GPS

Global Positioning System

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General Information

"*The Global Positioning System (GPS) is a U.S. space-based radionavigation system that provides reliable positioning, navigation, and timing services to civilian users on a continuous worldwide basis -- freely available to all. For anyone with a GPS receiver, the system will provide location and time. GPS provides accurate location and time information for an unlimited number of people in all weather, day and night, anywhere in the world.*"

http://www.gps.gov/

GPS

History

The design of GPS is based partly on similar ground-based radio navigation systems, such as LORAN and the Decca Navigator developed in the early 1940s, and used during World War II.

•1956 Friedwardt Winterberg proposed a test of General Relativity using accurate atomic clocks placed in orbit in artificial satellites. To achieve accuracy requirements, GPS uses principles of general relativity to correct the satellites' atomic clocks.

• Additional inspiration for the GPS came when the Soviet Union launched the first man-made satellite, Sputnik in 1957. A team of U.S. scientists led by Dr. Richard B. Kershner were monitoring Sputnik's radio transmissions. They discovered that, because of the Doppler effect, the frequency of the signal being transmitted by Sputnik was higher as the satellite approached, and lower as it continued away from them. They realized that since they knew their exact location on the globe, they could pinpoint where the satellite was along its orbit by measuring the Doppler distortion.

•The first satellite navigation system, Transit, used by the United States Navy, was first successfully tested in 1960. It used a constellation of five satellites and could provide a navigational fix approximately once per hour. In 1967, the U.S. Navy developed the Timation satellite which proved the ability to place accurate clocks in space, a technology that GPS relies upon.

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•In 1960, the Air Force proposed a radio-navigation system called MOSAIC (Mobile System for Accurate ICBM Control) that was essentially a 3-D LORAN.
•A follow-on study called Project 57 was worked in 1963 and it was "in this study that the GPS concept was born.
•The Navy Research Laboratory continued advancements with their Timation (Time Navigation) satellites, first launched in 1967, and with the third one in 1974 carrying the first atomic clock put into orbit.
•With these parallel developments out of the 1960s, it was realized that a superior system could be developed by synthesizing the best technologies from 621B, Transit, Timation and SECOR in a multi-service program.
•Over the Labor Day weekend in 1973, a meeting of about 12 military officers at the Pentagon discussed the creation of a Defense Navigation Satellite System (DNSS). It was at this meeting that "the real synthesis that became GPS was created." Later that year, the DNSS program was named Navstar. With the individual satellites being associated with the name Navstar . This more complete name was Navstar-GPS which was later shortened simply to GPS.
•After Korean Air Lines Flight 007, carrying 269 people, was shot down in 1983 after straying into the USSR's prohibited airspace, in the vicinity of Sakhalin and Moneron Islands, President Ronald Reagan issued a directive making GPS freely available for civilian use, once it was sufficiently developed, as a common good.
•The first satellite was launched in 1989, and the 24th and last satellite was launched in 1994.
•Initially, the highest quality signal was reserved for military use, and the signal available for civilian use intentionally degraded ("Selective Availability", SA). This changed in 2000, with U.S. President Bill Clinton ordering Selective Availability (SA) turned off at midnight May 1, 2000, improving the precision of civilian GPS from about 1000 feet to about 65 feet.

GPS

Technical Features

24 NAVSTAR Satellites

Approx altitude 10,900 Miles = ~17500 km

Satellite weight 2 ton, ~6 meter long

Orbits earth less than 12 hours

Every satellite has an unique signal

Requires at least 4 satellites to measure receivers location with 3 meters accuracy at horisontal level. In vertical level accuracy is 2 or 3 times worse.

Till 1st of May 2000 U.S ministry of defence weakened GPS data. Accuracy was vertically 156m and horizontally 100m.

Calculations made so that theres 5 ”visible” satellites on earth at one time

Can be used in any type of weather, used on land, and for marine applications

Limitness in indoor usage, forest with heavy tree covers

GPS-location is based to a atom clock time sent by satellites with navigation signal received by GPS-receiver..

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Technical Features

GPS-signal:

- •GPS-satelliite send over the carrier so called PRN signal (PRN, *Pseudo Random Noise*). Signal can not penetrate constant materials.
- •GPS works with to separated frequency (L1 ja L2):

1. L1 (1575,4200 MHz) civil usage
2. L2 (1227,6000 MHz) military usage and hidden during 2003
3. L3 (1381,0500 MHz) military usage, used for global nuclear detonation info system (NUDET – Nuclear Detonation)
4. (L4 (1841,4000 MHz) experimental, not used)
5. L5 (1176,4500 MHz) for civil usage (available 2005)
6. (2227,5000 MHz) space-crafts telemetrie

Modulations used by frequencies:

- •C/A (Coarse/Acquisition) -code, which is individual of each sallettile. Send in L1-freq. A bit flow, one bit microsecond; full lenght 1024 bits = micro second.
- •P(Y)-code, Sent as a coded signal in both frequencies. P(Y)-code is for military usage and it's encrytion keys are handled by U.S government.
- •Information part, which includes satellites orbit and clock parts and satellites "healthy" information.

