Global Positioning System (GPS) and its application in Forestry

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1. Introduction: What is Global Positioning System (GPS)?

Fig. 1: GPS Constellation

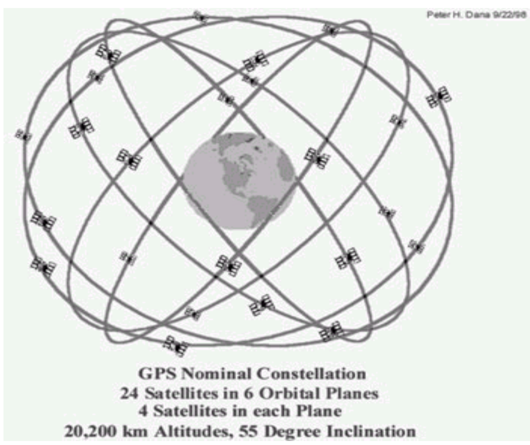
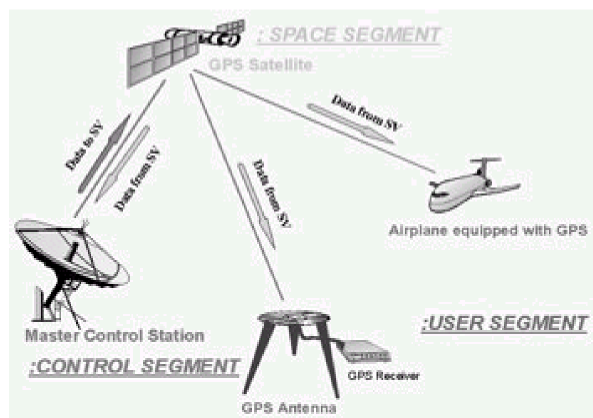


Fig. 2: Different segments of a



Global Positioning System or GPS is a constellation of 27 satellites orbiting the earth at about 12000 miles. These satellites are continuously transmitting a signal and anyone with a GPS receiver on earth can receive these transmissions at no charge. By measuring the travel time of signals transmitted from each satellite, a GPS receiver can calculate its distance from the satellite. Satellite positions are used by receivers as precise reference points to determine the location of the GPS receiver. If a receiver can receive signals from at least 4 satellites, it can determine latitude, longitude, altitude and time. If it can receive signals from 3 satellites, it can determine latitude, longitude and time. The satellites are in orbits such that at any time anywhere on the planet one should be able to receive signals from at least 4 satellites. The basic GPS service provides commercial users with an accuracy of 100 meters, 95% of the time anywhere on the earth. Since May of 2000, this has improved to about 10 to 15 meters due to the removal of selective availability.

2. GPS Master Plan

The launch of the 24th block II satellite in March of 1994 completed the GPS constellation. Four additional satellites are in reserve to be launched "on need."

The spacing of the satellites are arranged so that a minimum of five satellites are in view from every point on the globe. The basic orbits are quite exact but just to make things perfect the GPS satellites are constantly monitored by the Department of Defense.

They use very precise radar to check each satellite's exact altitude, position and speed.
The errors they're checking for are called "ephemeris errors" because they affect the satellite's orbit or "ephemeris." These errors are caused by gravitational pulls from the moon and sun and by the pressure of solar radiation on the satellites.

GPS Satellites
Name: NAVSTAR **Manufacturer:** Rockwell International
Altitude: 10,900 nautical miles **Weight:** 1900 lbs. (in orbit)
Size: 17 ft with solar panels extended **Orbital Period:** 12 hours
Orbital Plane: 55 degrees to equatorial plane **Planned Lifespan:** 7.5 years
Current constellation: 24 Block II production satellites
Future satellites: 21 Block IIrs developed by Martin Marietta

3. Ground Stations or Control Segment

These stations monitor the GPS satellites, checking both their operational health and their exact position in space. The master ground station transmits corrections for the satellite's ephemeris constants and clock offsets back to the satellites themselves. The satellites can then incorporate these updates in the signals they send to GPS receivers. There are five monitor stations: Hawaii, Ascension Island, Diego Garcia, Kwajalein, and Colorado Springs.

