What is RTK-GPS and why is it important?

UAV LiDAR Mapping

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Abstract

RTK-GPS systems are one solution to getting centimeter-level positioning accuracy. This technology is more accurate than the GPS found inside smartphones, but this begs the question: Why is centimeter-level positioning accuracy important? Several examples of RTK-GPS uses will be discussed. In addition, the reader will be introduced to the history of RTK-GPS, a high-level explanation of how it works, and its uses in the Jazzberry Jam senior design project. By the end of this document, the reader should be able to explain how RTK-GPS works, give examples of its importance, and determine situations that require it.

A Brief History and Background

The Beginning of GPS

It all started with Sputnik. The night after its launch on October 4th, 1957, MIT scientists noticed that the satellite would emit radio signals at a higher frequency when it was near their location and lower frequencies when it was far

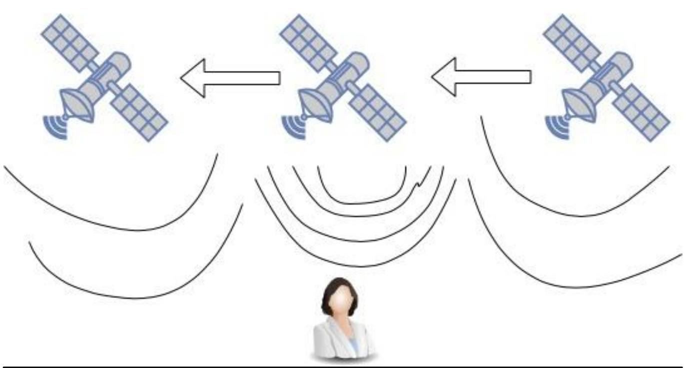

Figure 1: Doppler effect of Sputnik. Frequency of signals increases when the satellite is close to the observer.

away. This, phenomenon, known as the Doppler effect, guided scientists and engineers towards using satellite signals to determine the location of any point on earth's surface. To do this, it would be like monitoring the location of the satellite from a point on earth, except the concept would be reversed to monitor one's location from the satellite. Thus, the Global Positioning System array of satellites were born and unleashed to the world. GPS became increasingly popular for an incredibly wide array of applications. All seemed well, up to a point.

Where Does GPS Work?

GPS applications are everywhere. The most obvious examples are found in your smartphone. But just because they are widely used doesn't mean that they're perfect. Far from it, actually. If you've ever tried to use your mapping app underground, in cities, or even on certain days, you'll noticed that the locations reported by the app can be wildly wrong. Or, if you take exit ramp off of a freeway, it can take the GPS several seconds to realize that you have changed your side-to-side position. RTK-GPS can solve these inaccuracy issues with very precise measurements, but it is only suitable for certain applications. In the next section, you will see how and why.

Ideal GPS Performance

"Traditional" GPS receivers can locate themselves within a 2-4 meter radius. These receivers rely on knowing the current time and position of at least four satellites to calculate their positions. Signals emitted by the satellite on the L1 (legacy broadcast for civilian use) band travel at 1575MHz, which translates to a wavelength of 19cm. In addition, these receivers can measure the phase of the incoming signal. It would seem that it is possible to get centimeter to sub-centimeter accuracy. Yet, in practice this is not realizable. Other sources of error abound.

Error Sources and Solutions

To reach the receiver on the ground, the satellite signal has to travel through the atmosphere and the ionosphere. In atmospheric regions such as the troposphere and stratosphere, the signal loses its energy through absorption and cloud, rain, hail, snow, or fog attenuation. As it travels through the ionosphere, it encounters interference from absorption, reflection, refraction, scattering, polarization, group delay, and fading. GPS engineers knew this, so they developed GPS augmentation systems (see SBAS and WAAS systems) that measured error at ground stations around the world. These ground stations send localized error data through radio and satellites. Any differential GPS operating near a base station will receive the correction data and be able to find its position within less than a meter. This is essentially a larger scale version of RTK-GPS.