http://en.wikipedia.org/wiki/Global_Positioning_System

GPS

Technical Features

Anything familiar? Pseudo distance =

$$p = \sqrt{(x - X)^2 + (y - Y)^2 + (z - Z)^2} + c(\Delta t - \Delta T),$$

X,*Y*,*Z* is receivers location in three dimentional space
x,*y*,*z* satellites location in space, counted from info sent by satellite, orbital info equals *efemerids*
Δ*t* satellites atom clock error; small, known, sent by sattellite
Δ*T* receivers clock error, unknown like its coordinated.
X, *Y*, *Z* ja Δ*T* these are unknown variables which can be solved by help of four satellites located in correct location, visible.

http://en.wikipedia.org/wiki/Global_Positioning_System

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Techniques inside GPS

Differential GPS

- Was invented to remove SA-disturbance for marine usage.
- New basestation, referrence station, which location was well known, calculates SA-disturbance location and compared it to reference data. This was a way to calculate error in navigation.
- Make locationing complicated and caused situation when there was no locationing data available from DGPS-receiver. (Baltic Sea, Gotland).
- Maintained by third party companies (Digita, Focus).
- Chargeable.
- Even SA-disturbance is ut of use, DGBS is used for removing athmospherical interruptions.

Relative GPS. Used for land-measurement. Based to two separated measuring devices. Calculates coordinate distances.

Techniques inside GPS

Assisted GPS

Assisted GPS (A-GPS) covers a lot of different techniques.

- One well know technique reads satellites fligh and calendar information using cellular networks. Information can be read days before so in real life usage of A-GPS is possible even without cellular network.
- Forehand information helps connectivity and startup of an navigation application, even inside buildings.
- Second version of A-GPS uses also data received from mobile operator which includes a raw estimate based to devices location.
- Third version send continuisly info about it's own satellite positioning.
- Used also for person and animal locationing.

Real Time Kinematic

- Is most commonly used for land-measurement.
- Based into two separated GPS-receivers where one of receivers knows second ones destination.
- Accuracy is few centimeters.

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Sources of GPS signal errors

•Ionosphere and troposphere delays - The satellite signal slows as it passes through the atmosphere. The GPS system uses a built-in model that calculates an average amount of delay to partially correct for this type of error.

•Signal multipath - This occurs when the GPS signal is reflected off objects such as tall buildings or large rock surfaces before it reaches the receiver. This increases the travel time of the signal, thereby causing errors.

•Receiver clock errors - A receiver's built-in clock is not as accurate as the atomic clocks onboard the GPS satellites. Therefore, it may have very slight timing errors.

•Orbital errors - Also known as ephemeris errors, these are inaccuracies of the satellite's reported location.

•Number of satellites visible - The more satellites a GPS receiver can "see," the better the accuracy. Buildings, terrain, electronic interference, or sometimes even dense foliage can block signal reception, causing position errors or possibly no position reading at all. GPS units typically will not work indoors, underwater or underground.

•Satellite geometry/shading - This refers to the relative position of the satellites at any given time. Ideal satellite geometry exists when the satellites are located at wide angles relative to each other. Poor geometry results when the satellites are located in a line or in a tight grouping.

•Intentional degradation of the satellite signal - Selective Availability (SA) is an intentional degradation of the signal once imposed by the U.S. Department of Defense. SA was intended to prevent military adversaries from using the highly accurate GPS signals. The government turned off SA in May 2000, which significantly improved the accuracy of civilian GPS receivers.

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Applications

Military:

Navigation
Target Tracking
Missile and Projectile guidance
Search and Rescue
Recoinnaissance and Map creation
Nuclear detonation detectors

GPS

When significanse of GPS grows it's disturbance and misleading comes a part of warfare.
In Iraq war 2003 U.S claimed that iraqs used GPS dirturbance devices made by Russian company Aviakonversija. A head of company denies claims naturally. Meaning of these devices can be understood because U.S troops destroyed 6 separated disturbance stations equiped with disturbance devices.

- Cost of single device is 40k$
- Disturbance distance is hundreds of kilometers
- Transmit power is only 4W
- Different type of devices on the markets ← Can be neutralized with devices used against disturbance ☺ Disturb disturbance device!
- Added costs in warfare, higher prices in GPS based weapons. In Iraq the one in question was so called JDAM bombs capability to enter it's target.
- During fights in South-Ossetia 2008 GPS-signal was weaked. A signal accuracy received by Russian troups was only 300m.
- 5000 GPS receivers used in oparation Desert Storm in year 1991. Also

disturbance and signal weakening used against Iraqi forces.

GPS

•Meaningful in Desert Storm. Opens a possibility to attack from west through a desert. → Iraqs thought that theres no possibility to operate with large troups in desert.
•GPS helpt to operate tanks and fuel deliveries.
• Weather was still a limiting factor 1991 but afterwards GPS based weapond made breakthrough in Kosovo 1999 and Afhganistan 2001.