4. How GPS works

1. The basis of GPS is **"triangulation"** from satellites.
2. To "triangulate," a GPS receiver measures distance using the travel time of radio signals.
3. To measure travel time, GPS needs very accurate timing, which it achieves with some tricks.
4. Along with distance, it is needed need to know exactly where the satellites are in space. High orbits and careful monitoring are the secret.
5. Finally you must correct for any delays the signal experiences as it travels through the atmosphere.

Improbable as it may seem, the whole idea behind GPS is to use satellites in space as reference points for locations here on earth.

That's right, by very, very accurately measuring our distance from three satellites we can "triangulate" our position anywhere on earth.
Forget for a moment how our receiver measures this distance. First let us consider how distance measurements from three satellites can pinpoint you in space.

The Big Idea Geometrically
Suppose we measure our distance from a satellite and find it to be 11,000 miles.
Knowing that we're 11,000 miles from a particular satellite narrows down all the possible locations we could be in the whole universe to the surface of a sphere that is centred on this satellite and has a radius of 11,000 miles.
Next, say we measure our distance to a second satellite and find out that it's 12,000 miles away. That tells us that we're not only on the first sphere but we're also on a sphere that's 12,000 miles from the second satellite. Or in other words, we're somewhere on the circle where these two spheres intersect. If we then make a measurement from a third satellite and find that we're 13,000 miles from that one, that narrows our position down even further, to the two points where the 13,000 mile sphere cuts through the circle that's the intersection of the first two spheres. So by ranging from three satellites we can narrow our position to just two points in space. To decide which one is our true location we could make a fourth measurement. But usually one of the two points is a ridiculous answer (either too far from Earth or moving at an impossible velocity) and can be rejected without a measurement. A fourth measurement does come in very handy for another reason however, but we'll tell you about that later. Next we'll see how the system measures distances to satellites.

Triangulating: At a Glance

- Position is calculated from distance measurements (ranges) to satellites.
- Mathematically we need four satellite ranges to determine exact position.
- Three ranges are enough if we reject ridiculous answers or use other tricks.
- Another range is required for technical reasons to be discussed later.

The Big Idea Mathematically
In a sense, the whole thing boils down to those **"velocity times travel time"** math problems:
Velocity (60 mph) x Time (2 hours) = Distance (120 miles)
In the case of GPS we're measuring a radio signal so the velocity is going to be the speed of light or roughly 186,000 miles per second.

The problem is measuring the travel time.

The timing problem is tricky. First, the times are going to be awfully short. If a satellite were right overhead the travel time would be something like 0.06 seconds. So we're going to need some really precise clocks. We'll talk about those soon.

But assuming we have precise clocks, how do we measure travel time? To explain it let's use a goofy analogy:

Suppose there was a way to get both the satellite and the receiver to start playing "The Star Spangled Banner" at precisely 12 noon. If sound could reach us from space (which, of course, is ridiculous) then standing at the receiver we'd hear two versions of the Star Spangled Banner, one from our receiver and one from the satellite. These two versions would be out of sync. The version coming from the satellite would be a little delayed because it had to travel more than 11,000 miles. If we wanted to see just how delayed the satellite's version was, we could start delaying the receiver's version until they fell into perfect sync. The amount we have to shift back the receiver's version is equal to the travel time of the satellite's version. So we just multiply that time times the speed of light and we've got our distance to the satellite. That's basically how GPS works. Only instead of the Star Spangled Banner the satellites and receivers use something called a "Pseudo Random Code" - which is probably easier to sing than the Star Spangled Banner.

A Random Code?