The Introduction of RTK-GPS

In the 1990's, RTK-GPS was introduced to increase the performance of GPS readings near base stations. It is commonly used in land surveying applications where accuracy is extremely important. Topographical maps, construction layouts, and volumetric surveys all depend on accurate height, latitudinal, and longitudinal data. According to Natural Resources Canada, topographical maps show "ground relief (landforms and terrain), drainage (lakes and rivers), forest cover, administrative areas, populated areas, transportation routes and facilities (including roads and railways), and other man-made features." An example use case for a topographical map could be a hiker trying to plan their way through some unknown terrain. In order to conserve energy, they might want to take the most gradual ascent through a forest. Construction layouts need to be mapped from paper to the physical site. The more accurate these translations are, the higher the chances of completing the project on schedule, on budget, and to specification. Any imprecise measurement weakens the structure's integrity. Finally, volumetric survey measurements, such as volume of material stockpiles, amount of material removed from excavation sites, dam capacity, and remaining airspace in landfills also depend on accurate measurements. Knowing this information can prevent overexcavating, flooding, and overfilling.

RTK's Workings, Benefits, and Drawbacks

How does RTK-GPS Physically Work?

Now that we've had an introduction to RTK-GPS use cases and why centimeter-level accuracy can be important, the question still stands: How does RTK-GPS work? At a high level, the base station (a stationary receiver) measures errors and sends accurate correction data to a rover (a mobile receiver or another station). To measure the error, the base station counts the number of carrier signal cycles coming from the satellite, then multiplies this error by the wavelength. Since the base station is stationary, there will be less error between it and the satellite compared to a moving GPS receiver. The calculations required to determine these cycles are called ambiguity resolution. These involve complex statistical methods, so the details are left out of this article. Once the correction data has been created at the base station, it is sent to the rover via a radio modem. The rover can now calculate its relative position with millimeter accuracy. However, its absolute position is dependent on the computed accuracy of the base station and the quality of the station's satellite observations. It is therefore very important to place the base station in a location that renders it free from interference and multipath.

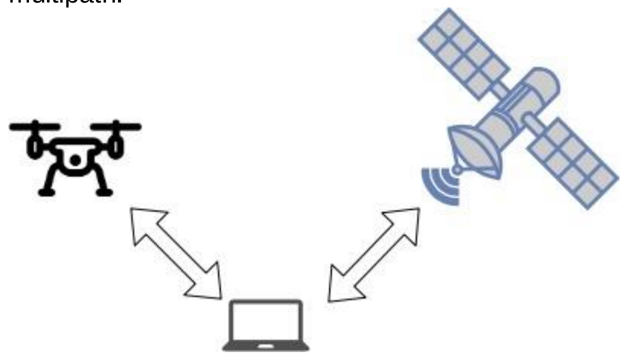

Figure 2: Direction of communication between satellite, base station (middle), and drone (rover).

How Can the Data Be Communicated to Computers?

Once the location data is sampled on the rover, there are two ways it can be processed: in real time or post-flight. Kinematic GPS data that is processed in real time is called RTK-GPS (real time kinematic) while post processed kinematic is called PPK-GPS. RTK relies on a strong radio connection between the rover and the base station and sends real-time positioning data to the base station via this channel. The benefit is being able to see the drone's position instantaneously, but with less accuracy than PPK due to the possibilities of a broken radio and GNSS links. PPK saves the data onto the rover, which is then combined with the base station data once the data collection has finished. There is no need for a radio link, which means that the risk of data loss is significantly lower. Additionally, more powerful post-processing methods can be used with PPK, such as sweeping over the data several times to give more comprehensive results.

Conclusion

For the Jazzbery Jam senior design project, a LiDAR-equipped drone will be using RTK-GPS to map accurate positioning data to points on a 3D map using a Here+ RTK-GPS system. As it flies, the drone will project GPS data to the points that are mapped by the LiDAR sensor. The goal is to enhance 3D map accuracy on applications such as Google Maps, Apple Maps, and others.

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