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Applications

Civilian:

Navigation

- SW (Google Maps, Nokia Ovi Maps, Tracker Hunter, ..)
- HW Navigators (TomTom, Garmin, ...)

Emergency calls

Surveying tool

Tectonics

GPS tours

Marine

GPS

•The GPS system is widely used in geodesy and Geoinformatics. Static GPS is currently the standard method, and also mapping of detail measurements used ns. kinematic GPS (RTK, Real Time Kinematic).

•Geotrim maintain Finland VRS correction signal which allows the GPS device is accurate to around 15 mm lateral class, and about 25 mm in height.

•In addition, GPS is increasingly penetrating daily life. Is already available on your mobile phone integrated with GPS, and many taxis and cars using GIS-integrated GPS navigation system.

•In some cases, GPS's and believe the widespread use of GPS-maps in the criticism, because there is no longer follow the terrain and the environment no longer as closely as map and compass for navigating. In Poland, the driver drove a small bus into a lake believing GPS obviously outdated map.

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Disadvantages

Cost in some cases
Reception
Accuracy
Battery life
Focusing
Tracking
Military Based / One nation based technology

Future

“The United States Government Accountability Office (GAO) issued on May 7 an alarming report on the future of GPS, characterizing ongoing modernization efforts as shaky. The agency appears to single out the IIF program as the weak link between current stability and ensured future capability, calling into doubt “whether the Air Force will be able to acquire new satellites in time to maintain current GPS service without interruption.” It asserts the very real possibility that “in 2010, as old satellites begin to fail, the overall GPS constellation will fall below the number of satellites required to provide the level of GPS service that the U.S. government commits to.”

“Prepared at the request of the U.S. House of Representatives’ Subcommittee on National Security and Foreign Affairs, Committee on Oversight and Government Reform, and titled "Global Positioning System: Significant Challenges in Sustaining and Upgrading Widely Used Capabilities," the report concludes that "it is uncertain whether the Air Force will be able to acquire new satellites in time to maintain current GPS service without interruption. If not, some military operations and some civilian users could be adversely affected.”

In addition,” the report summary continues, “military users will experience a delay in utilizing new GPS capabilities, including improved resistance to jamming of GPS signals, because of poor synchronization of the acquisition and development of the satellites with the ground control and user equipment. Finally, there are challenges in ensuring civilian requirements for GPS can be met and that GPS is compatible with other new, potentially competing global space-based positioning, navigation, and timing systems.“

The full report can be downloaded from the GAO website.

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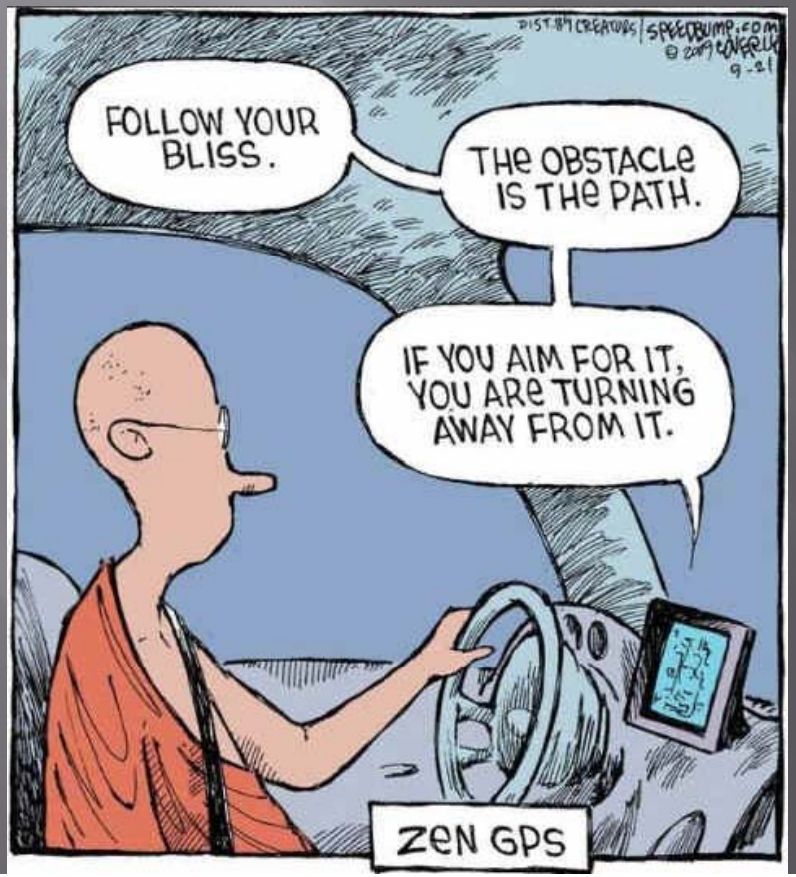
Nice to know

http://www.maps-gps-info.com/gp.html

http://www.roadnotes.com/gpscalc.htm



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GPS for dummies Writer Joel McNamara