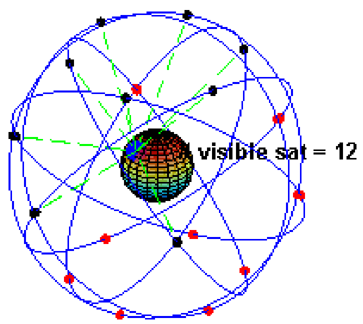
EACHTRA
Archaeological Projects

Historic Graves
Global Navigation Satellite System

A global navigation satellite system (GNSS) is a technology that provides geo-spatial positioning with global coverage. At the moment the United States Global Positioning System (GPS) is the only fully operational GNSS and this is the reason why the term GPS is often use to describe the technology itself. Other nations are developing similar systems as well: The Russian GLONASS is expected to reach global coverage by the end of 2011; The Republic of China is developing an independent global navigation system called Compass, scheduled to be fully operational by 2020; The European Union has a GNSS called Galileo in initial deployment phase which is scheduled to be fully operational by 2020 at the earliest.

The structure

This system consists of three segments: the space segment, the control segment, and the user segment. The U.S. Air Force develops, maintains, and operates the space and control segments.



Space Segment

The space segment consists of a nominal constellation of 24 operating satellites that transmit one-way signals that give the current GPS satellite position and time. The satellites orbit with a period of 12 hours (two orbits per day) at a height of about 20,200 kilometers.

Control Segment

The control segment consists of worldwide monitor and control stations that maintain the satellites in their proper orbits through occasional command manoeuvres, and adjust the satellite clocks. It tracks the GPS satellites, uploads updated navigational data, and maintains health and status of the satellite constellation.

User Segment

The user segment consists of the GPS receiver equipment, which receives the signals from the GPS satellites and uses the transmitted information to calculate the user's three-dimensional position and time.

How it works

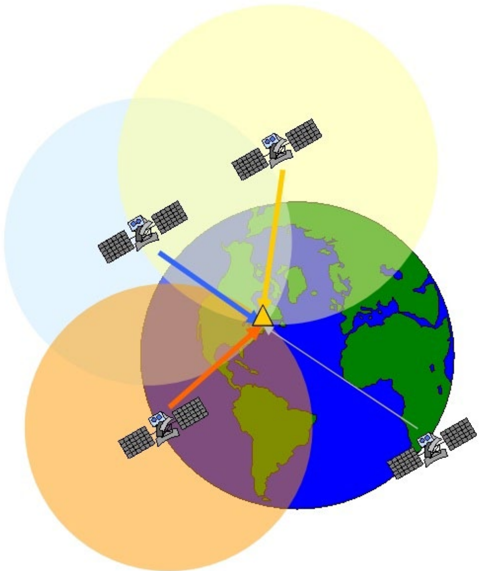
Each satellite continually transmits messages that include:

- the time the message was transmitted
- precise orbital information (the Ephemeris)
- the general system health and rough orbits of all GPS satellites (the Almanac).

A GPS receiver compares signals from at least three or four (3D measure) GPS satellites to determine its own location.

How does a GPS receiver calculate its location?

- A GPS receiver figures out how far away it is from each satellite based on how much time it takes a broadcast signal to travel from the satellite to the receiver.
- Since the location of each GPS satellite is known (Ephemeris), the receiver's location can be determined by *trilateration* of the distances from several satellites



The system is based on a very simple formula we all know:

[distance] = [speed] * [travel time]

We know [speed] because GPS signals are electromagnetic waves, which travel at light speed (approximately 300,000,000 meters per second).

We can figure [travel time] by comparing [time sent] and [time received].

Each GPS satellite has an on-board clock and includes [time sent] in the signal it broadcasts.

A GPS receiver also keeps track of time, which gives [time received].

The accuracy

Because a GNSS system has several components, errors that affect accuracy can be produced in several ways.

Types of errors in GPS

Satellite errors

Timing is critical to GPS, and the GPS satellites are equipped with very accurate atomic clocks, but they are not perfect and slight inaccuracies can lead to errors in position measurements.

The atmosphere

GPS satellites transmit their timing information by radio, and since radio signals in the earth's atmosphere don't always behave predictably, this is another source of error. The assumption is that radio signals travel at the speed of light, and that the speed of light is a constant, but this is only true of light if it is in a vacuum. In the real world, light slows down, depending on what it is travelling through.