The Pseudo Random Code (PRC, shown above) is a fundamental part of GPS. The signal is so complicated that it almost looks like random electrical noise. Hence the name "Pseudo-Random." There are several good reasons for that complexity: First, the complex pattern helps make sure that the receiver doesn't accidentally sync up to some other signal. The patterns are so complex that it's highly unlikely that a stray signal will have exactly the same shape. Since each satellite has its own unique Pseudo-Random Code this complexity also guarantees that the receiver won't accidentally pick up another satellite's signal. So all the satellites can use the same frequency without jamming each other. And it makes it more difficult for a hostile force to jam the system. In fact the Pseudo Random Code gives the DoD a way to control access to the system.

But there's another reason for the complexity of the Pseudo Random Code, a reason that's crucial to making GPS economical. The codes make it possible to use "information theory" to "amplify" the GPS signal. And that's why GPS receivers don't need big satellite dishes to receive the GPS signals. We glossed over one point in our goofy Star-Spangled Banner analogy. It assumes that we can guarantee that both the satellite and the receiver start generating their codes at exactly the same time.

If measuring the travel time of a radio signal is the key to GPS, then our stop watches had better be darn good, because if their timing is off by just a thousandth of a second, at the speed of light, that translates into almost 200 miles of error!
On the satellite side, timing is almost perfect because they have incredibly precise atomic clocks on board.

But what about receivers here on the ground?

We have to remember that both the satellite and the receiver need to be able to precisely synchronize their pseudo-random codes to make the system work. If our receivers needed atomic clocks (which cost upwards of $50K to $100K) GPS would be a lame duck technology. Nobody could afford it. Luckily the designers of GPS came up with a brilliant little trick that lets us get by with much less accurate clocks in our receivers. This trick is one of the key elements of GPS and as an added side benefit it means that every GPS receiver is essentially an **atomic-accuracy clock.**
The secret to perfect timing is to make an *extra* satellite measurement.
That's right, if three perfect measurements can locate a point in 3-dimensional space, then four *imperfect* measurements can do the same thing.

Extra Measurement Cures Timing Offset

If our receiver's clocks were perfect, then all our satellite ranges would intersect at a single point (which is our position). But with imperfect clocks, a fourth measurement, done as a cross-check, will NOT intersect with the first three.
So the receiver's computer says "Uh-oh! there is a discrepancy in my measurements. I must not be perfectly synced with universal time."
Since any offset from universal time will affect all of our measurements, the receiver looks for a single correction factor that it can subtract from all its timing measurements that would cause them all to intersect at a single point.

That correction brings the receiver's clock back into sync with universal time, and bingo! - you've got atomic accuracy time right in the palm of your hand.
Once it has that correction it applies to all the rest of its measurements and now we've got precise positioning. One consequence of this principle is that any decent GPS receiver will need to have at least four channels so that it can make the four measurements simultaneously.
With the pseudo-random code as a rock solid timing sync pulse, and this extra measurement trick to get us perfectly synced to universal time, we have got everything we need to measure our distance to a satellite in space.
But for the triangulation to work we not only need to know distance, we also need to know exactly where the satellites are.

Getting Perfect Timing

6. Accurate timing is the key to measuring distance to satellites.
7. Satellites are accurate because they have atomic clocks on board.
8. Receiver clocks don't have to be too accurate because an extra satellite range measurement can remove errors.

The errors are usually very slight but if you want great accuracy they must be taken into account.

Getting the message out

Once the DoD has measured a satellite's exact position, they relay that information back up to the satellite itself. The satellite then includes this new corrected position information in the timing signals it's broadcasting. So a GPS signal is more than just pseudo-random code for timing purposes. It also contains a navigation message with ephemeris information as well. With perfect timing and the satellite's exact position you'd think we'd be ready to make perfect position calculations. But there's trouble afoot.

Satellite Positions

- To use the satellites as references for range measurements we need to know exactly where they are.
- GPS satellites are so high up their orbits are very predictable.
- Minor variations in their orbits are measured by the Department of Defense.
- The error information is sent to the satellites, to be transmitted along with the timing signals.

