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Global Navigation Satellite System (GNSS) and other geospatial tools for various applications

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Abstract

Nowadays the Global Satellite Navigation Systems (GNSS) play a fundamental role in many areas as civil aviation, maritime and land navigation and geomatics, owing to the ability to provide worldwide, tridimensional, all-weather position, and velocity and time synchronization. The final product of the Global Navigation Satellite System exercise is the Three - Dimensional coordinates (3D) of the receiving station. These coordinates have been found reliable for most geospatial applications. However, some applications in data management required other information apart from geodetic coordinates. Hence; GNSS has been integrated with other methods of data acquisition to improve the quality of data for various applications. These have helped in solving a lot of problems where individual methods failed. This paper examines some satellite-based systems and reports the integration of GNSS with other data acquisition tools such as geodetic levelling, Remote Sensing, Geographic Information System (GIS), Inertial Navigation System (INS) and many others. In some cases, the synergy had resulted in other satellite or payload programs such as Gravity Recovery and Climate Experiment (GRACE), while it has improved the GNSS applications in so many areas. GNSS integration is therefore recommended for any application that requires the use of the location.

Keywords: GNSS; Geospatial; Three Dimensional Coordinates; Position; Integration

1. Introduction

Global Navigation Satellite System (GNSS) is the standard generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. A GNSS allows receivers, such as the NAVSTAR Global Positioning System (GPS), to determine their location (longitude, latitude, and altitude) within a few meters using time signals transmitted along a line of sight from satellites. GNSS is a satellite system that is used to pinpoint the geographic location of a user's receiver anywhere in the world.

Global Navigation Satellite System (GNSS) is any location fixing system, based on acquiring satellite signals (tracking) with the aid of the receiver and processing of data to obtain the three-dimensional (3D) coordinates of the receiving station concerning a word Geodetic System reference ellipsoid. Therefore, the Holy Grail for future high accuracy GNSS applications is to have the maximum number of satellites, broadcasting the maximum number of signals, being tracked by the least expensive receivers, delivering the most robust solution. The families of GNSS include the following:

- Global Positioning System (GPS) of USA
- Global Navigation Satellite System (GLONASS) of Russia
- The European Union's Galileo positioning system
- Compass Navigation Satellite System (CNSS) of China

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- Indian Regional Navigation Satellite System (IRNSS)
- Bedouin of China
- Quasi-Zenith Navigation Satellite System (QZSS) of Japan

1.1. Global Positioning System (GPS)

The best known and most popular of the GNSS is the United States (US) Global Positioning System (GPS), although the Russian GLONASS system is regaining its strength and other systems are being developed, most notably Galileo in Europe, the Chinese BeiDou navigation system, WAAS of United States, EGNOS of Europe, MSAS & QZSS (Quasi-Zenith Satellite System) of Japan and Compass in China.

GPS is a location fixing system initiated by the US Department of Defence (DoD) based on acquiring satellite signals (tracking) with the aid of the receiver and processing of data to obtain the three dimensional (3D) coordinates of the receiving station. GPS is a fully functional Global Navigation Satellite System (GNSS). At present, it utilizes a constellation of about 31 medium Earth-orbiting satellites. These satellites transmit precise microwave signals and enable the GPS receiver to determine its location, time and speed (if the antenna is moving). Various Authors have discussed the system segments, configuration, policies, implementation and applications (King et al., 1985; Grenoble and Mark, 1995; Leick, 1995; Gregory, 1996; Featherstone, 1996; Agajelu, 1997; Franke, 1999; Higgins, 2000; Adhikery, 2001; Vanicek, 2001; El-Rabbany, 2002; Martti, 2002; Seeber G. 2003; NIS, 2004; Moka and Okeke, 2005; Uzodinma, 2005; Kaplan and Hegarty, 2006; Fajemirokun, and Nwillo, 2007; Ogundare, 2007a; Olopa, 2007; Sarumi, 2007and Aleem, 2013). Apart from GPS, there are other systems, which serve the same function as GPS but belong to other nations. They are discussed below:

1.2. GLONASS

The recent enhancement of the GLONASS satellite system suggests the combined use with GPS to increase satellite availability, especially in places with a lack of GPS signals; also GLONASS measurements are affected by blocking and multipath problems.

