Analytical and Computer Cartography

Lecture 3:
Review: Coordinate Systems
Figure 2.6 Geographic coordinates. The familiar latitude and longitude system, simply converting the angles at the earth’s center to coordinates, gives the basic equirectangular projection. The map is twice as wide as high (360° east-west, 180° north-south).
NAD83

- NAD27 remained in use until the earth-centered international GRS80 was complete (Geodetic Reference System 1980)
- Then converted to NAD83, using GRS80 ellipsoid
- Very similar ellipsoid WGS84 was adopted by DOD and many other mapping agencies
- Meades ranch now just a historical relic
IERS

- Provides data on Earth orientation, on the International Celestial Reference System/Frame, on the International Terrestrial Reference System/Frame, and on geophysical fluids
- Maintains Conventions containing models, constants and standards
- Includes ITRS
## Organization

The IERS was established in 1987 by the International Astronomical Union and the International Union of Geodesy and Geophysics. According to the Terms of Reference, the IERS accomplishes its mission through the following components: Technique Centres, Product Centres, Combination Centres, Analysis Coordinator, Central Bureau, Directing Board.

- More

## Data / Products / Tools

The IERS provides data on Earth orientation, on the International Celestial Reference System/Frame, on the International Terrestrial Reference System/Frame, and on geophysical fluids. It maintains also Conventions containing models, constants and standards.

- More

## Publications

The IERS issues Messages to distribute news, Bulletins to provide Earth orientation data, Technical Notes to publish research results and proceedings of workshops, and Annual Reports to inform the public about its work.

- More

## Science background

Information about Earth rotation, reference frames, and observation techniques in general - Glossary - References - List of acronyms.

- More
NAD2022 and NAVD2022

• North American Datum of 1983 will be replaced by a new geometric datum which provides latitude, longitude, height and time information.

• Will rely completely on the CORS network (continuously operating reference stations)

• NGS is completing a major project called Gravity for the Redefinition of the American Vertical Datum, or GRAV-D.

• The scale of the change will vary depending on your location, ranging from 0.5 to 1.5 meters in a horizontal direction, and 0 to 1.3 meters in elevation.

• Many state and other governmental entities passed laws on NAD83 that will need to be changed to reflect the new datum

• Will create the National Spatial Reference System
Resources

- http://alt.ngs.noaa.gov/web/science_edu/online_lessons/
- http://www.ngs.noaa.gov/corbin/class_description/NGS_Video_Library.shtml
NAD83 to NAD2022

Approximate Ellipsoid Height Change

Ellipsoid Height (Meters)

High: 2 m
Low: -2 m
Datums and Map Projections

- Assuming an earth model sets the initial surface that will be transformed
- Influences both position and height
- If projection does not document the datum, it may be irreversible
- Most GIS packages create metadata files that establish key parameters
- After NAD2022, time will be an integral part of position
### Ways to Record Lat/Long

<table>
<thead>
<tr>
<th>Method</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decimal Degrees</td>
<td>38.8998339 -77.0463660</td>
</tr>
<tr>
<td>DMS</td>
<td>38°53′59″N 077°02′47″W</td>
</tr>
<tr>
<td>Hemisphere First</td>
<td>N38°53′59″W077°02′47″W</td>
</tr>
<tr>
<td>Decimal Minutes</td>
<td>38°53.98′ N 77°02.78′W</td>
</tr>
<tr>
<td>Decimal Seconds</td>
<td>38°53′98.333″ N 77°02′78.333″W</td>
</tr>
</tbody>
</table>
Problems with Geographic Coordinates

• Spherical geometry difficult, need great circle arcs for many applications
• Precision depends on mixed DMS and DD origin maps
• Axes are not orthogonal
• Difficult to use algorithms for spherical measurements e.g. simple distance in $x = \cos(\phi)$
• Solution: Planar geometry
• But, price is living with an imperfect projection
USGS Topographic maps

• Seven and a half minutes of longitude wide
• Seven and a half minutes of latitude high
• So why aren’t they square?

