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Introduction to GPS and GIS I

The revolution in geo-location.
Lost Treasure...

- On October 25th, 1891 Jacob Waltz a German immigrant and prospector was dying of pneumonia.
- Before he died he confided to a friend who was caring for him, an African-American woman named Julia Thomas, that he knew the location of a gold mine in the mountains of Arizona nearby.
- He told her that the mine contained wealth of fantastic proportions; drew for her a map to the location of the mine, showed her some gold to prove his story, and then he died.
... this is that map!

Questions:
1. Is this a good map?
2. Why or why not?
3. Do you think Julia Thomas found the gold?
Relative References

- The main problem with the 'Thomas' map is that it uses relative references. We use relative references all the time when we say things like “go two blocks and take a left” or “meet me in the park by the baseball fields”.
- When an **exact location** is important relative references can be a problem. How was Thomas to know if she was starting at the correct location? The apaches had lived in that part of Arizona for centuries and had camped in many places.
- Likewise, could there be more then one rock that looked like a horse, or a weaver’s needle? Did he mean exactly 3 miles? What if it was in fact 3.1 or 3.2 miles?
- And even if everything in the map was exactly correct, how long would it be correct for? Rocks tumble, trees fall down and decay (even mountains crumble over time).
Exact Location

- Julia Thomas never found the gold, and the mine which came to be known as the “Lost Dutchman's Mine” is perhaps the most famous mine in American history.
- If Waltz had been able to tell Thomas the exact latitude and longitude of the mine then she might have become a very rich woman.
- Sadly there are hundreds of other tales similar to the Waltz’s and Thomas’s.
- **Moral:** Sometimes knowing **exactly** where something is very important.
Determining "exact" location

- So how do we determine our "exact" location on Earth, without using relative (or environmental) references.

- Some of the first people to answer that question were sailors, because although relative references can sometimes fail on land, they are almost worthless at sea (where one stretch of water looks pretty much like the next).

- In order to navigate at sea, early sailors needed two important tools; the first was a sextant and the second was a really accurate watch.
Sextant

- A sextant is an instrument used to measure the angle between any two visible objects.
- Commons uses include finding the angle of the sun and starts above the horizon.
Latitude

- Lines of Latitude are the horizontal lines shown running east-to-west on maps, like the rungs of a ladder ("the ladder of latitude").
- These rings allow us to establish the location of a place on Earth north or south of the equator.
- The equator is the imaginary line that circles around the middle of the Earth.
- At sea, a sailor could use a sextant to measure the angle of the sun above the horizon at noon; this would allow him to establish how far north or south of the equator he was, provided he also knew what day of the year it was.
Let’s imagine it’s either the spring or the fall equinox. That means it’s one of the two times of the year when the sun’s rays hit the earth exactly from the side.

During an equinox at noon, someone standing at the equator would see the sun directly above them, or to put it another way at 90° in relation to the horizon.

However someone standing in New York would see the sun at 50° (much closer to the Horizon), while someone in south Florida would see it at 68°.
Determining Latitude

- To find your latitude (during an equinox,) take the angle that you measured the sun above the horizon and subtract that from 90.
- At the equator the latitude is 0° (90-90), in south Florida it’s 22° (90-68) while in New York City it’s 40° (90-50).
- Sailors used numbers other than 90 for the rest of the year.
- In the southern hemisphere latitude is specified with a negative sign.
Question of Accuracy

Questions:
1. How accurate do you think determining latitude by measuring the angle of the sun is?
2. What other problems might occur when trying to use the sun to determine latitude?

Answers:
- On land with practice a person could use a sextant to determine within a few miles what their actual latitude was (a difference of a single degree is equal to almost 69 miles).
- Bad weather and fog could make it impossible to use a sextant, and at extreme latitudes North and South the sun doesn’t shine for as much as 3 months a year (the stars and moon are used instead).
**Longitude**

- Longitude is the east-west geographic coordinate measurement and it describes the location of a place on Earth east or west of a north-south line called the Prime Meridian.
- You may already be familiar with the idea of longitude as a measure of time from watching television.
- Question: If a football game will be shown at 5:00PM Pacific Time, what time will it be on here, in New York?
LINES OF LONGITUDE

The Prime Meridian (the 0 line on our map) passes through the Royal Observatory, Greenwich in southeast London, United Kingdom. That is why you will sometime here reference to known as the Greenwich Mean time (which basically means the time in London).
Measuring Longitude

- We can measure our longitudinal position using time. (remember our football game). The theory is very simple.
- Get a clock and set it to the time in London (Greenwich Mean Time). As you sail around the ocean use the Sun to determine when noon is and then compare that time to what the clock says. The difference in time will tell you how far east or west you are from London.

