is actually in France. Your group is one survey team among many that is updating the Cassini sheets and providing extra local detail for the purposes of **public works administration, taxation, and natural resource management. The year is 1800.** Using as much as possible the techniques of surveying prior to 1800, your goal is 1) to determine the lengths of some triangle sides which cannot be measured directly and to document features for a topographical map of the area that is in progress.

You are assuming that what you see around you in 2016 = what you are mapping as if it were 1800.

Goals:

1. To measure the distances between specific points on campus:
   1. The diagonal from the intersection of College and Russell to the intersection of Campus and Central.
   2. The diagonal from the intersection of College and Campus to a useful station in the area between Pettengill and Commons. (You can determine what the specific stations are for these points.)
2. To establish the location on a map of significant human-made and natural features, in accordance with the stated purpose above, within and near the triangles that you build to measure this diagonal.

Requirements:

* Build at least 4 triangles.
* Keep detailed field notes as a group (share afterwards as image files)
* Create map on drafting paper
* Turn in group and individual lab reports (see steps below for details)

Good rules of thumb:

* “Strong” triangulation chains depend on, among other things, triangle angles greater than 10 degrees
* Take multiple measurements of each angle and use mean values for final angle.
* In selecting stations, choose *permanent* built or natural structures. A survey is only valuable beyond its initial purpose if it can be repeated or provide control points for future work.
* Use inches and feet.

Kinds of error:

* Mistakes, carelessness (errors of a meter or a degree)
* Systematic errors (cumulative, by inaccurate instrument or personal reading technique)
  + Errors in leveling the instrument
  + Errors in centering the instrument over the station
  + Errors in pointing the instrument
  + Errors in reading the angle
* Random errors (environmental, such as differential temperatures)

Methods:

For **distance**: measuring unobstructed lengths with pacing or measuring tape

1. Use the tape measure to determine the length of unobstructed triangle sides, where needed.
2. Pace out distances (determine ahead of time the average length of your pace).

For **angles**: measuring interior triangle angles with graphometer or compass

1. Set the compass over one of the vertices of the triangle (find a way to support it so that it is level).
2. Use a rod to mark the other vertex
3. If using the compass, lower the needle, place the North end of the compass box to the front, sight the rod.
4. When the needle vibrations stop, read the north end of the needle to the nearest 5 minutes. This is your observed bearing.
5. Lift the needle, verify the sighting and also the reading.
6. Turn the compass box to the other point and determine the bearing, as before. The required angle is the difference between the two bearings.
7. Measure the 2 other angles in the triangle using the same steps. The “error of closure” should not exceed 5 minutes.
8. Be sure to secure the needle before you transport the compass.
9. If using the graphometer, measure the angles of a triangle ABC such that you measure from vertex A to vertex C.

For **projecting** the work on paper:

1. Determine your scale (1 inch = 100 feet, for example)
2. Outline the area you will be mapping on the paper (which is fastened to your plane table).
3. Using the existing maps provided as an aid, indicate minutes of latitude/longitude as a grid (your map represents points and lines using plane geometry).
4. Plot your control points (see above).
5. Include the angles and lines of your triangles on your map as another reference for plotting features. Use a compass/protractor to accurately determine angle measurements as determined through your observations. Triangle lengths that you measure directly should match your scale – i.e., if you use the scale example above, a 200 foot triangle side should equal 2 inches on your map.
6. Using the method below, plot your features in relation to your triangles.

**For features**: pacing the size of features and sketching them into the map

1. Consider which features (both built and natural) you wish to represent. You can think of your map as an “abstract” of the ground. The map is an “abstracted” or abridged representation of the ground: you cannot include every detail. Consider the purpose of your map and determine which features are most important for helping your reader interpret the map. Likewise, consider what information to generalize. Some features could be included but not always at the same level of detail as other features.
2. The map should be consistent in how it represents the topography (which features are included, how they are labeled, etc.)
3. There should be no obvious omissions that strike the reader who is familiar with the landscape, within the purview of the purpose of the map.
4. Place your graphometer on the paper along one of the triangle sides for which you have lat/long and length.
5. Mark both vertices of the triangle on the paper that correspond to their ground positions (See Figure below)
6. Position plane table at one of the triangle vertices. Place your graphometer at A’B’ (as in figure below)
7. Moving the graphometer alidade, measure angle between A’B’ and A’C’. Without moving the plane table, use this technique to record angular relationship to other objects in the line of sight of this station.
8. Pace distance from station to make proportional feature on map or use tape measure. If you use pacing, determine how long your stride is (in inches). Count your strides as you walk.

Computations:

18th-century French mathematician Pierre-Simon Laplace credited logarithms with doubling the life of the astronomer. After the availability of locational data on celestial bodies and events, the widespread publication of log and trig tables transformed what calculations could be accomplished on any project using plane or spherical geometry, including surveying. The first tables for logarithms using base 10 were prepared by Henry Briggs and published (in Latin) in 1617. In 1685 it was discovered that logarithms could be defined as exponents. In the 18th century, tables of base 10 logarithms were published to 10-second intervals. Trigonometric tables were first published by Rheticus (Copernicus’s student) in the middle of the 16th century. A posthumous compilation of his and his student’s computations for trig tables were used by astronomers until the early 20th century.