Multipath error

When the signal arrives at the surface of the earth, it can reflect off obstructions such as buildings and trees, before making it to the receiver's antenna. The signal arrives at the antenna by 'multiple paths' which is why this type of error is called multipath error. If this happen, then the time spent by the signal to reach the antenna (travel time) is longer than it should be, producing errors in the location.

Receiver error

Anyway, one of the most significant error sources is the GPS receiver's clock. Because of the very large value of the speed of light, the estimated distances from the GPS receiver to the satellites, are very sensitive to errors in the GPS receiver clock: an error of one microsecond (0.000 001 second) corresponds to an error of 300 metres.

Most consumer GPS units have an accuracy of about +/-10m. Other types of receivers use a method called Differential GPS (DGPS) to obtain much higher accuracy. DGPS requires an additional receiver fixed at a known location nearby. Observations made by the stationary receiver are used to correct positions recorded by the roving units, producing an accuracy greater than 1 meter.

Cold Starts & Warm Starts

Almanac and Ephemeris data should be periodically updated to increase the startup performance or TTFF (Time To First Fix). In this regard, there are three type of condition:

- Factory Start
  - All data is considered invalid.
- Cold Start
  - Almanac data is current but Ephemeris is not or has expired.
- Warm Start
  - Both Almanac and Ephemeris data is current.

If the GPS has been turned off for a certain period or you are several kilometres away from your last fix then the ephemeris data (and probably also the almanac) will no longer be valid. In this case the receiver will initiate a factory start and begin downloading both almanac and ephemeris data. This will extend the initial time to lock considerably, and should be taken in consideration when starting a new job on the field.

A-GPS

A solution to this problem is A-GPS (Assisted GPS), a system that is used extensively with GPS-capable cellular phones. It uses network resources to locate and utilize the satellites faster as well as better in poor signal conditions.

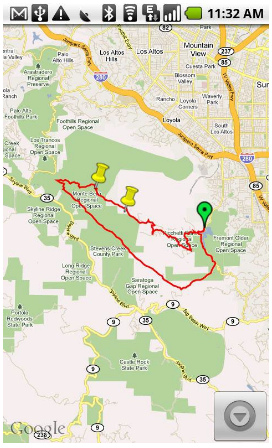
Assistance is given in the form of Information used to more quickly acquire satellites:

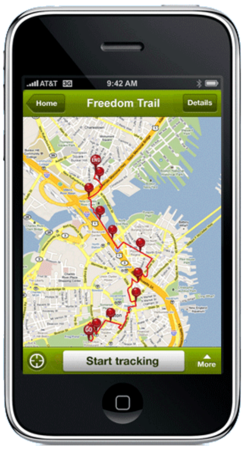
- It can supply orbital data or almanac for the GPS satellites to the GPS receiver, enabling to lock to the satellites more rapidly.
- The network can provide precise time.

How we use it

In our project the GPS technology plays an important role. We use it to Geotag the photos of the graves, that is to give them an absolute geographical position in the form of latitude and longitude coordinates. To accomplish this task, we can use several ways:

Method	Pros	Cons	Example
Camera with an internal GPS chipset	No post-processing Low-cost Good quality photos Very easy to use	Average accuracy	Sony HX5V
Smartphone + dedicated App	Fairly widespread Easy to use	Requires post-processing Average accuracy Lower photo quality	Android phone + My tracks / iPhone + EveryTrail
Camera + GPS log	Low-cost Better quality photos	Requires post-processing Average accuracy Requires two handsets	Camera + Holux
Camera + Handheld Computers with GPS	Better quality photos High accuracy	Requires intensive post-processing and a more complex survey Requires two handsets	Camera + Thales Mobilemapper
Camera + Differential GPS	Better quality photos Very high accuracy	Requires intensive post-processing and a more complex survey Requires three handsets	Camera + Thales Mobilemapper + Base station





The first three methods use, immediately or in post-processing, the GPS data of the position of the camera at the time the photo of the grave was taken, instead of the position of the grave. Considering that those methods are not highly accurate (5 to 10 metres of possible error) this does not represent a problem.

If we are using a highly accurate method that is able to set the location of the grave with an error less than 2 metres, is recommended to record a position very close to the gravestone.

Handling the GPS receiver

To guarantee the best possible GPS reception is important to hold the device in a vertical position, out of pockets or possible cases, avoiding covering it too much with the hands. If you are using a camera with a GPS chip inside, normally the position of the antenna is indicated by the presence of a logo (ie. Sony camera at the top of the page) and is preferable to leave that side facing up.

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