Introduction to Land Measurement (Field Surveying and Navigation)

ESRM 304

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Overview

- Overview of surveying
- Survey mathematics
- Collecting and recording data
- Correcting data
- Completing data

Overview of surveying

What is surveying?

"The science and art of making all essential measurements to determine the relative position of points and/or physical and cultural details above, on, or beneath the surface of the Earth, and to depict them in a usable form, or to establish the position of points and/or details."

-American Congress on Surveying and Mapping (ACSM)

Overview of surveying

Why survey?

Surveying allows us to get accurate and valid measurements of things that are on the surface of the earth.

Why would this be important? What would you want to measure?

[Discussion]

History of surveying

Overview of surveying

History of surveying (from Wikipedia)

- The **Egyptian** land register (**3000 BC**).
- A recent reassessment of **Stonehenge** (**c.2500 BC**) indicates that the monument was set out by prehistoric surveyors using peg and rope geometry.
- Under the **Romans**, land surveyors were established as a profession, and they established the basic measurements under which the Roman Empire was divided, such as a tax register of conquered lands (**300 AD**).
- The rise of the Caliphate led to extensive surveying throughout the Arab Empire. **Arabic surveyors** invented a variety of specialized instruments for surveying, including:
  - **Instruments for accurate leveling**: A wooden board with a plumb line and two hooks, an equilateral triangle with a plumb line and two hooks, and a reed level.
  - A rotating **alhidade**, used for accurate alignment.
  - A surveying **astrolabe**, used for alignment, measuring angles, triangulation, finding the width of a river, and the distance between two points separated by an impassable obstruction.

Overview of surveying

History of surveying

- In **England**, The Domesday Book by William the Conqueror (**1086**)
  - covered all England
  - contained names of the land owners, area, land quality, and specific information of the area's content and habitants.
  - did not include maps showing exact locations
- **Continental Europe's Cadastre** was created in **1808**
  - founded by Napoleon I (Bonaparte)
  - contained numbers of the parcels of land (or just land), land usage, names etc., and value of the land
  - 100 million parcels of land, triangle survey, measurable survey, map scale: 1:2500 and 1:1250
  - spread fast around Europe, but faced problems especially in Mediterranean countries, Balkan, and Eastern Europe due to cadastre upkeep costs and troubles.

Overview of surveying

Surveying methods (2 main methods):

- Geodetic surveying
  - Takes into account the theoretical shape of the earth.
  - Generally high in accuracy, and covering large areas (greater than 300 mi^2).

- Plane surveying
  - Assumes that the survey area is a flat plane.
  - Generally covers small areas (less than 300 mi^2).
  - Most common method used.

Overview of surveying

Types of surveys

- Control surveys
- Topographic
- Land, Boundary and Cadastral surveys
  - Original surveys
  - Retracement surveys
  - Subdivision surveys
- Hydrographic surveys
- Route surveys
- Construction surveys
- As-built surveys
- Mine surveys

Overview of surveying

Control of the surveying profession and standards

- National Geodetic Survey (NGS)
- Bureau Of Land Management (BLM)
- The U.S. Geological Survey (USGS)
- The Defense Mapping Agency (DMA)
- U.S. Army Corps Of Engineers (COE)

Strict licensing

- State licensing boards
- Apprenticeships

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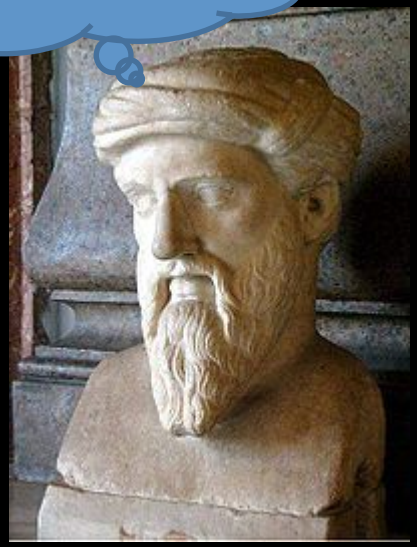
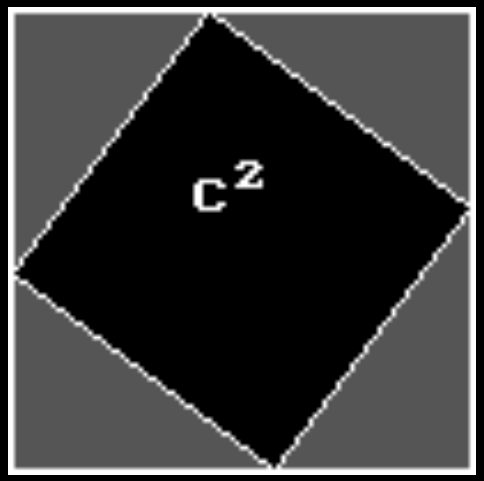
Survey mathematics

