Lab 3: Land Navigation

OBJECTIVES

This exercise will take you through some basic land navigation methods. You will learn how to use a compass, orient a map, read bearings, location your position by resection, and traverse a multi-leg dead reckoning course.

MATERIALS

USGS Goleta Quadrangle map, Magnetic compass, Ruler, Protractor, Pencil, Calculator

BACKGROUND

True North (geographical north)	Direction to the geographical north pole along a line of longitude.
Magnetic North	Direction to the north magnetic pole
Magnetic Declination	Difference between true north and magnetic north at any given location
Azimuth	Direction of one point of interest to another, usually expressed in degrees (0-360) relative to north.
Bearing	Direction, not exceeding 90 degrees, measured from either a north or south baseline, whichever is nearer to the direction being designated.
Resection	Method of determining one's location by reference to three known features on the ground.
Dead reckoning	Method used by navigators for route planning or for keeping track of progress toward a destination. Depends on knowing (or predicting) the starting point and the direction, speed, and time of travel away from that point.

EXERCISE

Part 1. Map Orientation

Magnetic Declination

A map can be oriented simply by relating it to recognizable landmarks in the landscape, although a more exact method of orientation involves a compass. Most maps, including quadrangles, are oriented with *true (geographic) north* at the top because the geographic North Pole (the axis around which the earth rotates) does not change over time. However, a compass needle will point to *magnetic north*, which is determined by the earth's magnetic field. Unlike the geographic north pole, the location of the north magnetic pole changes slowly over time, and is currently in northern Canada (approximately 700 km from the geographic north pole). Magnetic declination, the deviation between true north and magnetic north at a given location, must be taken into account when orienting a map.

a. Declination information is usually printed on USGS quadrangles to the left of the scale bar at the bottom of the map. Copy the declination diagram from your quadrangle in the space below.

b. According to this declination diagram, what is the magnitude (degree) and direction of the magnetic declination on your map? _____

c. What is the date of this information? _____

d. Does true (geographic) north point to the east or to the west of the direction of your compass needle? _____

e. Current magnetic declination can be estimated for your location at the NOAA Geophysical Data Center website, http://www.ngdc.noaa.gov/geomagmodels/Declination.jsp. What is the current declination for your location?

_____

f. By how much is it changing every year?

_____

Part 2. Bearings

Azimuths

Azimuths are measurements of direction between two points in degrees (0-360). While it can be measured from any baseline, it is usually measured in a clockwise direction from north, making north 0°, east 90°, south 180°, and west 270°. It is important to note which North is your reference. We'll practice measuring and converting between true and magnetic north, and converting forward azimuths to back azimuths. A back azimuth is the exact reverse of forward azimuth, always differing by 180 degrees.

Quadrant Bearings

A quadrant bearing is the angular difference from a north or south reference to the direction of the surveyed line in degrees (0-90). It contains three parts:

- Base direction (N or S)
- Angle between the base direction and the surveyed direction (not to exceed 90 degrees)
- Direction of travel (E or W)

a. Locate these UTM coordinates on the Goleta map using the TerraGo Toolbar. Use NAD83/UTM11N.

Point A: NW Corner of Ellison Hall, UCSB Campus
UTM: 238471E, 3811937N

Point B: Benchmark 24 (Behind Vons on Fairview)
UTM: 239633E, 3814788 N

Use your ruler to draw a line between the two points. Set your compass to zero and put the compass edge along the drawn line, careful to put the compass travel arrow in the direction of the azimuth. Now, rotate the bezel until the needle is boxed. Read the bearing on the travel arrow which indicates the magnetic forward azimuth.

b. Record the magnetic forward azimuth in the table, using whole degrees. From this, calculate the true azimuth. If your declination is *west*, subtract the declination from the magnetic azimuth to get true azimuth. If the magnetic declination is *east*, you'll add the declination to magnetic north to get true azimuth. Finally, calculate back azimuths from both true and magnetic forward azimuths. Do the same for Quadrant Bearings and Back Bearings.