7 ½'
Let's check two locations

Flag Island, Minnesota at 49°22′N

Card Sound, Florida at 25°22′N
Card Sound, Florida at 25°22'N.  
Flag Island, Minnesota at 49°22N.
Using Projections

• Choice of projection allows control over map center, plus pattern of distortion
• Can optimize projection for map purpose, e.g. choose standard parallels
• Allows customizations for particular maps and applications, e.g. navigation
• Often chosen once then choice remains in place
• E.g. Mercator for navigation by compass
Great circles are straight on some conformal projections (Gnomic): Note crossing angles
JFK to LHR: Approximating a great circle on the Mercator. Only 41km farther (0.74%)
Projection and Coordinate Systems

• A coordinate system is a standardized method for assigning codes to locations so that locations can be found using the codes alone
• Standardized coordinate systems use absolute locations
• In a coordinate system, the x-direction value is the **easting** and the y-direction value is the **northing**
• Most systems make both values positive
• Can use letters, numbers
• Can interweave digits for x and y
Coordinate Systems for the US

- Some standard coordinate systems used in the United States are:
  - geographic coordinates
  - universal transverse Mercator system
  - military grid/MGRS/National grid
  - state plane

- To compare or edge-match, both maps MUST be in the same coordinate system.
Equatorial Mercator
The advantage of the transverse Mercator projection
UTM

• Universal transverse Mercator coordinate system
• Basis for 3 grid systems: Civilian UTM, MGRS and US National Grid
• Used in Hybrid form by geohack
• Uses 60 projections with 6 degrees between central meridians
Applies 80°S to 84°N
60 zones each $6^\circ$ of longitude wide
UTM Zones

• One degree = 111,111m
• Six degrees = 666,666
• Set Zone false origin so that central meridian is 500,000m
• Gives 166,666m of overlap on each side at equator
• Overlap ends at about 25°N/S
Zones overlap slightly when 1 million meters wide
Grid north and the Zone

UTM GRID AND 1988 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
Universal Polar Stereographic (UPS)
Example, GPS fix

238499E; 3811905N 11, N
Geohack Isla Vista
UTM zones in the USA
Military Grid Coordinates
First Reference (6 x 8 degrees)
USMG: 2\textsuperscript{nd} Reference 100,000m cells
MGRS Grid Cell Designators
Produced by the United States Geological Survey
North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS84). Projection and
1 000-meter grid: Universal Transverse Mercator, Zone 15R
10 000-foot ticks: Louisiana Coordinate System of 1983
(south zone)

Imagery..............................................NAIP, September 2007
Roads........................................National Transportation Dataset, 2004
Names........................................GNIS, 2008
Anatomy of a MGRS coordinate

4Q .................GZD only, precision level 6° × 8° (in most cases)
4QFJ ...............GZD and 100 km SQ_ID, precision level 100 km
4QFJ16 ............precision level 10 km
4QFJ1267 ..........precision level 1 km
4QFJ123678 ........precision level 100 m
4QFJ12346789 .......precision level 10 m
4QFJ1234567890 ......precision level 1 m
USNG: The National Grid

Same as the MGRS except uses NAD83
Maximum difference only c 2m worldwide
Supported in National Map
Some problems at cell boundaries
State Plane Coordinates
Zones:

Lambert Conformal Conic vs. Transverse Mercator (Plus one Hotine Oblique Mercator)
Roseville, CA School Districts

State Plane Coordinates in meters California Zone 2
Measurement: Just use GPS

6 decimal places
0.000001° x 111111m
=0.11m
Converting

NGS GEODETIc TO SPC

This utility uses NGS program SPCS83 or program GPPCGP

to convert NAD83 or NAD27 Geodetic Positions
to State Plane Coordinates (SPC)

This utility supports Internet Explorer versions 6.0+ and Netscape versions 6.0+.

© NAD83 (SPCS83)
© NAD27 (GPPCGP)

LATITUDE = N350933.970 example = N385930.99999
LONGITUDE = W0982632.009 example = W0985930.99999
ZONE = Leave ZONE blank if you want the program to determine it.

Submit Reset

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Web site owner: National Geodetic Survey (NGS),
National Oceanic & Atmospheric Administration (NOAA)
Convert Coordinates - Calculate a position in a variety of formats.

A user account is not needed for the features on this web page.

Enter latitude/longitude or position. Click the corresponding "Calc" button. Lat/Lon, UTM, UPS, MGRS, USNG, Georef, and State Plane are supported. WGS84 datum.