- The problem is that you need a very accurate clock, which will remain accurate even when traveling on a ship at sea.
- By 1714 no such clock existed and in response to a major naval disaster the British Parliament commissioned a prize of £20,000 to anyone who could create such a clock or some other method of accurately determining longitude within ½ of a degree.
John Harrison

- John Harrison built the first clock that was able to attain the British Parliament's designated level of accuracy in 1761.
- Because Harrison was a common carpenter and not a gentleman the British Navy refused to award him the full prize amount.
- In 1773 King George III (you may remember him as the bad guy in the story of the American Revolution) awarded Harrison the prize himself bypassing the Navy.
Question of Accuracy

Questions:
1. Why do you think it was difficult to make a clock keep accurate time at Sea?
2. How accurate can you be determining longitude using only a clock?

Answers:
- Most clocks before 1714 used a swinging pendulum to keep time and the roll of a ship at sea interfered with the motion of the pendulum.
- Harrison’s son used one of his father’s clocks to plot the longitude of a ship within two miles of its actual location.
GPS (Global Positioning System)

- For over 200 years after Harrison received his prize little changed in how we determined longitude and latitude.
- Men and women explored the earth and even space often using little more than clocks, stars and the sun.
- In 1993 the NAVSTAR GPS system built by the United States Department of Defense went active and almost overnight everything changed.
- The NAVSTAR system was built primarily so that the United States military could deliver missiles and bombs with pinpoint accuracy.
- But the system designed as a tool of war has proved invaluable in saving lives as well.
How does GPS work?

- The NAVSTAR system is currently composed of 31+ satellites in orbit around the Earth.
- Each of these satellites is composed of an incredibly accurate clock, a powerful radio transmitter and a sophisticated onboard computer that allows the satellite to determine exactly (in 3 dimensions) where it is (in relation to the Earth) at all times.
- Each of these satellites continuously broadcasts a signal to earth which contains the satellites current location and the time.
How does GPS work?

- A GPS receiver unit on the ground can listen to these satellite signals and determine with incredible accuracy where it is on the planet.
- It does this by comparing the time recorded in the radio messages (called the time stamp) with the current time and calculating how far the radio messages must have traveled from the satellites before they were received.
- By calculating its own distance from several different GPS satellites, a GPS unit can determine where it is as the single point of overlap among several circles.
- GPS units can establish exact latitude and longitude with as little as 10 meters of error.
SINGLE POINT OF OVERLAP
Question of Accuracy

Questions:
1. How accurately can you measure Latitude and Longitude with a GPS device?
2. A GPS unit needs at least 3 different satellites signals in order to find its location. Why?
3. Since radio waves travel at the speed of light (roughly 299,792 km or 186,282 miles per second), how accurate must the clocks in GPS units be?

Answers:
- In general GPS units can establish latitude and longitude with as little as 10 meters of error. Special techniques can reduce that level of error to 10 cm.
- Some GPS units are capable of measuring time in nanoseconds. A nanosecond is $10^{-9}$ (or 1 billionth of a second). In 1 nanosecond light can travel about a foot.
- The clocks on the GPS satellites themselves measure time in picoseconds ($10^{-12}$ seconds). It takes light 3.3 picoseconds just to move 1 millimeter.
GPS – Saves Lives

- Every year the U.S. Coast Guard rescues thousands of people.
- Life threatening emergencies take on new meaning when your nearest rescuers may be a hundred miles away.
- GPS has already saved lives at sea by allowing rescuers to find people in distress immediately without having to search for them.
- The Coast Guard officially recommends that anyone going out in a boat also carry a GPS unit.
GPS – Saves Lives

- Some new cars have a feature called OnStar which is a service that includes a GPS unit.
- If a car is in an accident (for example drives off the road into a ditch at night) and the driver is disabled OnStar can dispatch help immediately to the exact location of the injured driver.
- Many new cell-phones include a GPS unit as part of the phone.
- In a 911 emergency the cell-phone companies will be able to pinpoint the location of the caller in order to send help.
The End