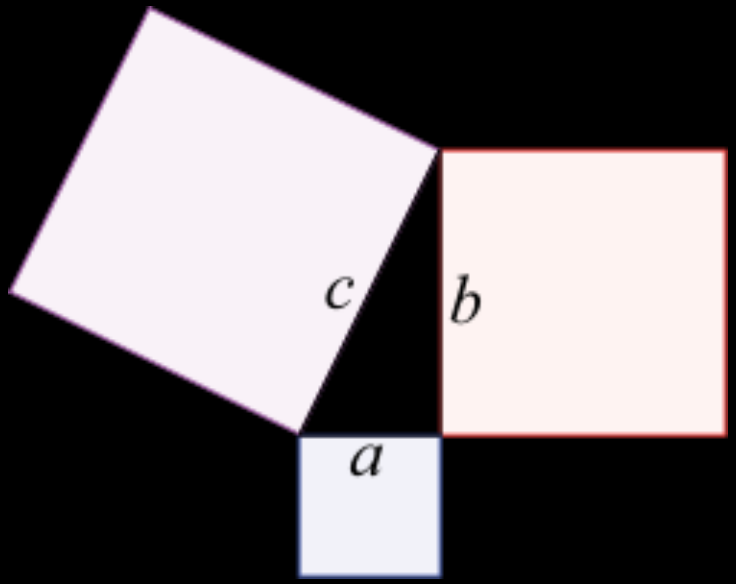
It's all about triangles:
Pythagoras knew,
and so should you!

$a^2 + b^2 = c^2$



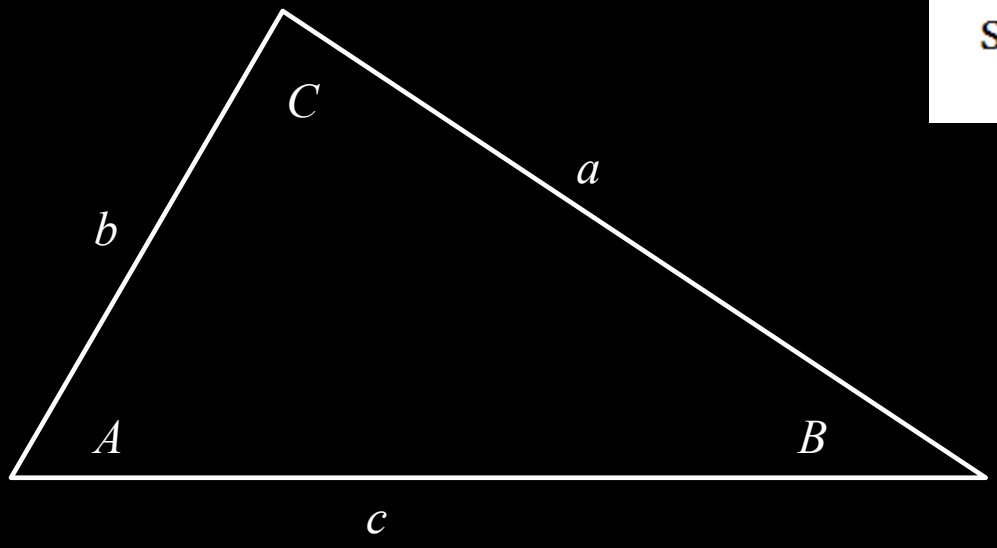
c. 570-c. 495 BC





Survey mathematics

The Law of Sines



$$\frac{a}{\sin(A)} = \frac{b}{\sin(A)} = \frac{c}{\sin(C)}$$

Survey mathematics

The Law of Sines:

- Given:
  - two sides and one angle *or*
  - two angles and one side
- It is possible to get values of all angles and all sides

Example: given side $a = 20$, side $c = 24$, and angle $C = 40°$

$$\frac{\sin(A)}{20} = \frac{\sin(40°)}{24} \qquad A = \arcsin\left(\frac{20\sin(40°)}{24}\right) \cong 32.39°$$

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Collecting and recording data

Measurement devices

- Three basic instruments are used, to measure distance and angles.
  - Compass for planimetric angle
  - Clinometer for elevation angle
  - Tape for distance

- Other devices may be used (e.g., theodolite, laser rangefinder), but the basic functionality is the same

Compass

- Looking from point to point, deviation from north is measured
- May include correction for magnetic declination (true north and magnetic north may vary)
- Mirror allows the user to sight the target and adjust the dial simultaneously
- May need to step away from ferrous metallic objects to avoid magnetic effects

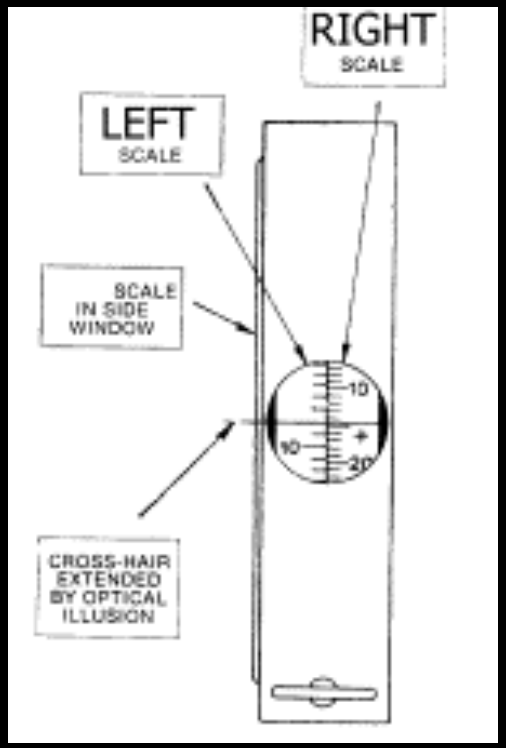
Compass

- Foreshot and backshot angles should be measured
- Foreshot angle+ 180° = Backshot angle
- Allows a check on your measurements
- If there is a large discrepancy, measurements should be repeated.

Clinometer

Rotating dial indicates angle of elevation

- Align the cross hair with the target
- Read the angle of inclination through the viewfinder
- Percent scale is on the right; degree on the left
- Depending on your application, record in either degree or percent (use percent for most applications)



Measuring tape

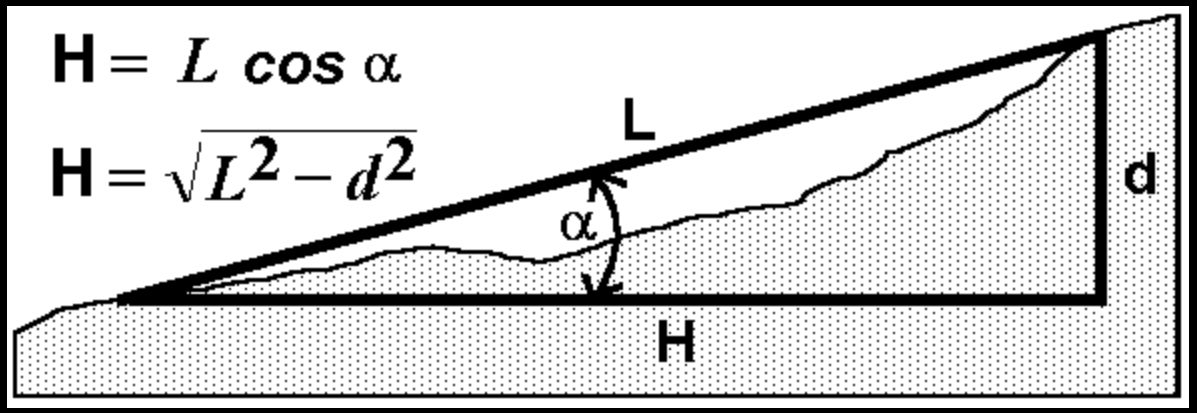
Simple device for measuring distance

- Various materials are used (for strength, lack of elasticity, etc.)
- Proper tension required to avoid sag
- Straight line required (sometimes vegetation needs to be cut)
- Air temperature should be recorded (due to shrinkage/expansion)

