Review: Position Finding

- Environmental
- Aids to Navigation
  - Map+
  - Compass (declination)
  - Gyrocompass
  - Digital compass
  - GPS

Grid, True and Magnetic North

UTM Grid and 1988 Magnetic North Declination at Center of Sheet

6400 MILs to a circle

Declination WEST

Magnetic north is 10 degrees west of true north

To correct a map TRUE bearing (e.g., 30) to MAGNETIC, we need to rotate the map counterclockwise to correct

So declination is ADDED to the magnetic bearing

WEST IS BEST, SO ADD 30 + 10 = 40

For magnetic to true, do the opposite (SUBTRACT)
Declination EAST

Magnetic north is 10 degrees east of true north

To correct a map TRUE bearing (e.g. 30) to MAGNETIC, we need to rotate the map clockwise to correct

So declination is SUBTRACTED from the true bearing

EAST IS LEAST, SO SUBTRACT
30 – 10 = 20

For magnetic to true, do the opposite (ADD)

Quick solution

- Remember:
  1. START WITH THE TRUE BEARING (map to compass)
  2. WEST IS BEST ADD: EAST IS LEAST SUBTRACT
  3. NOTE THAT YOU MAY GO OVER 360, IF SO JUST SUBTRACT 360 FROM RESULT
  4. TO START WITH MAGNETIC NORTH BEARINGS, DO THE OPPOSITE

Flight gyrocompass: Azimuths/10

For the Kiosk by Campbell Hall
(34 24 58N 119 50 44W)

Declination 7/7/1988 = 14° E
Declination 10/29/2008 = 13° 15’ E changing by 0° 5’ W/year
Declination 10/20/2010 = 13° 03’ E changing by 0° 5’ W/year
Declination 10/19/2011 = 12° 57’ E changing by 0° 5’ W/year
Same goes for GRID

- Look at declination diagram
- Compute from change diagram and declination map or NGS web site
- Correction depends on UTM easting wrt 500000
- Usually averaged at center of map sheet

UTM grid North

UTM Grid North and True North

Directions on Maps

- Orthodrome: line of true azimuth, Great Circle
- Loxodrome (aka Rhumb line): Constant azimuth; directional line that crosses each successive meridian at a constant angle
Navigating along a great circle

- Need to convert compass bearing to true north
- Azimuth = bearing
- Course vs. bearing

Map orientation

- Use all possible position clues to physically rotate map to align with landscape
- Many in-vehicle systems (and GE) rotate to direction-of-motion (North up vs. Direction ahead) and perspective
- Simplest navigation: pick target or intermediate target and align

Map inspection and resection

Select visible target along azimuth
Route Selection

Objective: get from A to B BUT…..

• Positive
  – Minimize time, distance, gradient
  – Maximize safety, scenery
  – Visit N locations, include points

• Negative
  – Eliminate obstacles
  – Avoid locations, areas, turns, risks
  – Three rights can make a left!

Least cost path

Hierarchy: Washington DC Metro
Shortest path

The importance of landmarks

Route selection at sea

NOS Charts
- Harbor Charts
- Coast charts
- General charts
- Sailing charts

Ocean Charts

- Show azimuths and conversions
- Show many features, aids, and “hazards to navigation”
- “Notice to Mariners” and revisions
- Nautical mile: length of a minute of arc (1852m, 6076.12ft., 1.151 statute miles)
- Knot (kt) a unit of speed equal to one nautical mile (1.852 km) per hour, approximately 1.151 mph
- Distance by dividers, bearing by straight edge
- Includes soundings, sea level, currents & tides
Ocean currents: Global and local

Distance and bearing

Dead reckoning

- Oldest way of navigating (and position finding) at sea (and on land)
- Divide trip into legs
- Legs are distance and bearing only
- Errors are additive and multiplicative!
- Errors common in $d$, but measurement of $b$ also poor

Typical Dead Reckoning Plot

C=course (bearing) S=Speed (kts)
Navigation Aids at Sea

RADAR
- Radio detection and ranging
- Beam of radio signals from known points
- Measures return (reflection from object)
- Beam sweeps to get 360 degrees
- Interpretation a skilled art!

RDF Radio Direction Finding
- Radio signals transmit from multiple known locations
- Receiver computes range and solves for position
- Works in all weather
- Common in aircraft

LORAN
- Master and slave synchronized radio transmitters
- User measure time between receiving two signals
- At all equidistant points, signals arrive together
- Time delays are printed on LORAN charts
- Some atmospheric issues, and PDOP
- World-wide system of transmitters & charts
- Similar DECCA system outside N. Pac, N. Atl and Med.

LORAN: How it works
A arrives before B
B arrives before A
**LORAN map with delays**

**Air Navigation**

- Various maps and charts at scales from 1:12K to 1:2M
- Global coverage at 1:1M WAC; DoD 1:250K JOG
- Lambert conformal conic: Shows land only
- Corrected by Notice to Airmen (NOTAM)
- Overseen by FAA
- Includes graticule/restrictions/radio navigation by RDF

**JOG: San Diego**

**WAC legend**
IFR/VFR

• Different charts for Visible vs. Instrument flight rules
• Both include maximum elevation in grid cells
• Concept of vectors, flight plans
Direction indicators!

Height in aircraft
- Altimeter: uses $h = f(P)$
- Must continuously correct, via radio

Summary
- Maps show information that allows direction finding
- Projection (grid) and declination are important
- Maps are often more useful when oriented
- Route selection depends on goals
- Simplest is dead reckoning
- Many different aids to navigation for air, land and sea
- Special purpose charts assist navigation