- If azimuth is less than 180 degrees, add 180
- If azimuth is more than 180 degrees, subtract 180
- Ex: Forward Azimuth = 10 degrees
  Back Azimuth = 10 degrees + 180 = 190 degrees

	Magnetic Azimuth	True Azimuth
Forward Azimuth		
Back Azimuth		
Quadrant Bearing		
Back Bearing		

c. Locate these UTM coordinates on the Goleta map using the TerraGo Toolbar. Use NAD83/UTM11N.

Point C: Middle of Goleta Pier (at the bend)
UTM: 239997E, 3811736N

Point D: End of Goleta Pier
UTM: 240050E, 3811573N

d. Complete the table for points C to D.

	Magnetic Azimuth	True Azimuth
Forward Azimuth		
Back Azimuth		
Quadrant Bearing		
Back Bearing		

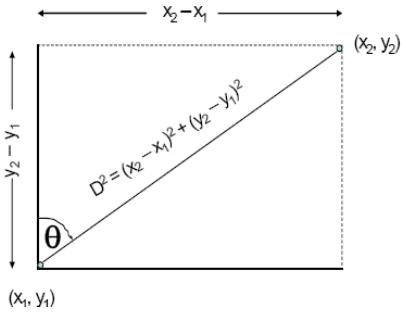
Part 3. Calculating Distance and Bearing

Given the coordinates for two points, we can calculate the distance between them and their bearing without a compass. Here we will use the UTM system for all coordinate calculations. You may wish to review the distance formula (Pythagorean Theorem) and sine, cosine, tangent, radian, and arc-tangent.

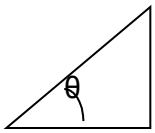
$\sin \theta = (x_2 - x_1)/D$

$\cos \theta = (y_2 - y_1)/D$

$\tan \theta = (x_2 - x_1)/(y_2 - y_1)$



a. Using the formula above and basic trigonometry, calculate distance and azimuth using the coordinates for points A, B, C, D. Show your sketch of the angle you are measuring. Tip: Remember to add or subtract 90, 180, 270 to your angle θ when necessary.

Heading	Distance	Bearing
Example: X to Y X (235000 mE, 3811000 mN), Y (235650 mE, 3811200 mN)	ΔE = 235650 − 235000 = 150 m ΔN = 3811200 − 3811000 = 100 m D = $\sqrt{(\Delta E^2 + \Delta N^2)}$ = 180 m	 sin θ = 100 m / 180 m θ = 33.7° azimuth = 90 − 33.7 = 56.3°
A to B		
D to B		
C to D		

D to C		

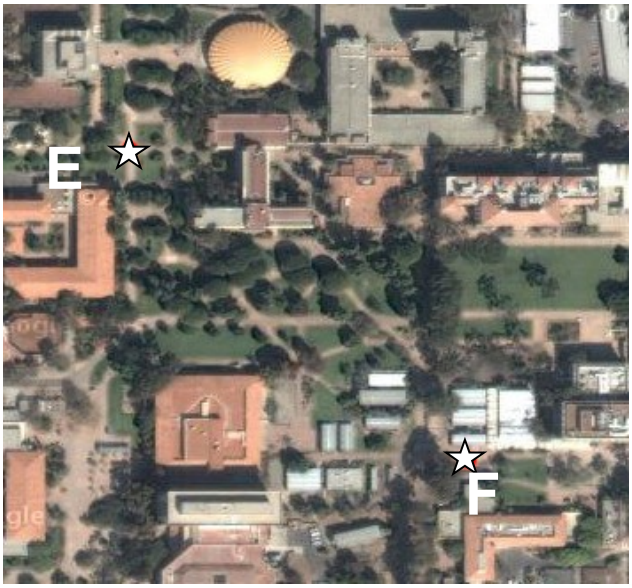
Part 4. Resection - On your own time

Now you can get from point A to point B on a map using your compass, but what if you're unsure of where you are on the map? You can locate your position on a map quite accurately by using your compass to triangulate between three points in a method called resection. This is an important skill that you should practice on your own.