Historical trig and log tables can be found here: http://locomat.loria.fr/locomat/reconstructed.html#triglog

In particular, take a look at these if you are interested:

1) a reconstruction of Brigg’s 1624 table of logarithms: http://locomat.loria.fr/briggs1624/briggs1624doc.pdf

2) Gunter’s trig tables: http://locomat.loria.fr/gunter1620/gunter1620doc.pdf

Each page of the tables covers ½ a degree and gives the logarithms of sines and tangents. The left-hand table “M” is minutes of a degree. (Gunter’s table does not have columns for cosine and cotangent, but note that log cos x = log sin (90\*- x) and log cot x = log tan (90\*- x). He is the first to use cosine and cotangent as words (see page 15 of the doc in the link above.)

Logarithm reminders:

by=x is logb(x)

Logarithm of 100 (base 10) = 2 or log10(100)=2

* If your triangle angles exceed 180\*, take the difference from the observed total
* If you measure a series of angles around a point in a full circle these should equal 360\*. If you go over divide the difference (as above) by the number of angles. Apply this proportional amount to each angle value so that the sum of angles now equals 360\*.
* Use Sine Rule to determine 2 unknown triangle lengths when you have one side length and its opposite angle + one other angle. For a triangle with angles A, B, and C and sides a, b, and c:

b = a sin B/sin A

c = a sin C/sin A

* Use Cosine Rule to find length of a side where you know two other dies and the opposite angle.

a2 = b2 + c2 -2bc cos(A)

Steps:

1. Determine who will play which roles these should stay stable throughout the exercise for consistency in practices):
   1. Draftsperson documenting built features including structures (as simple rectangles/squares), roads/pathways, and other human alterations to the landscape
   2. Draftsperson documenting natural features (*not including elevation*)
   3. Rodperson
   4. Observer
   5. Recorder (you might want to have 2 persons record independently so that you ensure accuracy)
   6. Calculator (could also be the rodperson, observer, or recorder depending on group #s)
2. Perform a quick reconnaissance to identify where you are going, what obstructions have to be accounted for, any other environmental factors.
3. **Decide where your triangles are located in order to meet your goals. Sketch these out in your notes to guide your work before you plot them on the drafting paper where you are making your map.**
4. Practice setting up your tripod with plane table.
5. Attach drafting paper to plane table with tape or screws.
6. Use the level on the compass to level the plane table
7. In your field notebook(s) you will have an entry for each station you visit. Use the sample field notes sheet to organize your data collection.
8. Set up at first station. Give this station a memorable name related to the environs.
9. Measure necessary angles, measure distances of triangle lengths as necessary. Remember to measure angles from center of tripod that is placed over station center. Measure lengths from same origin point. (See Methods for details below.)
10. Record station locations (lat/long) on map (See Methods below.)
11. Repeat as many times as necessary to find data required to achieve lab goals.
12. Perform calculations to measure lengths required.
13. Label map and indicate scale. Clean map after fieldwork is complete. Darken any lines that were merely sketched (with ink if you like).
14. Take a photo of your group field notes (one image/page).
15. Take a photo (perhaps multiples for detail) of your map.
16. Upload your map notes and images to the Lab Forum on Lyceum (be sure to indicate the names of your group members).
17. Complete the group and individual lab reports and email to me:
    1. Group report should include:
       1. Discussion of your triangulation method (about 200 words)
       2. Discussion of errors encountered and level of accuracy you were able to achieve (100 words)
       3. Discussion of what features you chose to represent and the rationale for your choices (100 words).
    2. Individual report should include answers to the following questions in about 200 words:
       1. What did you learn about the history of mapping from this exercise?
       2. How has the experience highlighted certain kinds of historical knowledge that was not as apparent from reading or discussion?

**Triangulation Lab Sample Field Notes**

**For each station, record the following:**

Project Name:

Date:

Observer name:

Recorder name:

Rodperson:

Instrument used (name of compass or graphometer):

Weather conditions:

Station name:

Station description:

Latitude/Longitude if known (you can use your compass app on smart phone for this):

Triangle being observed:

Depending on your instruments, the following columns are indicated. I have filled in the first row as an example.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Station Name (where you are located) | Line being sighted | Observed bearing (if using compass) | Angle name | Angle measurement | Distance of line being sighted *(if necessary to complete triangle measurements)* | Method of measuring distance |
| *David* | *David/Quad (rod should be placed at 2nd station)* | *Bearing of David to Quad* | *(empty if using compass)* | *(empty if using compass)* | *In feet* | *Pacing or tape to rod at 2nd station* |
| *David* | *David/Coram* | *Bearing of David to Coram* | *Quad/David/Coram* | *= difference in bearings (if using compass)*  *= angle measurement if using graphometer* | *Etc.* | *Etc.* |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |