

/technology

In the right direction with GPS

Virtually every smartphone has GPS these days and in-car navigation systems have become indispensable. In the space of ten years, satellite positioning has become a mass product and work is already well underway on a new generation of GPS.

Initial development

We all use the term GPS as a collective name for satellite navigation and positioning. However, GPS is actually a brand name for the American system. There are also systems from other continents such as GLONASS (Russia) and Galileo (Europe). The general term is Global Navigation Satellite System (GNSS). The development of the United States' GPS began in 1967 as a military application. Eleven years later, the first satellite was launched. The 1990 Gulf War was the first conflict in which GPS was used on a large scale. Only in 1995 did GPS become officially available for civilian navigation. However, the army did not release the highest degree of accuracy. They degraded the civilian signal, restricting its accuracy to a hundred metres. In order to avoid dependence on the American GPS, Europe decided to build its own system: Galileo. America watched these developments closely. The frequency bands chosen for Galileo were so close to those of GPS that the US would not be able to interfere with Galileo without paying a price: if they did, they would degrade their own GPS.

Eventually, Europe chose a different frequency band. And the US switched off the jamming signal in 2000 in order to ward off competition from Galileo. Accuracy went from a hundred metres to fifteen metres, making GPS attractive for civilian navigation. Moreover, at that point PDAs were just powerful enough to run navigation software and mapping material was becoming available for PDAs. This conjunction of factors made a personal navigation device feasible. And so TomTom was born.

As at 2010, the future of Galileo is still uncertain. Recent developments have been more political than technical. Even so,

Galileo has already been very important in keeping the Americans on their toes. They keep on dreaming up new things to stay ahead of Galileo. If Galileo never becomes a reality, that need not be a problem, technically-speaking. Strategically it would be risky: Europe would then have no system of its own and would be permanently dependent on other powers such as Russia, China, India and, of course, the USA.

How does satellite navigation work?

A GNSS satellite is not a spy satellite that continuously follows you. It is exactly the other way around; the user tracks the satellites in order to calculate his position. Positioning using satellites works according to a geometric principle; if you know three fixed points in space and you know your distances to those three points, you can calculate where you are. A GNSS receiver can calculate the position of the satellite and its distance to the satellite from a satellite signal. If it knows the positions of three satellites, it can calculate its own position on earth.

A satellite is constantly sending out messages with information about its orbit. A satellite's orbit is roughly elliptical, with several parameters being of interest; the zero point of the orbit (position at time point zero), its velocity and the dimensions of its orbit (which is an ellipse, so the relevant parameters are the short axis and the long axis; a and b). Because the orbit information is not exact, it is corrected every few hours by a ground station. This involves the ground station sending the satellite a new set of parameters to transmit.



The receiver, for example the smartphone or an in-car application, does two things with the satellite signal. It processes the information about the orbit in order to calculate the satellite's position and it very accurately measures the arrival time of the signal. The report states the time that it was sent. The difference between the two times tells the receiver how long the signal has taken to travel; it can use this information to calculate its distance to the satellite.

In order to determine distance in this way, accurate time measurement is essential. Every satellite is therefore equipped with an atomic clock. The clock in a simple GNSS receiver is not accurate enough for this purpose. You therefore need a fourth satellite for accurate time measurement. The clock in the receiver is synchronised with the atomic clocks of the four satellites. That generates four mathematical equations with four unknowns: time + XYZ coordinates, which can be resolved mathematically by the GNSS receiver.

>>the user tracks the satellites, not the other way round

Satellites for navigation do not hang in geostationary orbit. They fly over the earth, each one in its own orbit. So the receiver sees different satellites coming by all the time. The receiver needs to be able to be receiving at least four satellites in order to calculate a position. So the system needs to plan the orbits of the satellites in such a way that there are always at least four of them well above the horizon everywhere in the world.





Ever-improving signal

Although, ten years on, GNSS systems are now completely established, development goes on. The accuracy of fifteen metres can already be increased by a factor of five with a differential GNSS. This makes use of a (purchased) signal from a ground station alongside satellite signals. However, such devices are more expensive and require a subscription to receive the extra signals. Civilian applications currently only use one frequency band, around 1500 MHz. In the future, a lower frequency band will be added (the L5 band), which will allow transmission at greater power. This will carry extra signals, for greater accuracy and other services (at a charge). The basic signal will remain free to use.

More data, more signals and more frequencies will make GNSS systems a lot more accurate. This will enable us to navigate better. And new applications are coming into view, such as indoor reception. However, we will have to wait until there are enough satellites which offer services on the L5 band. Changes to the GNSS system take time. You cannot simply bring down the satellites for modifications. Improvements are always introduced in new satellites. Satellites have a lifespan of ten to fifteen years. They stay in use until they fail; only then is a new one launched and the replacement satellites are ready to go. Only when that stock is used up will a new generation of satellites be built. This means that

rapid modification to the system is impossible. Around 2018, the current American GPS system will have been entirely replaced by modern satellites. The expectation is that the Galileo system will be fully operational by then.

Own R&D

Most companies that want to build GNSS functionality into their applications buy a standard GPS module for the purpose. There are only a few manufacturers in the world that make these positioning chips. These are chips with limited functionality which the user cannot modify. For example, most standard GPS modules transmit their position once every second. But if you are using position for regulation and control purposes, you may want to know your position ten or a hundred times per second. That capability is not sold as standard, except in very expensive systems.

Technolution wants to have this flexibility, which is why it has built its own GNSS receiver. Not with a view to marketing it as such but to acquire knowledge and experience and to be able to try out the extra possibilities of the new generation of satellites and combine the signals from the different GNSS systems. Our own design receives the basic signals on the L1, L2 and L5 bands used in GLONASS, GPS, EGNOS and Galileo. The receiver can accept several frequencies at once. The signals are digitised and then go



to an FPGA with a built-in GNSS receiver. As a developer, this means you can do what you want: calculate where you are, make measurements and experiment. At any point in the process, you can draw off signals and see what happens. The optimisations you want for a particular application, for example higher reliability, accuracy or speed, you can make yourself. You can combine GNSS with sensors. In this design, we can do that as soon as the signals come in and not, as with the ready-made modules, only when the receiver transmits its position. For example, we are going to use this receiver to investigate the availability of the Wide Area Augmentation System (WAAS) signal of the EGNOS satellite.

>>realising new innovations with GNSS

In other words, our GNSS receiver creates opportunities for realising new innovations with GNSS. For example, it is crucial to current applications such as intelligent speed modification, helping to minimise changes to the intended steady speed and avoid incorrect interventions. In addition, the improved reception in the L5 band makes possible navigation within buildings, more accurate positioning on the road for road pricing and better navigational support for the driver..



Projections: WGS84

In order to accurately determine your position with satellites, you also need a good mapping system. No problem, you might think – after all, maps have been made for centuries. But map-makers were using different systems side by side. This is also linked to how maps used to be made: by means of land surveying, with everyone using their own local mapping systems with their own points of beginning. Land maps used one system and nautical charts another. GPS requires a worldwide standard for map projections (*). This was only established in 1984 with WGS84 (World Geodetic System 1984). Only by using WGS84 can you represent your position unambiguously anywhere in the world with a single mapping system.



(*) A cartographic projection is a way of translating a physical location to a point on a map.