Measuring slope distance

Horizontal distances are assumed

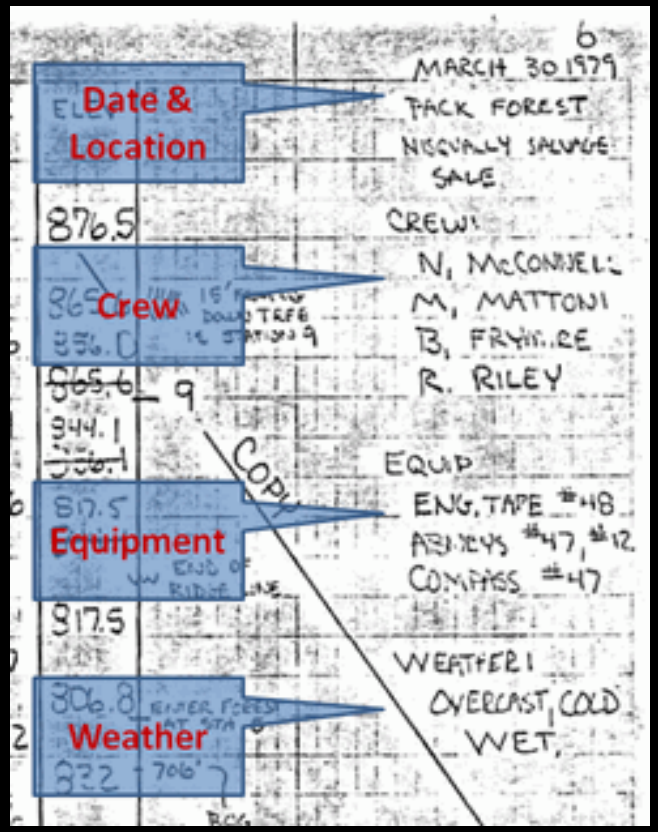
- If stations are not at the same elevation, the tape should be held level.
- If this is not possible, measure the elevation angle and correct using the law of sines



Collecting and recording data

Recording field measurements

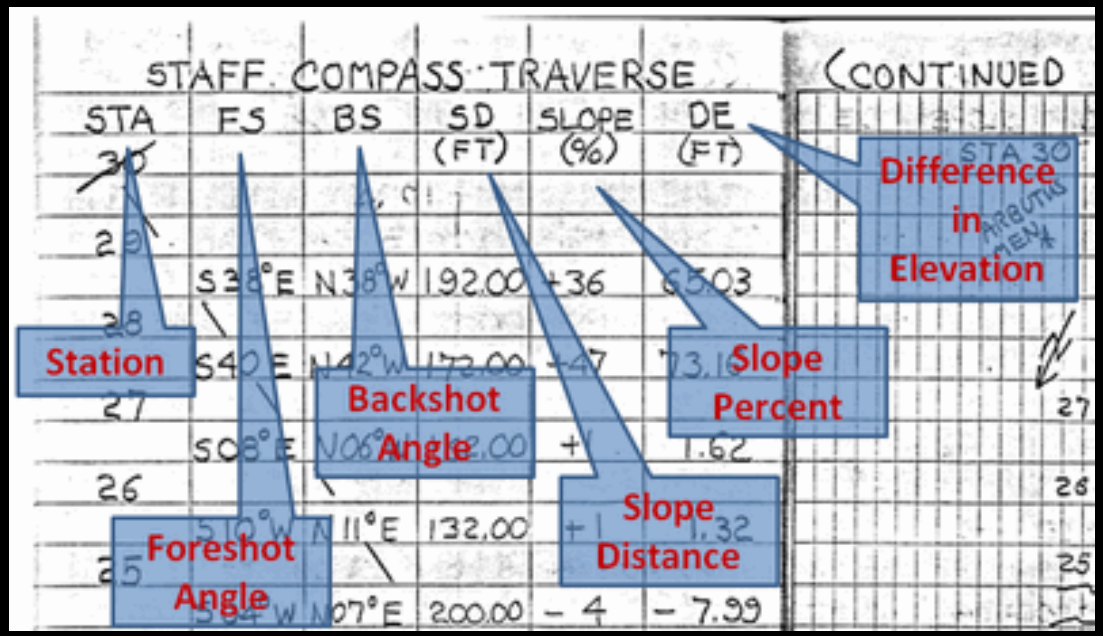
- Measurements should be taken carefully and recorded in field books
- Include general information



