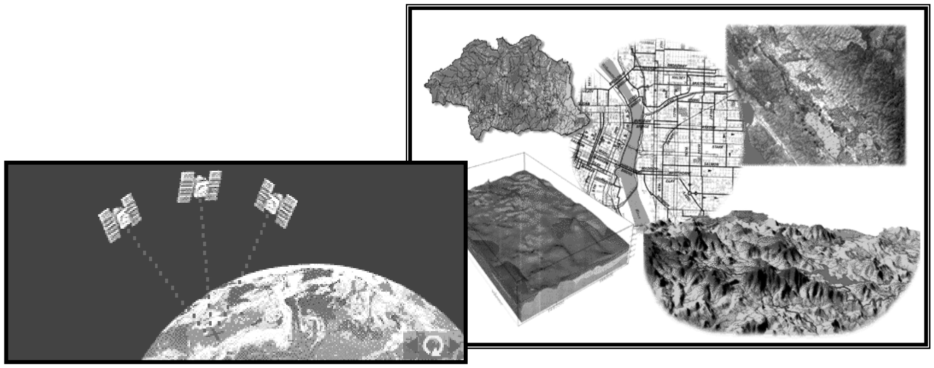


Integrated GPS and GIS Engineering Applications

CEIE 410-510 GIS in Engineering

Use of GPS/GIS in Engineering

- **GPS gizmos are getting increasingly popular for engineering applications**
  - **We will use GPS data loggers for class project**

What you should know

  - **How GPS works**
  - **How to plan for your project**
  - **How to gather data**
  - **How to integrate it into GIS**

© Mohan Venigalla, Fall 2009 GPS and GIS

The Global Positioning System

- GPS was originally designed and developed for the military use only
- Bush (Sr.) administration's "defense conversion" policy:
  - Made available for public use in the early 90s
  - Explosive growth of use of GPS since then – estimated 2001 market for GPS related products and services: above $11 billion
- Extensively used in
  - Surveying, agriculture, construction, vehicle tracking, archeology
- Embedded GPS chips:
  - A host of mobile electronic devices

Generalized Civilian GPS Uses

- Location
  - Where am I?
  - For precise scientific work (navigation related)
- Navigation
  - Point ***a*** to point ***b***
    - Sailors
    - Road-warriors
  - Landing on the middle of the runway, safe and sound
- Tracking
  - Automated vehicle tracking
    - Fleet management
    - Emergency response
- Mapping
  - Bring on the X's and Y's
  - Put them on the map or add them to map

GPS is "Precise Timing"

- **Beneficiaries of "precision timing"**
  - **Astronomers**
  - **Power companies**
  - **Computer networks**
  - **Communication systems**
  - **Banks**
  - **Radio and TV stations**
- **Examples:**
  - One investment banking firm uses GPS to guarantee their transactions are recorded simultaneously at all offices around the world
  - A major Pacific Northwest utility company makes sure their power is distributed at just the right time along their 14, 797 miles of transmission lines

What Comprises GPS?

- **Three main components**
  - **A constellation of 27 NAVSTAR satellites**
  - **Five monitoring stations on remote locations on earth**
  - **Individual GPS receiver units**
- **Individual receiver**
  - **The essential *passive* element of the system**
    - **Passive means – the units won't talk back to the satellite (imagine TV sets)**
  - **Interpret the satellite data**
  - **Tell you where you are**

NAVSTAR Satellites

- The system needs only 24 satellites, the other three are spare
- They orbit the Earth at a height of 12,600 miles
  - Deployed in six evenly spaced orbits
- Each satellite orbits Earth at speeds that help it pass the monitoring stations every 12 hrs
- At any given time and at any location on Earth, at least four satellites are visible
- Continuously transmit signals
  - On two L band (L1, L2) frequency
  - Using pseudo-random scrambling