Measuring Distance: Summary of Discussion

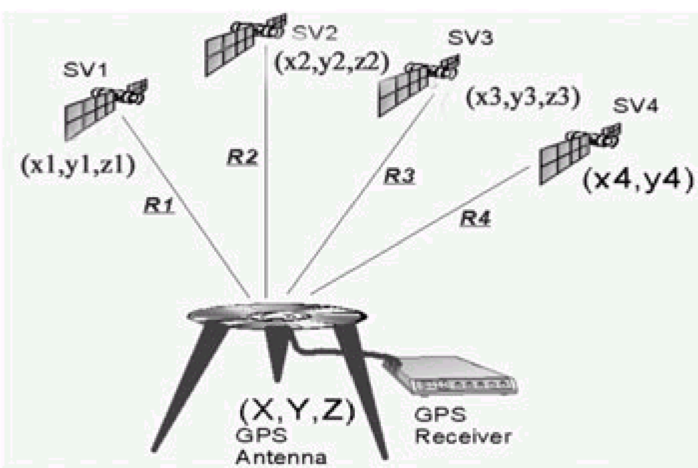


Fig.3: Calculation of Position

A GPS receiver determines its position by using the signals that it observes from different satellites. Since the receiver must solve for its position (X, Y, Z) and the clock error (x), four SVs are required to solve receiver's position using the following four equations:

$R_1^2 = (X - X_1)^2 + (Y - y_1)^2 + (Z - z_1)^2 + x^2$

$R_2^2 = (X - X_2)^2 + (Y - y_2)^2 + (Z - z_2)^2 + x^2$

$R_3^2 = (X - X_3)^2 + (Y - y_3)^2 + (Z - z_3)^2 + x^2$

$R_4^2 = (X - X_4)^2 + (Y - y_4)^2 + (Z - z_4)^2 + x^2$

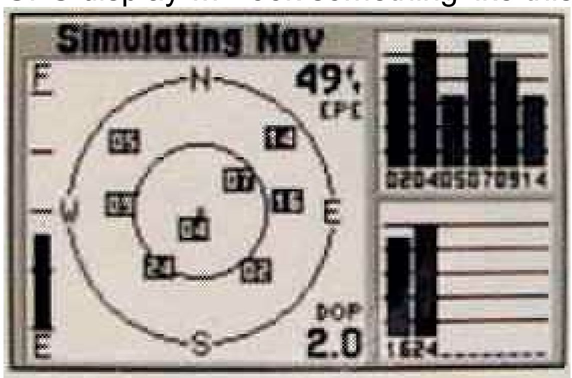
where (x_1,y_1) (x_2,y_2) (x_3,y_3) and (x_4, y_4) stand for the location of satellites and R1, R2, R3, R4 are the distances of satellites from the receiver position (Figure-3). Hence solving the four equations for four unknowns X, Y, Z and x, the position or location of the station is calculated.

9. Distance to a satellite is determined by measuring how long a radio signal takes to reach us from that satellite.
10. To make the measurement we assume that both the satellite and our receiver are generating the same pseudo-random codes at exactly the same time.
11. By comparing how late the satellite's pseudo-random code appears compared to our receiver's code, we determine how long it took to reach us.
12. Multiply that travel time by the speed of light and you've got distance.

5. How a GPS Receiver works?

Fig.4: GPS Receiver

This is a handheld device weighing about 8 ounces and measuring about 6 inches by 2 inches (ignoring the antenna). The antenna is the vertical stub on the right, roughly three inches long. This unit has a small LCD screen and a set of buttons to activate its different features. When you turn on a GPS receiver, its first task is to try to find the radio signals for the satellites it can "see". GPS satellites live in very precise orbits about 11,000 miles up (for comparison, the space shuttle orbits at about 200 miles and geosynchronous satellites orbit at about 24,000 miles). Because the satellites are so far away, their radio signals are fairly weak. Therefore, for the GPS receiver to "see" a satellite, the satellite must be above the horizon and unobstructed by buildings, mountains, etc. At any given moment at any point on the planet there are between 6 and 9 satellites above the horizon. During the process of acquiring the satellites, the GPS display will look something like this:



On this screen, the larger circle represents the horizon and smaller circle represents 45
degrees. The dot in the centre is straight overhead. The numbers within the circles
represent satellites that are visible, and the bar chart on the right represents the relative
strength of the signals from the different satellites. Once the GPS receiver has locked on to 3 satellites, it can display your longitude and latitude to about 100 foot accuracy. If the receiver can see 4 satellites it can also tell you your altitude. With this information you know exactly where you are. Most modern GPS receivers are able to store your track. As you move, the GPS periodically stores your position in its internal memory. It can then show you the path you have followed on the display so that you can see exactly where you have been. Tacks also make backtracking easy. Most modern GPS receivers also support the concept of waypoints and routes. A waypoint is a specific point (longitude and latitude) that you have stored in memory. A route is a series of waypoints connected together to form a path from one point to another. The user can imagine that if you are a boater, he might mark certain buoys as waypoints, or store the coordinates of your favourite fishing spots as waypoints. A hiker might store different landmarks or resting points along a trail as waypoints. The user can then string a collection of waypoints together into a route. At the start of a trip you tell the GPS receiver which route he wants to follow. The receiver will then tell you the heading you need to take to get to the next waypoint in the route. As the user passes each waypoint, the GPS receiver gives the heading to the next waypoint on the route. Some of the newer receivers, like the GPS III shown above, have road maps stored in memory. The unit is therefore able to show the user exactly where he is on a map of the area. Internal maps usually show major highways. By hooking a GPS up to a laptop computer the user can locate you on very detailed road or topographic maps loaded from CD-ROMs. So over all the GPS receivers helps the user to:

- See exactly where the user currently is
- See exactly what path the user has followed using tracks
- Store and then get back to a place the user has visited using waypoints
- Get from point A to point B using waypoints and routes

GPS receivers are especially useful in environments where it is easy to get lost: on the ocean, in the woods, in the air flying at night, etc.

6. Types of Receivers

Aviation

Airborne GPS receivers are generally used for navigation and attitude determination. There is a wide range of receivers available to fit every budgetary requirement. There are handheld GPS receivers available, which can accept data cartridges containing Jeppson charts. High-end GPS units are being built into jumbo jets and are being tested for automated landing.

Computer Boards

These receivers are designed to fit inside a computer of some sort. A general purpose IBM-PC based receiver is made by Novatel while another GPS designer kit is made by GEC-Plessey.

Handheld

Quite a variety of these are now available. Many are intended to fit a specific purpose such as land navigation, boating, aviation and even industrial mapping. The range of features is therefore, fairly diverse. Some are available at prices as low as $300 with some high end-mapping units running up to $4000.

Mapping

These receivers are intended for mapping items for later inclusion in databases, maps or drawings. All will have DGPS capability and most will have the ability to store lots of points and add text or menu information to the points. These units will start around $1000 and go up from there.

OEM Modules

OEM modules are bare GPS receiver boards that are intended to be incorporated into other equipment. Many will be outfitted with one or two RS-232 ports from which the user is responsible for programming the unit and interpreting the output. These can run from a few hundred dollars to several thousand dollars.

PC Card (PCMCIA)

There are only three of these: The NavCard is made by Rockwell while Trimble Navigation makes the GPScard and the Gold GPScard. The Gold card accepts differential correction while the regular card does not. All of these cards are priced between $300 and $1600.

Marine

These are used almost exclusively for navigation. Many will have NMEA-183 interfaces for connecting to other ship electronics.

Space borne

Space born GPS receivers are used for satellite navigation and attitude determination. Most space borne receivers are radiation-hardened versions of ground-based receivers.

Surveying

This grade of receiver is used by surveyors to derive "measurements" rather than "position". For surveyors it is the relative relationship between two receivers that is important; from this relationship an absolute "position" may be derived if and as necessary, on whichever datum is appropriate for the survey. Surveying receivers are generally capable of the highest accuracies and cost the most (up to $30K per set).

7. Error in GPS

Up to now we've been treating the calculations that go into GPS very abstractly, as if the whole thing were happening in a vacuum. But in the real world there are lots of things that can happen to a GPS signal that will make its life less than mathematically perfect.