The former Soviet Union and now Russia developed 'GLObal'naya NAvigatsionnaya Sputnikovaya Sistema' meaning GLObal Navigation Satellite System (GLONASS). The GLONASS constellation also reached its full operational capability of 24 satellites in 1996. Currently, only twenty satellites are in operation with two active spares four are under maintenance. The average lifetime of the satellite which was about 4.5 years was improved. Russia has announced publicly its intention to restore the GLONASS constellation to full health status, through the deployment of longer life satellites. The fully operational capability expected in 2010 was achieved on the 5th of March, 2013, with the assistance of India which is currently participating in the restoration project.

With 24 satellites, Russia successfully developed its analogue of the American GPS, named GLONASS. It is providing now complete global coverage, a Russian daily reported Dr Andrei Ionin, who works for the operators of GLONASS explained that with 18 satellites, GLONASS was able to provide precise navigation across Russia. With all 24 GLONASS satellites in orbit, GLONASS receivers can pick signals from the quartets that are necessary for precise positioning anywhere in the world.

1.3. The European Union's Galileo positioning system

Galileo was built by European Union and the European Space Agency. The first satellite was launched in 2005 and the second in 2008. By early 2020, there were 26 launched satellites in the constellation: 22 in usable condition (i.e. the satellite is operational and contributing to the service provision), two satellites are in "testing" and two more not available to users. Out of 22 active satellites, three were from the IOV (In-Orbit Validation) types and 19 of the FOC types. Two test FOC satellites are orbiting the Earth in highly eccentric orbits whose orientation changes concerning other Galileo orbital planes. The Galileo system has greater accuracy than GPS, having an accuracy of less than one metre when using broadcast ephemeris (GPS: three metres) and a signal-in-space ranging error (SISRE) of 1.6 cm (GPS: 2.3 cm, GLONASS and BeiDou: 4–6 cm) when using real-time corrections for satellite orbits and clocks.

Europe's Galileo system (a navigation satellite system) has passed its latest milestone, transmitting its very first test navigation signal back to the Earth. According to European Space Agency (ESA) press statement, the different Galileo signals are being activated and tested one by one. Soon after the payload power amplifiers were switched on and 'outgassed'– warmed up to release vapours that might otherwise interfere with operations – the first test signal was captured at Redu. It is expected that the next generation of satellites will begin to become operational after 2025 to replace older equipment, which can then be used for backup capabilities.

1.4. Indian Regional Navigation Satellites System (IRNSS)

IRNSS is an independent regional navigation satellite system developed by India. It is designed to provide accurate position information service to assist in the navigation of ships in the Indian Ocean waters. It could replace the US-owned Global Positioning System (GPS) in the Indian Ocean extending up to approximately 1500 km from the Indian boundary. IRNSS is an independent regional navigation satellite system being developed by India. It is designed to provide accurate position information service to users in India as well as the region extending up to 1500 km from its boundary, which is its primary service area. An Extended Service Area lies between primary service area and area enclosed by the rectangle from Latitude 30 deg South to 50 deg North, Longitude 30 deg East to 130 deg East. All the satellites will be continuously visible in the Indian region for 24 hours a day.

IRNSS will provide two types of services, namely, Standard Positioning Service (SPS) which is provided to all the users and Restricted Service (RS), which is an encrypted service provided only to the authorized users. The IRNSS System has been providing a position accuracy of better than 20 m in the primary service area.

1.5. Some applications of IRNSS are

Terrestrial, Aerial and Marine Navigation**,** Disaster Management**,** Vehicle tracking and fleet management**,** integration with mobile phones**,** Precise Timing**,** Mapping and Geodetic data capture**,** Terrestrial navigation aid for hikers and travellers**,** Visual and voice navigation for drivers. (Jaiswal, 2021)

1.6. Compass Navigation Satellite System (CNSS) of China

The second generation of the BeiDou Satellite Navigation Experimental System is known as *Compass* or *BeiDou-2*. China has indicated her interest to have a global navigation system similar to GPS. It became operational with coverage of China in December 2011 with 10 satellites in use.