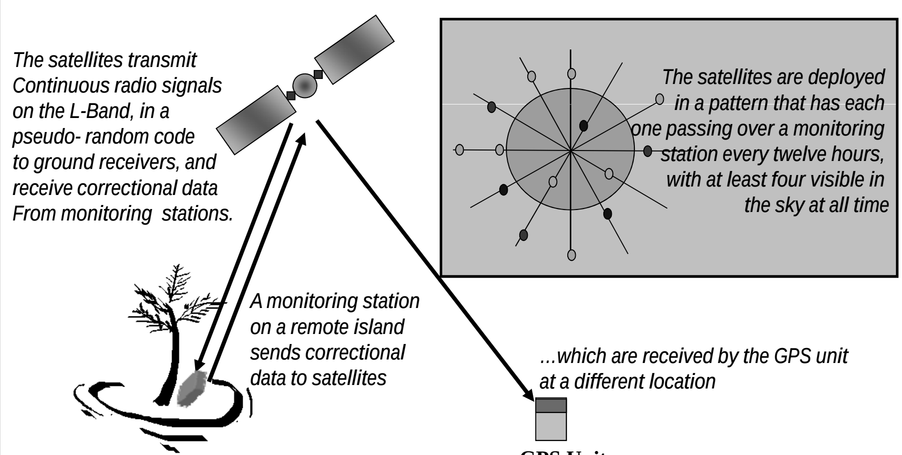
Earth Monitoring Stations

- Send correctional data to satellites
  - Purpose: to enable satellites to maintain proper orbit
- Deployed at five locations around the Globe
  - Hawaii
  - Ascension Island
  - Diego Garcia
  - Kwajalein, and
  - Colorado Springs

How the Three Components Work Together?

- **Distance between the ground unit and the satellite is computed**
  - **based on the length of the time it takes a signal to travel from a satellite to the receiver**
- **GPS satellites transmit continuous signals**
  - **to indicate their position and the exact time that signals are being sent.**
- **With a perfect clock and known distance from three reference points, you can locate the point**
  - **The process is called *trilateration*, also known (loosely) as *triangulation***
- **A fourth satellite - makes the measurement more accurate**
  - **The 4th satellite also helps you fix the elevation**

The Global Positioning System

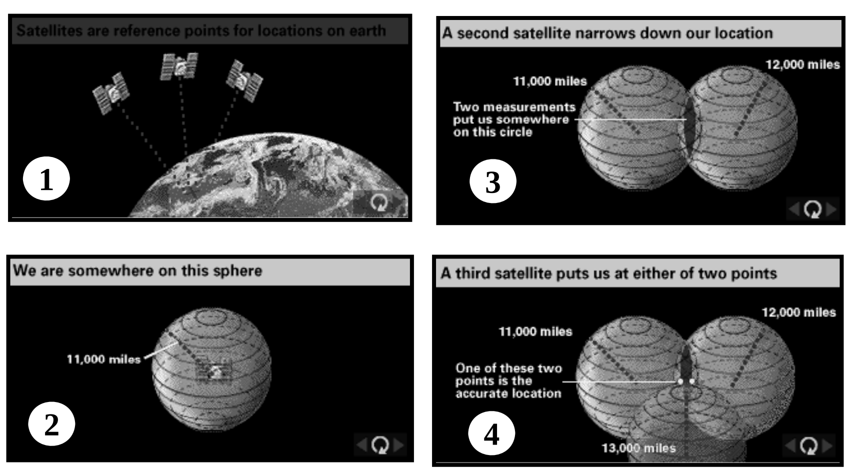


Adapted from: *Integrating GIS and the Global Positioning System*, ESRI press, 2000

Principle

- **Based on simple physics eq.**
  - ***Distance traveled = time * velocity***
- **At the receiver-end**
  - **Receiver reads radio signals from 3 satellites**
    - **Each satellite position and time of signal is known**
  - **Receiver computes distance(s)**
    - **How long did it take for this signal to travel here?**
  - **Does “trilateration/triangulation” to find the location**
    - **Quote from Trimble.com:**
      - *We're using the word "triangulation" very loosely here because it's a word most people can understand, but purists would not call what GPS does "triangulation" because no angles are involved. It's really "trilateration" or "resection.”*

How “Trilateration” Works?