To get the most out of the system, a good GPS receiver needs to take a wide variety of possible errors into account. Here's what they've got to deal with.

First, one of the basic assumptions we've been using throughout this tutorial is not exactly true. We've been saying that the user calculates distance to a satellite by multiplying a signal's travel time by the speed of light. But the speed of light is only constant in a vacuum.

As a GPS signal passes through the charged particles of the ionosphere and then through the water vapor in the troposphere it gets slowed down a bit, and this creates the same kind of error as bad clocks. There are a couple of ways to minimize this kind of error. For one thing we can predict what a typical delay might be on a typical day. This is called modeling and it helps but, of course, atmospheric conditions are rarely exactly typical.

Another way to get a handle on these atmosphere-induced errors is to compare the relative speeds of two different signals. This **"dual frequency"** measurement is very sophisticated and is only possible with advanced receivers.

Trouble for the GPS signal doesn't end when it gets down to the ground. The signal may bounce off various local obstructions before it gets to our receiver.

This is called **multipath** error and is similar to the ghosting you might see on a TV. Good receivers use sophisticated signal rejection techniques to minimize this problem.

The whole concept of GPS relies on the idea that a GPS signal flies straight from the satellite to the receiver. Unfortunately, in the real world the signal will also bounce around on just about everything in the local environment and get to the receiver that way too. The result is a barrage of signals arriving at the receiver: first the direct one, then a bunch of delayed reflected ones. This creates a messy signal. If the bounced signals are strong enough they can confuse the receiver and cause erroneous measurements.

Sophisticated receivers use a variety of signal processing tricks to make sure that they only consider the earliest arriving signals (which are the direct ones).

Problems at the satellite

Even though the satellites are very sophisticated they do account for some tiny errors in the system. The atomic clocks they use are very, very precise but they're not perfect. Minute discrepancies can occur, and these translate into travel time measurement errors.

And even though the satellites positions are constantly monitored, they can't be watched every second. So slight position or "ephemeris" errors can sneak in between monitoring times.

Ephemeris Errors

Ephemeris (or orbital) data is constantly being transmitted by the satellites. Receivers maintain an "almanac" of this data for all satellites and they update these almanacs as new data comes in. Typically, ephemeris data is updated hourly.

8. Correcting Errors

1. The earth's ionosphere and atmosphere cause delays in the GPS signal that translate into position errors.
2. Some errors can be factored out using mathematics and modeling.
3. The configuration of the satellites in the sky can magnify other errors.
4. Differential GPS can eliminate almost all error.

Basic geometry itself can magnify these other errors with a principle called "Geometric Dilution of Precision" or GDOP. It sounds complicated but the principle is quite simple.

There are usually more satellites available than a receiver needs to fix a position, so the receiver picks a few and ignores the rest. If it picks satellites that are close together in the sky the intersecting circles that define a position will cross at very shallow angles. That increases the grey area or error margin around a position. If it picks satellites that are widely separated the circles intersect at almost right angles and that minimises the error region. Good receivers determine which satellites will give the lowest GDOP.

Summary of GPS Error Sources

Typical Error in Meters (per satellite)	**Standard GPS**	**Differential GPS**
Satellite Clocks	1.5	0
Orbit Errors	2.5	0
Ionosphere	5.0	0.4
Troposphere	0.5	0.2
Receiver Noise	0.3	0.3

Multipath	0.6	0.6

Fig.5: GPS Error Sources

9. How is accuracy improved?

Differential GPS

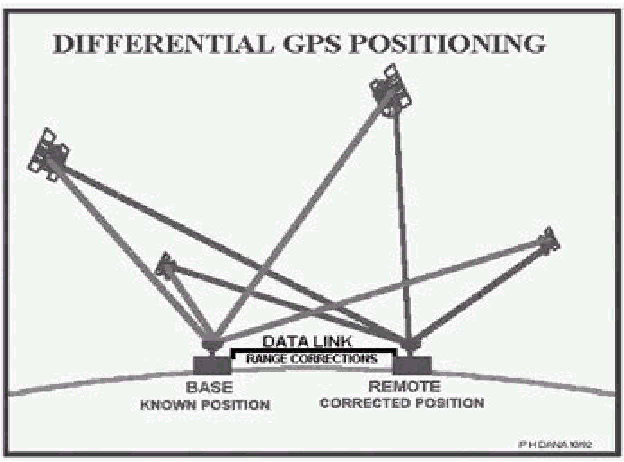


Fig.6: Differential GPS (DGPS)