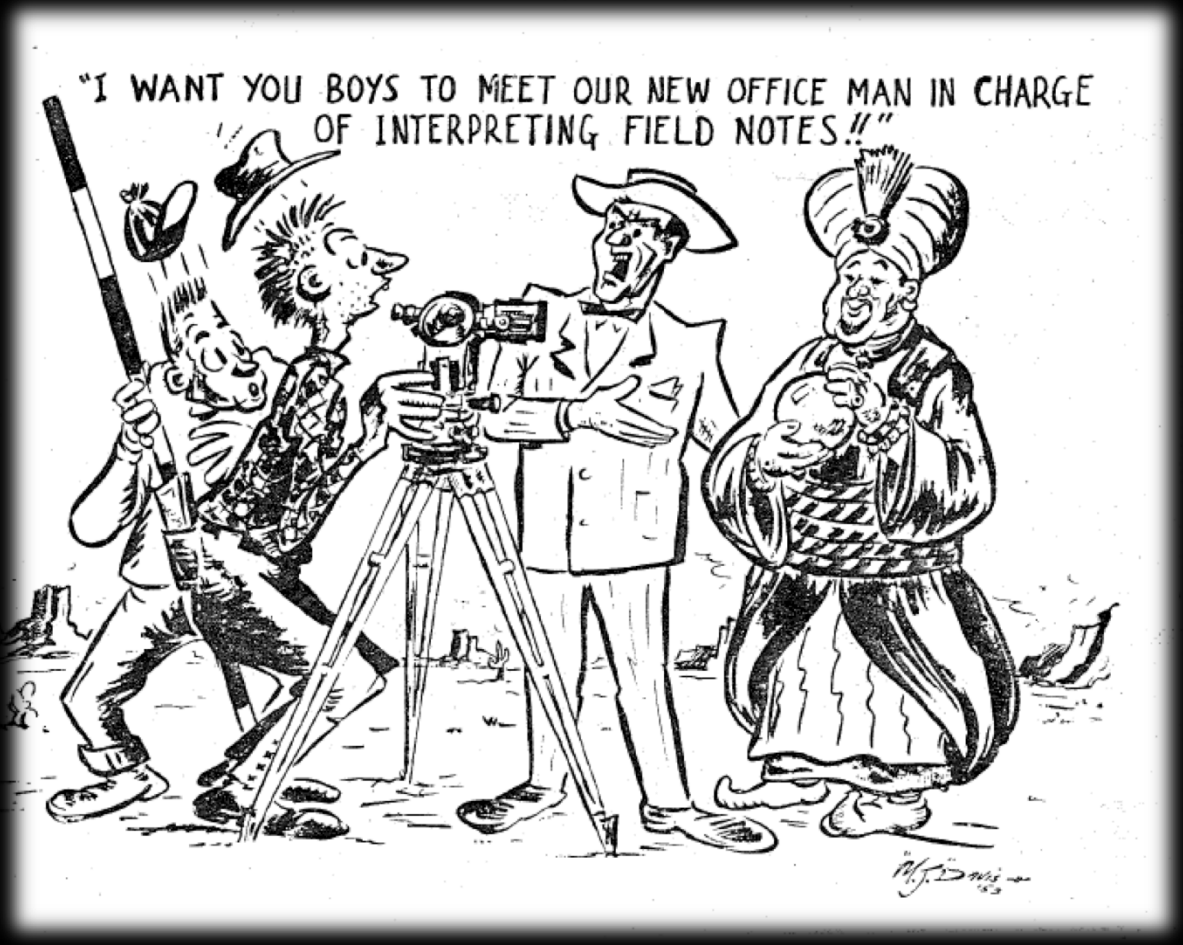
Collecting and recording data

Measurements are recorded in the field log book

- Station
- Foreshot angle
- Backshot angle
- Slope distance
- Slope (%)
- Difference in elevation



Interpreting Fieldnotes !!



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Station	FA	BA	SD	SLOPE %
1	138°	320°	79.5 ft	-4.5 % 7.5°
2	210°	30°	201.3 ft	-1 % 4°
3	344°	164°	42.5 ft	1 % 2°
4	22°	202°	173	1.5 % 3°

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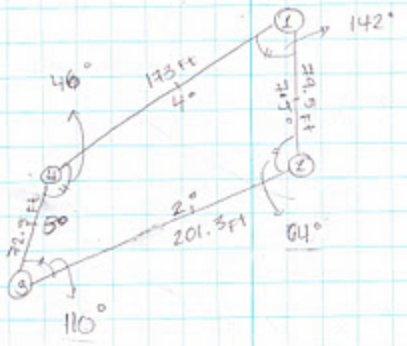
Date: Nov 9, 2011
Location: UW Rainier Vista, Seattle, WA
Crew: Tommy Vanness
Aliya Hall-ger
Afra Khan
Kathleen Dedos Reyes



weather: Clear skies, Partly cloudy
humidity: 44% Temperature: 59.5°C
Time: 1:30 - 2:30
measurements: Hand Compass
Clinometer
Cloth tape measure.

