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12.S56 GPS: Where Are You?
Fall 2008

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12S56 Seminar 1: Monday September 15, 2008

Topic:

Introduction to Seminar and what we want to during the semester. Definitions of Latitude/Longitude and Height

Primary Aim:

The main aim of this class is to discuss how positions on the surface of the Earth are defined when we need millimeter level positioning accuracy and how these positions were defined before the advent of GPS.

Discussion items

The idea of this seminar is to discuss how positions are defined on the surface of the earth. The basic concepts to discuss are:

(1) Why do we need to define positions?

Some ideas:

- To find a specific location (someone's house)
- To find your way back to where you started

But both of these could be done descriptively (e.g. follow this road, then take a left etc.)

However, from a descriptive approach, it can be difficult to determine quantitative information such as how far away a location is.

Coordinate systems provide a method for achieving both the above ideas (i.e., defining where something is located and being able to compute quantitative information about the location).

Coordinate systems also provide a means of transferring information in to maps of locations.

The production of maps pre-dates the development of global coordinate systems that we know today.

Anyone interested can read John Wilford, *The Mapmakers*, Vintage Books, New York, pp 414, 1981. ISBN 0-394-75303-8,

The earliest maps date from several centuries BC and seem to have developed in all parts of the world.

The maps seem to be have been produced for

- navigation,
- taxation (area of land) and
- military defense information.

(2) Latitude and Longitude

The notion of latitude and longitude require the concept that the Earth is nearly spherical. The Greeks certainly realized that the Earth was spherical (knowledge lost during the Dark ages).

Aristotle (4th century BC) realized the Earth was spherical by noting:

- Star constellations changed as you traveled north (i.e., new stars appeared and other others disappeared). Since this could be observed by traveling, he also deduced that the size of the Earth could not be too large.
- As ships sailed from harbor, rather than just getting smaller, they also "sunk" over the horizon.
- The shadow of the Earth that fell across the moon during lunar eclipses was always curved.

Eratosthenes (276-196BC) first radius determined (that we know about today) the radius of the Earth.

Ptolemy III appointed him librarian of the Alexandrian Museum in 240BC. He noted that in Syene (now Aswan), which was up the Nile from Alexandria that on June 21 at high noon, the sun shone to the bottom of a deep well there. No such phenomenon was observed in Alexandria. It was also known at this time that the sun appeared to move north south during the year by about 24 degrees, and the extremes defined what is now known as the tropics (from *tropos* "to turn"). On the day that the sun was

directly overhead at Syene, Eratosthenes measured the angle cast by shadows in Alexandria. He also found out that travel from Alexandria to Syene took 50 days at 100 stadia per day and so knowing the angle and distance and assuming Syene was due South of Alexandria he could deduce the circumference of the Earth. The angle was $7^{\circ}12'$ he deduced the circumference. Given 5.405 stadia in a kilometer: What result did he get?

Do the calculation in class $(360/7.20*50000)/5.405 = 46,250$ km (actual about 40,000 km from definition of kilometer). Result was closer than it should have been. Actual distance is 725 km (not 800 km) and Syene is $3^{\circ}3'$ east of Alexandria.

Claudius Ptolemy (no relation ship to the Egyptian rulers), most active period 127-151 AD, introduced and formalized many of our map concepts. He was also a librarian at the Alexandria Museum, although by this time most of the power in world resided in Rome. He introduced the division of degrees into degrees minutes and seconds. (The notion of 360 degrees in a circle comes from Babylon about 3000 BC. They thought a year was 360 days long and thus made a degree about 1 day).

Hipparchus (190-120BC) introduced the idea of latitude and longitude lines but Ptolemy used them systematically in his *Geography* book and improved on the mathematics of Hipparchus. Hipparchus also made measurements of the Earth moon distance using eclipse data and estimated the precession of the Earth rotation axis in space.

(<http://scienceworld.wolfram.com/biography/Hipparchus.html>).

This is some of the history of how the latitude and longitude system developed but what are the precise definitions?

Here you can use the notes from 12.215 to explain:

- Geocentric latitude and longitude: Based on normal to sphere (which is also the radial vector).
- Geodetic Latitude and longitude: Based on ellipsoidal normal
- Astronomical Latitude and longitude: Based on the direction of the gravity vector

By the end of class; the students should know:

- what the different types latitude and longitude are, and
- that they are measured relative to a set of axes attached to the Earth.

The directions of those axes are set by the mean position of the rotation axis and the arbitrary choice of Greenwich as the zero longitude point. The origin of the system is only needed for the geometric systems and these days is near the center of mass. (The astronomical measures do not need an origin because it is just the directions of vectors that are being measured and since astronomical objects (sun, stars, etc) are large distances away, translation of the system has a minute effect on angles.

In the next seminar, we look at how angle and time measurements to stars (including the sun) can be used to measure astronomical latitude and longitude (the students will need to do this on September 22.