In order to achieve on-line positioning with high accuracies, Differential GPS (DGPS) is used. Differential positioning user the point position derived from satellite signals and applies correction to that position. These corrections, difference of determined position and the known position, are generated by a reference receiver, whose position is known and is fed to the instrument, and are used by the second receiver to correct its internally generated position. This is known as Differential GPS (Figure-4).

The principal of DGPS is simple. If 2 receivers are placed close to one another, around 100-200 kms they will be subject to the same amount of errors and travel through the same atmospheric conditions. So one uses 2 receivers- one at a known point (base) while the other receiver is collecting the data in the field (rover). The base receiver at the known point stores the position data in the memory or on a PC, while the rover stores the data from the field in its onboard or external memory. The computer compares the second by second data from GPS unit at the base with the actual known point data at the base station and determines the amount of error. When the data from the rover is downloaded in the PC, the software applies the corrections to the rover data and corrects the rover readings. This method is called the post processing method. This method, while providing good accuracy has some limitations and disadvantages:

- One needs 2 receivers (thereby raising the cost) or access to some base station data from a location within 200 kms from the rover.
- This method also does not provide you with real time navigation capabilities.
- Frequently, if the satellites tracked by the base and rover units are different, the readings will not be corrected.
- The other factor to consider in this method is the fact that for every hour spent in the field to collect the data, one needs to spend about an hour in the office post processing this data.

Instead of using the post processing method, one can now utilize the real time correction method. In this case instead of storing the base station data and processing on the PC, the error is calculated in the receiver at the base and broadcast. The U.S. Coast Guard offers one such system and if one has a GPS receiver with an appropriate beacon receiver, one can receive the corrections in real time and accurate GPS readings are displayed. While the service is free, it has a limited range. This range is heavily dependent on the topography of the area. Therefore, this is not a solution for everyone. The second real time system is offered by private companies who are transmitting the correction signals from a satellite. This allows for far better coverage all over the world. But the service ranges around $800.00 to $5,000.00 per year for various areas in the world. Monthly service is also available. The last 2 methods offer the capability of real time accurate readings and therefore good navigation capabilities. Also one does not have to spend time in the office to correct the field data.

10. Uses of GPS

GPS receivers are used for navigation, positioning, time dissemination, and other research.

- Navigation in three dimensions is the primary function of GPS.
- Precise positioning is possible using GPS receivers at reference locations providing corrections and relative positioning data for remote receivers. Surveying, geodetic control, and plate tectonic studies are examples.
- Time and frequency dissemination, based on the precise clocks on board the SVs and controlled by the monitor stations, is another use for GPS.
- Research projects have used GPS signals to measure atmospheric parameters.
- Georeferencing: that is assigning correct latitude and longitude to the control points of satellite imageries and topographic maps.

11. Integration – GPS/GIS Technology

GPS is a powerful tool providing a unique position of a specific feature. With this information, one can navigate back to it. However, one cannot relate this “feature position” to any other “feature position” unless one is standing at the site and other features are visible.

GIS by itself provides great analysis capability but to achieve that one needs plenty of good data. As explained earlier, some data is available but a lot of other data needs to be collected to allow the full capabilities of GIS to be utilized.

Combining the GPS data with GIS allows for greater capabilities than what GPS and GIS can provide individually. With the combination of two technologies one is able to display the “FIELD/ACTUAL SITE” on a PC and make informed decisions. There is no need to make specific site visits or review several documents/drawings. Also, another benefit of the integration is the fact that the data can be shared by unlimited users in various departments for their own specific needs and analysis.