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Correcting data

No measurements are perfect. Various problems can arise from different sources.

- Some are systematic, and if known, can be corrected (e.g., incorrect tape length, incorrect declination set on compass)
- Some are random and cannot be controlled

- Examples
  - Device limitations (precision limits)
  - Environment conditions (e.g., expansion/shrinking of tape)
  - Blunders (user error)
  - Magnetic anomalies
  - Others?

Correcting data

Correcting angular error

- Sum of interior angles should be close to

$$\sum_{i=1}^{n} a_i = 180(n-2)$$

where *n* = count of angles

- Maximum error should be

$$k\sqrt{n}$$

where k = the smallest division readable on the compass

Correcting data

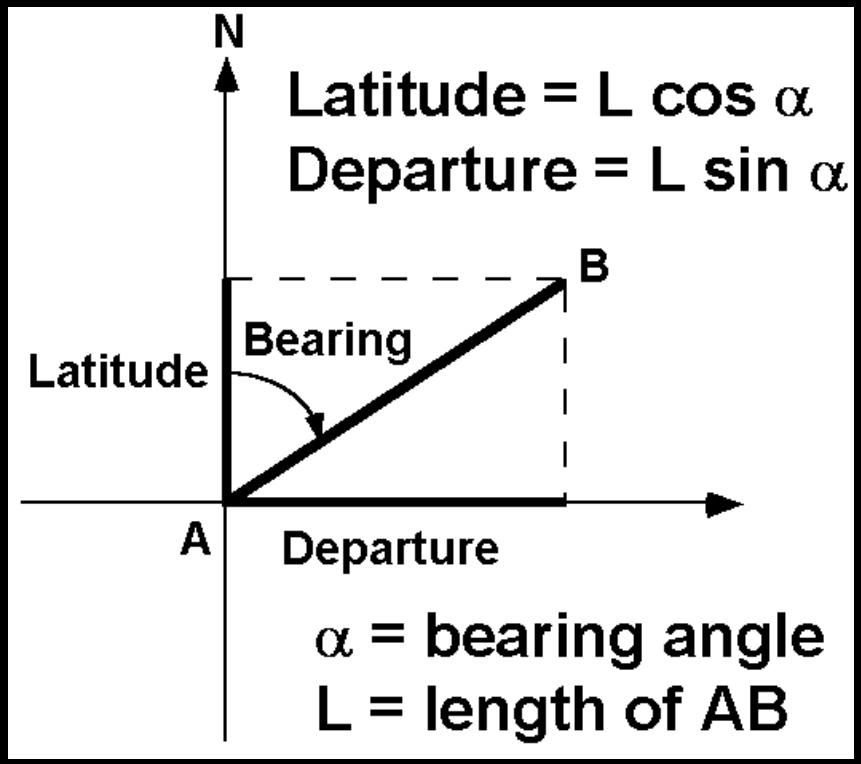
Correcting angular error

1. Calculate the theoretically "perfect" sum of interior angles
2. Calculate the measured sum of interior angles
3. Get the difference between the "perfect" and measured sums
4. Divide by the count of angles
5. Add back to each angle

Correcting data

Correcting linear measures

- First, relative coordinates of sides must be calculated (again, with trigonometric functions)



Correcting data

Correcting linear measures

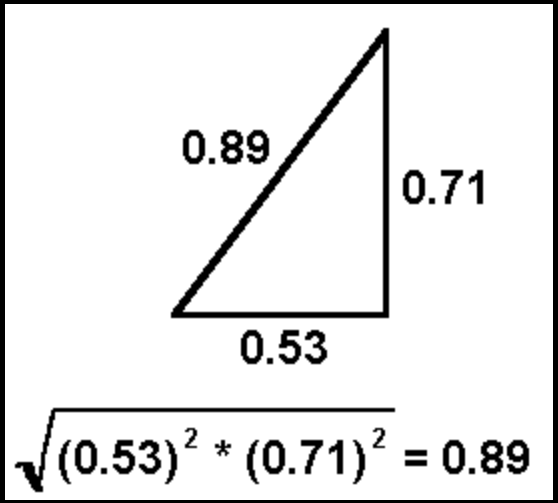
- Next, latitudes and departures are calculated for each side.
- Sums of latitudes and departures should equal zero
- Deviations are "misclosure"

