6 Field Traverse and Area Measurements

Objectives:

1. Learn the principles of running a closed field traverse.
2. Learn how to properly adjust the measured values of a closed traverse to achieve mathematical closure.
3. Determine the error of closure and compute the accuracy of the work.
4. Learn how to calculate the area of a closed traverse.

Overview:

Balancing Horizontal Angles

The first step in adjusting closed traverses is to balance the horizontal angles. This is done by summing all of the interior angles measured and comparing them with the geometric sum of the angles. The geometric sum of the interior angles of any closed traverse is:

\[ \Sigma \text{Interior Angles} = (n-2) \times 180^\circ \]

Where:

- \( n \) = number of angles/sides of the traverse

If the sum of the measured angles does not add up to the geometric value, the difference is divided by the number of interior angles, and the result is then distributed. This correction is either added to or subtracted from each measured angle depending on whether the measured values sum to less than or greater than the geometric sum. This process of balancing horizontal angles should be done before leaving the field, because if there has been an error in measuring the angles it will show up in the sum and you will have the chance to re-measure.

Traverse Coordinates

There are both open and closed traverses; in this lab we will be performing a closed traverse. A traverse is used to determine the exact location of an unknown point. By knowing a bearing angle and a distance from a known point, the \( \Delta X \) (also called easting, or departure) and \( \Delta Y \) (also called northing, or latitude) from the known point can be calculated. The rectangular coordinates of the new point can then be determined with respect to the known point. If the known point already has coordinates, the \( \Delta X \) and \( \Delta Y \) are added algebraically to these coordinates. This procedure is followed around the traverse and the coordinates for each new point are determined.

For this lab you will be given points with known x and y coordinates (northing and easting, latitude and departure). The coordinates are based on the UTM NAD 1983 Zone 12 projection which covers all of Utah. As you work through the lab keep in mind that these coordinates are measured in METERS, not feet. This is very important when you input these coordinates back into ArcMap to create your plot because you could be off by a factor of three+ in your results. The map at the end of this lab shows six control points with a master control point in the middle. Using your given point and the master control point you will orient north, which will assist you by giving true bearings and azimuth angles for the sides of your traverse. You will then
be able to compute the correct UTM NAD83 Zone 12 coordinates to input into ArcMap so the representation of your area will be accurate.

Either azimuth or bearing angles may be used, along with a horizontal distance to compute \( \Delta X \) and \( \Delta Y \):

**Azimuth Angles**
\[
\begin{align*}
\Delta X &= D \times \sin A \quad \ldots \quad (5.2) \\
\Delta Y &= D \times \cos A \quad \ldots \quad (5.3)
\end{align*}
\]

**Bearing Angles**

Northeast Quadrant
\[
\begin{align*}
\Delta X &= D \times \sin B \quad \ldots \quad (5.4) \\
\Delta Y &= D \times \cos B \quad \ldots \quad (5.5)
\end{align*}
\]

Northwest Quadrant
\[
\begin{align*}
\Delta X &= -D \times \sin B \quad \ldots \quad (5.6) \\
\Delta Y &= D \times \cos B \quad \ldots \quad (5.7)
\end{align*}
\]

Southwest Quadrant
\[
\begin{align*}
\Delta X &= -D \times \sin B \quad \ldots \quad (5.8) \\
\Delta Y &= -D \times \cos B \quad \ldots \quad (5.9)
\end{align*}
\]

Southeast Quadrant
\[
\begin{align*}
\Delta X &= D \times \sin B \quad \ldots \quad (5.10) \\
\Delta Y &= -D \times \cos B \quad \ldots \quad (5.11)
\end{align*}
\]

Where:
- \( \Delta X \) = change in X
- \( \Delta Y \) = change in Y
- \( D \) = Horizontal Distance
- \( A \) = Azimuth angle (measured clockwise from north)
- \( B \) = Bearing angle

Bearings are measured to the east or west from an axis running north and south. The quadrants are set up like a rectangular coordinate system. The known point is the origin and the unknown point lies in one of the four quadrants. The unknown point is north \( \Delta Y \) and east \( \Delta X \) of the known point in the figure below.