Courtesy: http:/www.Trimble.com

Some GPS Essentials

- Clock precision
  - Time has to be precise to the nanosecond
  - A timing error of 1/100th of a second
    - Means about 1860 miles of distance error
    - Enough to put you on different continent
  - Satellite clock precision – extremely important
    - Atomic clocks are used
    - Receiver clock precision – important
      - Determines the accuracy of your unit
  - There is no such thing as a perfect clock
- Error-free transmission – doesn't really exist
- Also, there is no such thing as a perfect clock

GPS Accuracy

- The engineer's take:
  - "All measurements are bad. They need correction"
  - GPS is no different from this!
- Random errors – beyond our control
- Systematic errors
  - Selective Availability (S/A)
    - Deliberate random error introduced by DoD
    - Restricted (in the past) accuracy to 100m
    - S/A turned off (permanently) in 2000
      - Originally scheduled for turning off in 2009
      - The US Govt. (DoD) reserves the right to turn S/A on at a time of their choosing

GPS Accuracy

- Just like in GIS, we can do something about the systematic GPS errors
- Accuracy can be improved
  - from being off by about 100 meters to being off by only 110-15 meters
- With S/A now turned off,
  - accuracy within 1 meter can be expected.

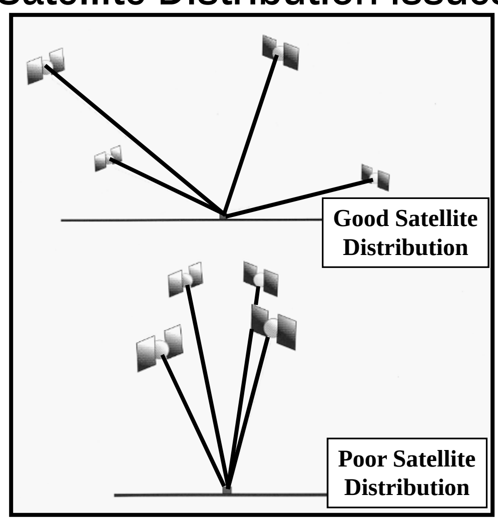
Factors Affecting GPS Accuracy (2)

- Poor satellite distribution
- Gravitational pulls of the Sun and the Moon
- Speed of light
  - Unlike what we might think, it is not a constant
- Receiver noise
- Unintended signal degradation
  - Signal delayed in troposphere due to ionized clouds
  - Ephemeris – minor disturbances of satellite orbit due to gravitational pull(s)
  - Other factors:
    - planetary, atmospheric, satellite specific, faulty clocks, receiver troubles, DoD’s S/A etc

Factors Affecting GPS Accuracy (2)

- **The Receiver Blues**
  - **The receiver may not be able to handle the errors**
  - **Receiver accuracy may not be dependent on its intended purpose**
    - **Example: a routing GPS unit will “snap” your location to the nearest road on the map**
  - **The GPS chipset used can make a big difference**
  - **The receiver clock can be faulty**
- **Multipath signals**
  - **Just like the “ghosts’ in your TV**
    - **Mainly due to the signals that are bouncing around**
    - **A good receiver can correct for multipath signals**

Satellite Distribution Issues



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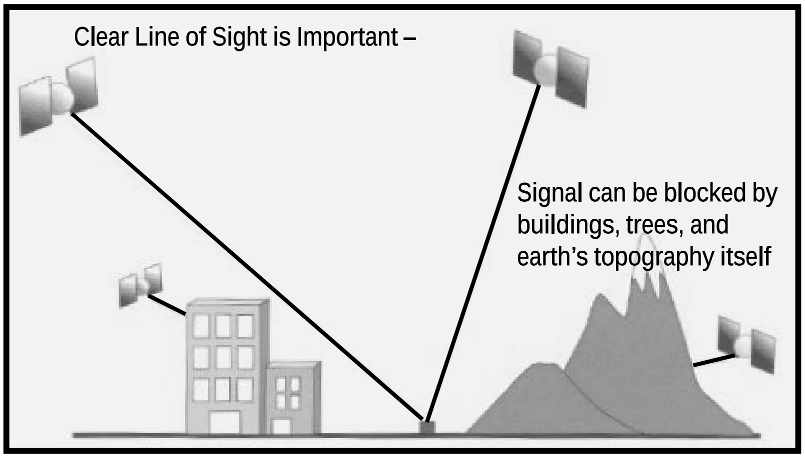
Line of Sight