Station	Azimuth	Length	Latitude	Departure
A				
	26° 10'	285.10	+255.88	+125.72
B				
	104° 35'	610.45	-153.70	+590.78
C				
	195° 30'	720.48	-694.28	-192.54
D				
	358° 18'	203.00	+202.91	-6.02
E				
	306° 54'	647.02	+388.48	-517.41
A				
MISCLOSURE			**-0.71**	**+0.53**

Correcting data

Error of closure (EOC) and precision: measures of how good the survey was

- EOC is calculated from the misclosures of latitude and departure



- Precision = EOC / traverse perimeter

Correcting data

Correcting linear measures

- Then, calculate an adjustment that distributes the latitude and departure error across each side

$$\text{Lat corr'n}_{AB} = \left(\frac{-(\text{Lat err})}{\text{Traverse dist}} \right) \times L_{AB}$$

$$\text{Dep corr'n}_{AB} = \left(\frac{-(\text{Dep err})}{\text{Traverse dist}} \right) \times L_{AB}$$

$$\text{Adj Lat}_{AB} = \text{Lat}_{AB} + \text{Lat corr'n}_{AB}$$

$$\text{Adj Dep}_{AB} = \text{Dep}_{AB} + \text{Dep corr'n}_{AB}$$

Station	Azimuth	Length	Latitude	Departure
A			**+0.08**	**-0.06**
	26° 10'	285.10	+255.88	+125.72
B			**+0.18**	**-0.13**
	104° 35'	610.45	-153.70	+590.78
C			**+0.21**	**-0.15**
	195° 30'	720.48	-694.28	-192.54
D			**+0.06**	**-0.05**
	358° 18'	203.00	+202.91	-6.02
E			**+0.18**	**-0.14**
	306° 54'	647.02	+388.48	-517.41
A				
TOTALS		**2466.05**	**-0.71**	**+0.53**

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Completing data

Getting XY coordinates of stations

- Start with one traverse vertex with known XY coordinates
- Add latitudes and departures sequentially