![Bearing grid showing four quadrants](image-url)
**Vector of Closure and Precision**

If all measurements were perfect when you add up the $\Delta X$’s and $\Delta Y$’s for a closed traverse they would each sum to 0 for perfect closure. Unfortunately even with the best equipment and practices this is impossible and so you will need to calculate the error of closure in the X (east or departure) and Y (north or latitude) directions. The error of closure is computed as:

$$C_X = \Sigma \Delta X$$ .................................................. 5.12
$$C_Y = \Sigma \Delta Y$$ .................................................. 5.13

Where:

$C_X =$ total closure distance of X

$C_Y =$ total closure distance of Y

The vector of closure (or error of linear closure) is determined using Pythagorean’s Theorem.

$$\text{Vector of Closure} = [(C_X)^2 + (C_Y)^2]^{1/2}$$ 5.14

The precision of your traverse can then be determined by dividing the vector of closure by the total perimeter of the traverse. This number will be small and should be converted to a fraction of $1/$Precision, where Precision is a whole number (just use the $1/x$ button on your calculator). You should round Precision to the nearest 10 or probably 100. In other words, Precision reads something like “one in sixteen hundred” which interpreted means that for every 1600 units (i.e. feet, inches, or miles) you traverse, you will have 1 unit of error. As a further example, if the vector of closure is 0.07 feet and the perimeter distance is 573 feet, the degree of accuracy would be 1/8180 or perhaps better 1/8100 feet. You want to round down because to round up would be to report more accuracy than you actually attained.

**Compass Rule Adjustment**

The Compass Rule Adjustment is used in survey computations to distribute the error of closure proportionately between the different legs of the traverse. If done correctly the traverse will close precisely to the point of origin.

The correction to each traverse leg is determined by the ratio of the distance between the two points and the total perimeter as given in the following:

$$\text{AdjAB}_X = C_X \ast \frac{AB}{P}$$ .................................................. 5.15

$$\text{AdjAB}_Y = C_Y \ast \frac{AB}{P}$$ .................................................. 5.16

Where:

$\text{AdjAB}_X =$ amount of adjustment for length AB in the X direction

$\text{AdjAB}_Y =$ amount of adjustment for length AB in the Y direction

$AB =$ length between points A and B

$P =$ total distance around the perimeter of the traverse

**Computing the Area**

When the coordinates of a traverse are known, the area can be calculated directly. The simplest method for computing the areas is the Area Coordinate
method. This is done by arranging the coordinates in a clockwise direction as shown below. Cross multiplication of each \((x, y)\) pair is performed and the result placed to the left or right side as indicated. The left and right columns are summed and the absolute value of the difference between \(\Sigma_1\) and \(\Sigma_2\) divided by two is the area of the polygon.

\[
\text{Area} = \frac{|\Sigma_1 - \Sigma_2|}{2}
\]

Where:
- \(\Sigma_1\) = sum of values in the left column
- \(\Sigma_2\) = sum of values in the right column

![Diagram showing the method](image)

**Area Computation**

For bookkeeping purposes the first point is repeated at the bottom of the column. If the coordinates are listed counter-clockwise the result will be negative but the magnitude will represent the correct area.

The textbook shows this method horizontally. Both accomplish the same goal and actually do the same thing; they are just set up differently.

**Area Program**

This program calculates the area of a closed figure from measured data. Press the MENU key and \(P\downarrow [F4]\) to get to the PROGRAMS [F1] option. Press \(P\downarrow [F4]\) to get to the AREA [F1] option. We will use the MEASUREMENT option, therefore press YES [F2]. We also will not be using the grid factor, so press DON’T USE [F2]. Sight the prism on the first point and press the MEAS [F1] key, move the prism to the next point and re-sight on the prism and press the MEAS [F1] key again, continue sighting and measuring to all points. When 3 or more points are measured, the area surrounded by the points is calculated and the result will be shown. Be sure you are in the units that you want. This can be changed by pushing the UNITS key and selecting those you want.
GIS Application

By now you should have completed the labs “Introduction to GIS” and “Applications of GIS” and with this new information and skills you will now create a map layout of your closed traverse using ArcMap.

After you have completed all of the above (correcting your coordinates, closing your traverse, etc.) you will input your corrected values for coordinates into an Excel spreadsheet. The first column should be the x-coordinate (departure) and the second column should be the y-coordinate (latitude). Using the information and the skills you gained while covering the material in Module 5 of “Learning ArcGIS Desktop” you will input the data in ArcMap and create a layer with the points you surveyed during lab.

Once you have created your point feature class containing your data, you will create a professional map layout by adding a basemap, adding other layers that you downloaded in the assignment on creating a GIS map, and inserting map elements (north arrow, scale, legend). While creating your map keep in mind the audience and who the map is being created for. A good map will include more than the minimum.

Equipment:

♦ Total Station and tripod
♦ Prism and prism rod
♦ Pins (make sure you have 11 before you start and after you go in)
♦ ArcMap

Location:
Kimball Quad

Procedure:

1. Stake out an area on the Quad with five sides with tilted stakes. Tilting the stakes allow the tip of the rod be directly at the desired point, which is the intersection of the pin and the ground. When the Total Station is placed over that point, laser plummet onto the same pin-ground intersection. Each side of the traverse should be greater than 100 feet long.