Another important advance in this technology has been the introduction of a software which allows bringing into GIS not only GPS position information but a digital picture. With this software, one can study relationships between features but also view actual photographs of the features right on your PC.

12. Pitfalls of Integration

Combination of GPS/GIS technology is limited by the amount of data. As explained earlier one needs lot of good data for conducting analysis. While some data is available, a lot of data has to be generated by the users for their use. Sometimes collection of field data could turn out to be time consuming and expensive.

Data collected must be accurate and meet the correct formats. For example one need to make sure that all the “layers” of data displayed are in same units (feet/meters) and the projections and datums match. Without this the analysis will not be correct.

13. Application in Forestry

GPS surveying applications:

1. Pre-Harvest & post-harvest cut block traversing
2. Road systems & landings
3. Mechanical site preparation
4. Juvenile spacing, mechanical brushing & planting
5. Forest health (ie) insect & disease tracking
6. Forest fire monitoring
7. Research plots

GPS is used in a wide range of activities such as navigation, tracking, positioning, and precision timing, in all sorts of technology sectors. By integrating the navigation, positioning, and timing abilities of GPS with other technologies and data collection, electronic displays, and communications, a vast amount of applications can be created. In forestry there are no shortage of uses. Large game tracking, vehicle dispatch, heavy equipment monitoring, and all sorts of field data collection application have already been initiated.

GPS has been rapidly evolving over the past few decades. This moving target is sometimes hard to keep up with: dropping prices, new features, Selective Availability (ON then OFF, On and now OFF again), Differential GPS Sources (beacons, satellites, the internet, Bulletin Boards, Wide Area solutions), Dual Frequency, Single Frequency, military bands civilian bands, code and phase processing. GPS can be used to create and maintain digital map databases for the forests we manage. Field digitizing silviculture features, wildlife habitats, cultural and infrastructure features are partly collected on foot. Fire spotting and areal spraying use GPS in aircraft. Field biologists and sport fishers use "fish finders" with integrated GPS units. Forestry applications that use GPS are continually changing.

Simple field digitization and differential processing is a good start, but individuals with knowledge and experience across the wider spectrum of GPS activities increase their appeal to forest companies and organisations.

GPS technology offers several advantages: First and foremost, the service is free worldwide and anyone with a receiver can receive the signals and locate a position.

Second, the system supports unlimited users simultaneously. Third, one of the great advantages of GPS is the fact that it provides navigation capability.

14. Limitations of GPS

As with any technology, GPS also has some limitations. It is essential that the users are aware of these limitations. One must recognize that a GPS receiver gives a location reading, which is subject to some inherent errors some under our control and some outside our control. Unless specific steps are taken to improve the accuracy, even with the Selective Availability (SA) off stand-alone receivers can be as much as 15 meters off.
In order to obtain a GPS position reading, one needs to occupy the point. Often one cannot get there (maybe you don't want to cross a highway with heavy traffic) or you do not want to get there (wildlife etc.).With GPS, if you cannot occupy a point, you cannot obtain the GPS reading. Even if one can reach the point, the area may be covered with a canopy (thick forest) where GPS signals cannot reach and therefore cannot get the reading. GPS needs clear view of the sky. The elevation readings from GPS receivers are not very accurate. Even with differential GPS, the elevation readings can be 2 to 3 times worse than horizontal readings.

15. Conclusion

The integration of GPS with GIS brings the real world to the desktop. What could take days to visit a specific site and analyze can now be performed on the desktop. The power of GPS/GIS is immense and application are unlimited and varied in all areas such as agriculture, environmental, defense, natural resources, health, business etc. As the price of hardware and software comes down the potential of this integration to grow tremendously in country like India. Use of this technology has tremendous application in forestry sector. Use of GIS/GPS & Remote sensing is now being incorporated to prepare the working plan of forest divisions. The tremendous potential of this integrated technology is getting explored in recent times.

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