Lesson 7 – Topographic Surveying

The key idea in topographic surveying is to develop a three-dimensional map of the area to be surveyed. This comes down to assigning \((x,y,z)\) coordinates to every point, based on a common reference point.

The key to assigning coordinates to a point is to use a math coordinate system that can be used to make measurements from one point to another. The math coordinate system that is used is a spherical coordinate system that uses a vertical angle (zenith angle), a horizontal angle (azimuthal angle), and a radius.

The coordinate system shown uses a South Azimuth, which means that South is given a value of zero degrees. In Hawaii, all the maps use South Azimuth. However, in practice it is common to use North Azimuth for calculations of coordinates.

The zenith angle is the angle measured down from the vertical axis. A straight horizontal shot has a zenith angle of 90°.

The azimuthal angle is always measured in a clockwise direction if viewed from the top. In surveying, this is referred to as angle-right.

Here is a top view showing how South Azimuths are defined:
Here is how North Azimuths are defined:

The reason why North Azimuths are used for calculations is that they allow for a consistent way of determining the change in x and y coordinates. This is given by:

\[ \Delta x = D \cdot \sin(\alpha) \]
\[ \Delta y = D \cdot \cos(\alpha) \]

where \( D \) = length of shot
and \( \alpha \) = the North Azimuth

So, for example if you are shooting from A to B and these are the measurements:

\[ D_{AB} = 200.0 \text{ ft.} \]
\[ \alpha = 217^\circ \]

The change in x and y coordinates would be given by:

\[ \Delta x = 200.0 \cdot \sin(217^\circ) = -120.36 \text{ ft.} \]
\[ \Delta y = 200.0 \cdot \cos(217^\circ) = -159.73 \text{ ft.} \]

As expected, both of the changes are negative.

The use of North Azimuths allow using a computer program or a spreadsheet to calculate the changes in coordinates when carrying out a traverse.

Here is an example of carrying out a traverse that goes from point A to point B to point C. The starting coordinates at A are (100, 200). The following shows a spreadsheet used to calculate the coordinates of B and C:

![Spreadsheet Image]
The resulting values will be:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Station</td>
<td>D</td>
<td>α</td>
<td>x</td>
<td>y</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>B</td>
<td>138.65</td>
<td>60</td>
<td>220.074</td>
<td>269.325</td>
</tr>
<tr>
<td>4</td>
<td>C</td>
<td>223.45</td>
<td>200</td>
<td>143.650</td>
<td>59.351</td>
</tr>
</tbody>
</table>

That traverse would look like this:

Changes in elevation

The distance, D, between stations is a horizontal distance. However, the actual shot from one point to another could involve an elevation change as well. This is illustrated below:

\[ EL_B = EL_A + L \sin(90 - \theta_z) + H_I - H_T \]
Measuring distances

Taping
The most accurate method for measuring distances up to 200 feet is taping. The tape has to be held horizontally and with the correct amount of tension. You also perform corrections for temperature and correct for sag if the tape is not supported. You should only support the tape (lay it on the ground), if the ground is smooth and horizontal.

If you are doing surveying to set up a construction site, you should tape any distance that is shorter than 200 feet. For shots longer than 200 feet, you can use an electronic distance meter.

Natural Pacing
All surveyors and surveying field workers need to be able to use natural pacing to get a rough estimate of distances simply by walking the distance and counting steps. You should lay out markers 100 feet apart (using tape) and count the number of paces you take when you take your most comfortable steps. Do this back and forth a couple times and take the average of the four runs.

\[
\text{Natural pace} = \frac{100 \text{ ft}}{\text{number of paces}}
\]

People who are good at this can usually pace distances up to 200 feet or more with precisions of 1-2%. If you can get within 5%, that is considered minimally acceptable.

Natural pacing can be a very good time-saving procedure if used wisely. In addition, natural pacing can help prevent making bad errors in taping, such as those caused by failure to record a leg when breaking tape. Suppose you need to tape a distance of over 500 feet, and you are using tape that is 100 feet long. You will have to break tape at least 5 times to do that. But, suppose the person recording loses tracking of one of the 100 foot lengths. Natural pacing the distance can help you avoid making that kind of mistake.