$$Y_B = Y_A + \text{latitude AB}$$

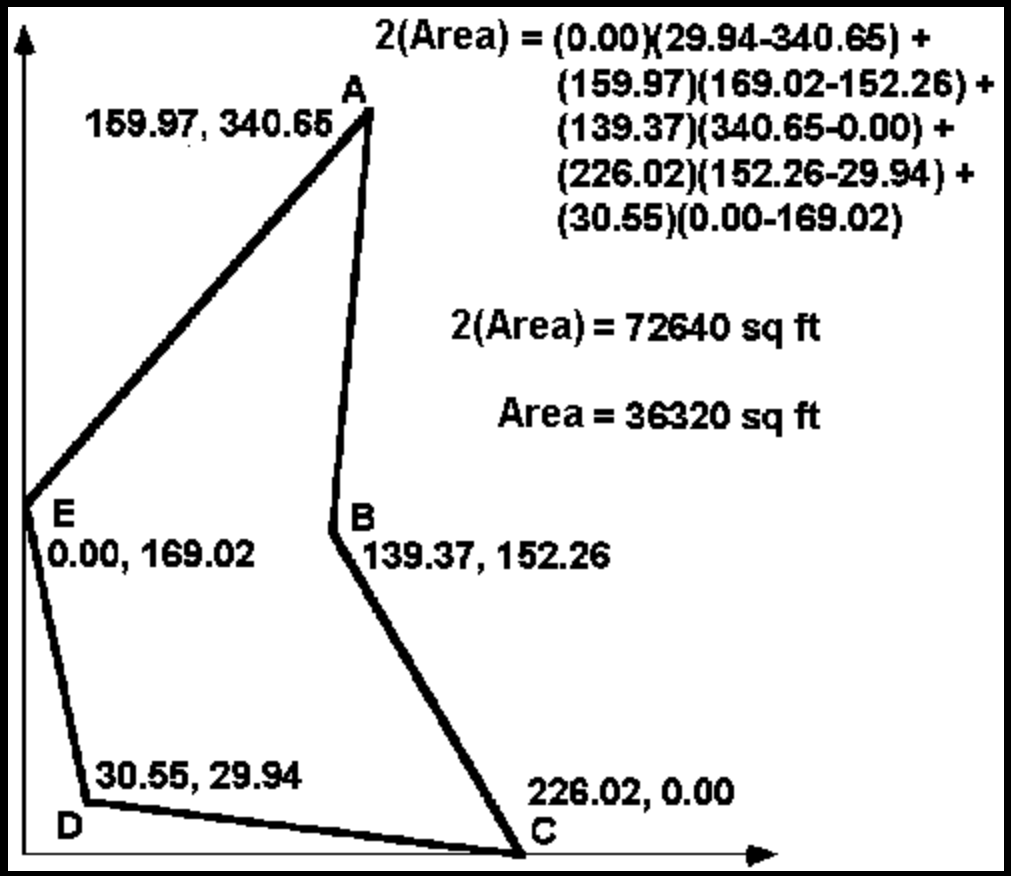
$$X_B = X_A + \text{departure AB}$$

	Balanced	Balanced		
Station	Latitude	Departure	Y-coord	X-coord
A			10000.00	10000.00
	+255.96	+125.66		
B			10255.96	10125.66
	-153.52	+590.65		
C			10102.44	10716.31
	-694.07	-192.69		
D			9408.37	10523.62
	+202.97	-6.07		
E			9611.34	10517.55
	+388.66	-517.55		
A			10000.00	10000.00
TOTALS	0.00	0.00		

Completing data

Calculation of area

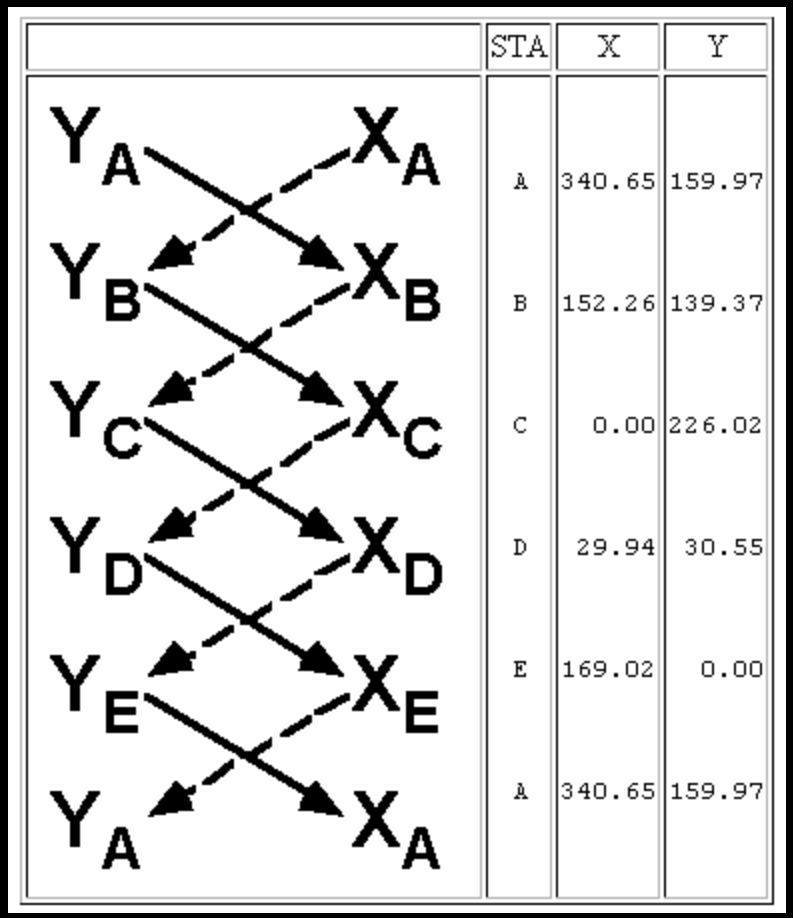
- X and Y coordinates are used to calculate area



Completing data

Calculation of area

- X and Y coordinates are used to calculate area



STA	X	Y
A	340.65	159.97
B	152.26	139.37
C	0.00	226.02
D	29.94	30.55
E	169.02	0.00
A	340.65	159.97

Sum1 = (340.65 * 139.37) + (152.26 * 226.02) + (0.00 * 30.55) + (29.94 * 0.00) + (169.02* 159.97) = 108928.30

Sum2 = (159.97 * 152.26) + (139.37 * 0.00) + (226.02 * 29.94) + (30.55 * 169.02) + (0.00 * 340.65) = 36287.63

108928.30 - 36287.63 = 72640.67

72640.67 / 2 = 36320.33 square feet

Completing data

Mapping

- XY coordinates can be plotted on a map or entered into a GIS

Surveying Assignment

Assignment

- No field work this module, this year
- Link to the Assignment is on the 304 "Schedule" page
- Remember to use your browser's "back" button to navigate back to where you've been
- Due Wed 4 Dec 2013 in the Collect It Dropbox