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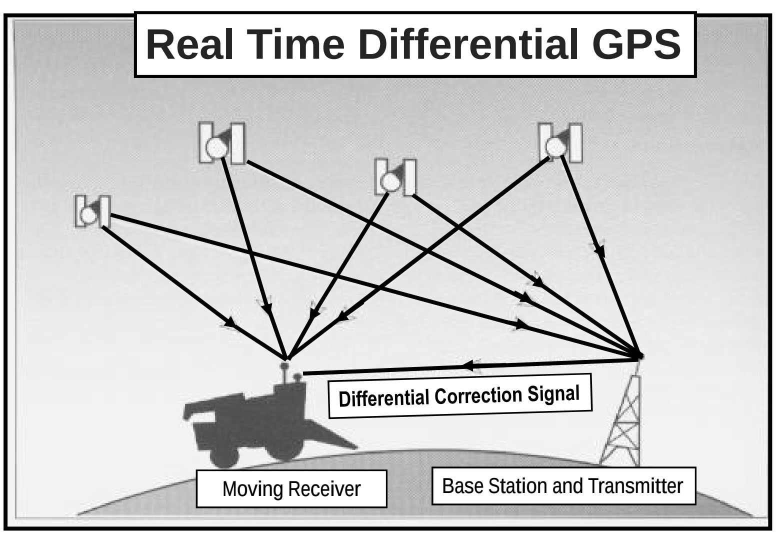
Differential GPS

- **Not a good idea to rely on uncorrected GPS data**
- **Most errors can be corrected using differential GPS or DGPS**
- **DGPS principle - use two receivers**
  - **place one receiver at a known location - an accurately surveyed point (base station)**
  - **carry the other receiver with you for getting lat/longs**
  - **base station compares the signal to known location**
    - **the difference is the error**
    - **and the error with the nomad receiver is then corrected**

DGPS (2)

- **Real-time DGPS**
  - **Correction made in real time**
  - **Mostly used for navigational purposes**
    - **Aircraft, hikers, campers, anglers etc.**
  - **Also used for scientific measurements**
- **Post-processing DGPS**
  - **Collect data in the field**
  - **Bring the data to the lab and make corrections using GIS or other tools**
  - **More accurate than RT-DGPS**



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Accuracy

Autonomous	15 - 100 meters
Differential GPS (DGPS)	0.5 - 5 meters
Real-Time Kinematic Float (RTK Float)	20cm - 1 meter
Real-Time Kinematic Fixed (RTK Fixed)	1cm - 5 cm

Using GPS/GIS for Engineering Projects

- **Applications are aplenty**
  - **Infrastructure inventory**
    - **Example: AM/FM mapping (utility mapping)**
  - **Research**
- **Four Stages**
  - **Planning**
  - **Data collection**
  - **Data screening**
  - **Organizing data in GIS**

Project Planning

- **Selecting GPS Unit - give considerations to:**
  - **Field conditions - weather and terrain**
  - **How sturdy the GPS unit(s) must be?**
  - **Transport to and at the site: Drive? Walk? Bike?**
  - **With the GPS unit, do you need:**
    - **A digital background map**
    - **An aerial photo?**
  - **Isolated unit vs. computer linked**
  - **What level of accuracy does the project need?**

Project Planning (2)

- **Pilot project and field reconnaissance**
- **Educate the decision makers**
  - **project scope**
  - **intended benefits**
- **Seek approval**
  - **Not only for initial data collection and implementation**
  - **But also for ongoing support**
- **Think about current and future needs**
- **Prepare a wok-flow chart**
- **Acquire the equipment**
- **Plan for DGPS, if possible**

Data Collection

- Create a data dictionary
  - Registering Lat/Longs is the easy part
  - What other attributes are you going to collect?
    - Prepare a list
      - Traffic Engineers: warning signs, regulatory signs, information signs
    - Make a data dictionary from the list
- Be mindful of GPS limitations
- Keep storing the collected data methodically
  - Have a backup plan – it won't be fun to go back and redo all that hard work
  - Be attentive and take breaks as necessary

Data Screening

- Screening is almost as important as the data collection itself
- Do not procrastinate screening
  - Concurrent collection and screening is better
- Where feasible, post-process the data and correct using DGPS

Organizing Data in GIS

- **This step is your ultimate goal**
- **GIS will help you**
  - **spot and correct the errors,**
  - **organize the data better**
- **Develop your analytical methods at this stage**

Class Project Overview

- **Theme**
  - **Integrated GPS and GIS for transportation engineering**
- **Objectives**
  - To collect travel time data using GPS data loggers and analyze the data using GIS tools.
- More on the project –posted separately