NEW: State Plane coordinates for the United States are supported. Accepted formats ...

HINT: If you have many coordinates to convert, try Batch Convert.

Latitude: ___________________________ Longitude: ___________________________

OR

Position: ___________________________

Calc View on Google Earth

Free. User account is not needed.

This page accepts a wide variety of latitude/longitude and position formats.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>Latitude of point. Google Earth uses the WGS84 geodetic datum. Valid formats include: N43°38.1939' E38°19.39'</td>
</tr>
<tr>
<td></td>
<td>43.3819.39'</td>
</tr>
<tr>
<td></td>
<td>43°38'19.39''</td>
</tr>
<tr>
<td></td>
<td>If expressed in decimal form, northern latitudes are positive, southern latitudes are negative.</td>
</tr>
<tr>
<td>Longitude</td>
<td>Longitude of point. Valid formats include: W116°14'28.86&quot; E110°14'28.86&quot;</td>
</tr>
<tr>
<td></td>
<td>-116.2413.5348.86&quot; -110.14.38.86&quot;</td>
</tr>
<tr>
<td></td>
<td>If expressed in decimal form, eastern longitudes are positive, western longitudes are negative.</td>
</tr>
<tr>
<td>Position</td>
<td>The position of the icon, in a number of formats: Lat/lon, UTM, UPS, MGRS, MGRS Polar, USNG (Identical to MGRS), Georef, and State Plane</td>
</tr>
<tr>
<td></td>
<td>Used in place of Latitude and Longitude.</td>
</tr>
<tr>
<td></td>
<td>The following positions refer to 38° 57' 33.804&quot; N, 95° 15' 55.739&quot; W which is</td>
</tr>
</tbody>
</table>
Coordinate examples

- 238,479 mE; 3,811,950 mN; 11, N
- 11SKU3847911950
- 11SKU3847911950 NAD83
- N 34°24’57.24” W 119°50’42.9”
- 603153 1830382 CA 5
Code Libraries

• Matthew's Map Projection Software
  http://www.users.globalnet.co.uk/~arcus/mps/

• PROJ.4 https://trac.osgeo.org/proj/

• GEOTRANS http://earth-info.nga.mil/GandG/geotrans/

• Java Map projection Library
  http://javamapprojlib.sourceforge.net/
• Issue: Much social data is “binned” by lat/long grid cells, not taking into account projection distortion

• Suggest ways that cells can be equalized: using hexagons and binning by equal areas
Fits distortion analysis tradition
Degree of digit variation in a line

- 4QFJ12345 67890
  Red values do not change
- 4QFJ12347 67897
  Green values are 2 of 10 possible values
- 4QFJ12349 67899
  Blue digits are 2 of 10 possible values
- 4QFJ12352 67903
- 4QFJ12355 67907
  Purple digits are 5 of 10 possible values
- 4QFJ12356 67910
Suspicious

- 4QFJ12345 67890
- 4QFJ12340 67897
- 4QFJ12340 67899
- 4QFJ12355 67903
- 4QFJ12355 67907
- 4QFJ12360 67910

Always 0 or 5, rounded? But only in the Easting
Information content

- For any digit $n$ at any one significant digit location out of $N$ possible digit values or states (10 for decimal), $I$ is defined, where:

$$I_n = \sum_{1}^{N} \left| \frac{D}{\sum D_n} - \frac{1}{N} \right|$$

First digit of the coordinates are all “4” so nine digits would have no occurrence (0.0 - 0.1 x 9 = -0.9) and one digit would occur alone (1.0 - 0.1 = 0.9), which sums to 1.8.
If all values are equally represented, $I = 0.0$
The Coordinate Digit Density Function

Coordinate Digit Density Function: Long Island Coastline

Information content vs. Precision

Entropy

Number of decimal places

Significant Digit Place
Summary

• Geographic Reference System allows positions to be described
• Geographic coordinates are not planar
• Euclidean coordinates need a plane, and orthogonal axes
• Many standard coordinate systems are in use e.g. State Plane, UTM, MGRS, National Grid
• We can compute information content for sets of coordinates
• Coordinate digits can be redundant to random
• To merge and overlap maps, they must be in the same map projection, datum and coordinate system