Take a magnetic azimuth with your compass on a distant landmark you see in the landscape and also recognize on the map. Calculate back-azimuth and draw this line through the landmark on your quadrangle. Repeat three times. Now, extend those lines with your ruler to where they look like they will meet. The point where the three lines converge on the map is where you are. Depending on your accuracy, there will probably be some error in your location called the Triangle of Error. Your location on the map is somewhere within this triangle.

Part 5. Dead Reckoning by Pace and Compass

Dead Reckoning is the process of estimating current position based upon a previously determined position and advancing that position based upon known or estimated speeds over elapsed time (distance travelled), and course (direction). In this next section, you will construct a dead reckoning course that you will follow to evaluate how effective dead reckoning is as a method of navigation, not simply get from place to place (which is relatively easy to do on campus).



a. An image of a portion of the UCSB campus has been provided. Use the star E as your starting point, and star F as your endpoint.

Point E: 238428E, 3811927N Point F: 238614E, 3811717N

b. Now we will establish the scale of this campus image.

What is the ΔEasting (Easting2 - Easting1)?

What is the ΔNorthing (Northing2 - Northing1)?

What is the distance between the points? $D=SQRT(\Delta E^2 + \Delta N^2)$

c. With a partner, construct a dead reckoning plot on the map with <u>at least four legs</u> that takes you from Point E to Point F. For each leg you will need a magnetic azimuth and a distance. An example might look something like this:

Leg 1: Magnetic Azimuth 180°, 100m
Leg 2: Magnetic Azimuth 90°, 100m
Leg 3: Magnetic Azimuth 180°, 100m
Leg 4: Magnetic Azimuth 90°, 100m

Be creative with your course. Avoid buildings, and try to make a course that doesn't always follow right angles. As you construct the course, first draw in the legs on the image. Measure the distances in centimeters for each leg and then convert to meters. Measure the azimuths with your compass and convert to true azimuths.

You can use the distance measurement tool in TerraGo Toolbar to help you create a route. However, it only gives measurements in feet, so you will need to translate the measurements into meters. It also gives bearings, which can help you with the calculations.

Fill in your dead reckoning course here. You will fill in column 5 later:

Leg Number	Magnetic North Azimuth (degrees)	True North Azimuth (degrees)	Distance (m)	Distance (Paces)
1				
2				
3				
4				

d. In order to follow distances, you will need to know how many paces of yours equal one meter. You will be shown two points near Ellison Hall that are 100 meters apart, marked by yellow survey tape. Point 1 is at the base of a tree at the south-side of the North-West corner of Ellison Hall, by the pencil sculpture. Point 2 is near the coral tree café. Walk from one end of this course to the other, and count your paces and record below. Now walk from Point 2 to Point 1, again counting your paces. Average the two numbers to get a more accurate measurement. Remember, everyone's stride is different.

How many paces equal 100 meters?

Number of Paces from Point 1 to Point 2:_____

Number of Paces from Point 2 to Point 1: _____

Average: _____

Using the average, what is the length of your pace in meters? _____

e. Fill in the last column of your dead reckoning plot by converting each leg's distances in meters plot to distance in paces. Divide the given distance of each leg by the length of your pace. For example, if my leg is 100 meters in length, and the length of my pace is .64 meters, I need 156 paces to walk 100 meters.

f. Now, walk the course. Start at Point E. Turn the bezel of your compass to the desired magnetic azimuth. Hold the compass directly in front of you, and rotate your body until the needle is boxed. You are now facing the direction you want to go. Walk and count paces for the length of the leg, then stop, and repeat for each leg. After you have walked your course, use landmarks to locate yourself on the map, and mark final position on your map with an X. **Don't use the map while you are walking your dead reckoning course.**

g. How far off were you from the endpoint (in meters)?

h. Where do you think the most error arose as you walked your dead reckoning course? What are other sources of error?

REVIEW QUESTIONS

1. What are the three ways of expressing scale on a map?
2. Define dead reckoning and its purpose.
3. Describe resection and how it is used.
4. Compare azimuth and bearing.

This lab was developed by Susan Tran | UCSB Geography | September 2009