2. Start your traverse on one corner of the area you just staked out and orient your total station to north.
   
   Note: If you need instructions on how to orient to north look at the instructions at the end of this lab.

3. Find the true azimuth angle to your first leg. Follow the same procedures of inverting and repeating as outlined in Lab 4. Because this azimuth angle will affect the rest of your traverse you should do at least a 3DR measurement (six measurements).

4. Each person will set up and run the instrument for at least one point of the traverse. Measure the horizontal angle and distance between the two adjacent points. Make sure you measure the HD, not SD, because you cannot assume the ground is level.

   Note: You will set up over each point of the traverse.
5. Each horizontal angle should be measured using one set, inverting and repeating (as described in Lab 4) each measurement. Measure the angle by turning between the pins, not the prisms, to avoid excessive error. Record the average of the angles (Hm). Each person should measure at least one angle set.

6. Determine the horizontal distances three times for each direction, then average the six values measured for each leg of the traverse to get the actual measurement.

7. Use the Area program on the Total Station to determine the area of the traverse. Remember the Total Station needs to be in a position to see all the vertices of the polygon, but not be on them. This can be either inside or outside the polygon or along one of the sides of the polygon.

8. Balance the angles as outlined in the lab. For this lab, if the sum of the interior angles is off by more than 1°, go back and re-survey.

9. Use the balanced angles to find bearings for each segment of the traverse. Going clockwise, use bearings and the horizontal distances to calculate X and Y coordinates for each point. You will calculate the bearing to the first leg from the true azimuth reading from Step 2 and then go around the traverse from there to find the other bearings.

10. Using your new data for point number one, calculate the closure error, and compute the precision of your survey.

11. Using the Compass Rule Adjustment, adjust the coordinates for each point. You will use the coordinates assigned to the first point of your traverse. See the map for point locations and coordinate values.

12. Calculate the area within the closed traverse.

13. Plot your traverse and create a professional map layout in ArcMap and turn in as part of your lab. Include labels for leg lengths and angle measurements.

**Field Book:**

1. Each person will do their own calculations using the group data.
2. Record the field notes for each set-up point.
3. Compute and show the error and the precision.
4. Show the balanced angles and each bearing.
5. Record the coordinates for each point. Show sample calculations.
6. Show calculations for the vector of closure and adjusting the coordinates by the Compass Rule Adjustment.
7. Sketch the area traversed and calculate the area.
8. Compare the area traversed by hand calculations, area given by the Total Station, and the area given by ArcMap.
9. Include a hand drawn sketch of your traverse in the field notebook and your printed ArcMap layout.
Lab 6 - Control Points

Legend

- Control Points

<table>
<thead>
<tr>
<th>Point</th>
<th>X Coordinate (m)</th>
<th>Y Coordinate (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>444,611.763</td>
<td>4,455,365.675</td>
</tr>
<tr>
<td>2</td>
<td>444,620.847</td>
<td>4,455,333.933</td>
</tr>
<tr>
<td>3</td>
<td>444,635.663</td>
<td>4,455,362.244</td>
</tr>
<tr>
<td>4</td>
<td>444,597.696</td>
<td>4,455,324.673</td>
</tr>
<tr>
<td>5</td>
<td>444,601.797</td>
<td>4,455,365.683</td>
</tr>
<tr>
<td>6</td>
<td>444,615.290</td>
<td>4,455,339.092</td>
</tr>
<tr>
<td>Control</td>
<td>444,621.640</td>
<td>4,455,361.450</td>
</tr>
</tbody>
</table>
Step 1 - Calculate differences in latitude and departure

Latitude

444,605.891 m - 444,621.640 m = -15.749 m

Departure

4,455,340.419 m - 4,455,361.450 m = -21.031 m

Step 2 - Calculate azimuth angle

<table>
<thead>
<tr>
<th>Quadrant 1 do:</th>
<th>Quadrant 2 do:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \tan \theta = \frac{</td>
<td>\text{Dep}</td>
</tr>
</tbody>
</table>

\[ \theta = \tan^{-1}\left(\frac{|\text{Dep}|}{|\text{Lat}|}\right) \]

<table>
<thead>
<tr>
<th>Quadrant 3 do:</th>
<th>Quadrant 4 do:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 180 + \theta )</td>
<td>( 360 - \theta )</td>
</tr>
</tbody>
</table>

Step 3 - Zero-set total station on control point

Step 4 - Turn back (left) calculated azimuth angle from control point

Because you zero set on the control point you will need to determine the angle the total station will end up on.

For example: If your Azimuth angle is 200 degrees, and you have zero-set on the control point, you will end up with a value on the total station of 360 - 200 = 160 degrees.

Step 5 - Zero-set total station on north