China has sent three satellites into geostationary orbit (80 geostationary orbits (80 °E (east longitude E (east longitude eighty degrees), 140 eighty degrees), 140 °E, 110.5 E, 110.5 °E) since E) since 2000, and then Compass/ 2000, and then Compass/BeiDou Navigation Test System has been established. The fourth experimental satellite was launched in Feb 2007 and the satellite was launched in Feb 2007 and brought into use on 26th March 2007.

The space segment of CNSS consists CNSS consists of 5 geostationary earth orbit (GEO) and earth orbit (GEO) and 30 medium earth orbit (MEO) satellites.

Two kinds of service are provided. One is the Open Service, which is designed to provide users with positioning accuracy within 10 meters, velocity accuracy within 0.2 meters per second and timing accuracy within 50 nanoseconds. The other is the Authorized Service, which will offer "safer" positioning, velocity, timing, communication services and integrity information for authorized users. (China Satellite Navigation Project Center, 2008)

1.7. BeiDou Satellite Navigation Experimental System

The BeiDou system was developed by the People's Republic of China. The first BeiDou system was officially called *BeiDou* Satellite Navigation Experimental System*.* The system started in the year 2000 and consists of 3 satellites called BeiDou-1, but has limited coverage and applications mainly for customers in China and from neighbouring regions.

The second generation of the system officially called the BeiDou Satellite Navigation System (BDS) and also known as COMPASS or BeiDou-2, will be a global satellite navigation system consisting of 35 satellites that were under construction as of January 2013. It became operational in China in December 2011.

1.8. Quasi-Zenith Satellite System (QZSS)

QZSS is owned and managed by Japan Aerospace Exploration Agency (JAXA). The first QZSS satellite called 'Michibiki' was launched on the 11th of September 2010. Other relevant information is available online on the JAXA website. Interestingly, JAXA has adopted a data interface based on Receiver Internet Exchange "RINEX 3.01" format in "MGM-Net" which includes the participating ground stations. The idea is to know the availability, capabilities evaluation of multipath and Radio Frequency Interference (RFI) environment of the GNSS for the future QZSS satellites to be launched. Full operational status was IS by 2017. The development in GNSS application is to integrate the system with other tools for various applications. GPS and GLONASS combined have already demonstrated the benefits of extra satellites, and Galileo brings all that and more. The benefits of the expected extra satellites and their signals can be categorized in terms of continuity, accuracy, efficiency, availability and reliability. Some of these integrations are as discussed below:

1.9. Integration of GNSS and Other Tools

GNSS has been integrated with other methods of data acquisition to improve the quality of data for various applications. These have helped in solving a lot of problems where individual methods failed. Such integration includes GNSS and Geodetic levelling, GNSS and GIS, GNSS and Inertial Navigation System (INS), Satellite – to - Satellite Tracking.

1.9.1. GNSS and Geodetic Levelling

All GNSS measure height with reference to the ellipsoid while geodetic levelling heights measurements are reduced to the geoid. The difference between the two is Geoidal Undulation.

1.9.2. GNSS and Remote Sensing

Remote Sensing and GNSS have a common origin in the use of satellites as the basic source of data. This shows that there is a closed link between the two systems. Therefore, integrating the system has improved the accuracy. Remote Sensing is capable of revealing a lot of information that may be hidden by other methods and it is used to monitor the environment while GNSS will give the position anywhere on the globe. The positions are accurate and the problems of image distortion in the Remote sensing method are solved with the integration. GNSS coordinates are equally used in geo-referencing the Remote sensing image for processing in any application.

1.9.3. GNSS and GIS Integration

GNSS and Geographic Information System (GIS) have been combined and used in various applications. According to Olaleye *et al* (1999) "two technologies on their show different areas of use but the integration of the two, open a new world of application”. This means fundamentally, that one can locate the position of any feature on the Earth surface (GPS) and plot this position in relation to a bigger spatial representation such as map on the digital environment (GIS)." Presently, there are software in the market which are capable of interfacing GNSS with GIS. Such may include IDRIS, ARC/INFor, ERDARS, TNTLite and so on.

1.9.4. GNSS and Inertial Navigation System (INS) Integration

The two positioning systems have their characteristics. Global Positioning System (GPS), one of the GNSS, provides positioning and timing information to worldwide users. However, GPS sometimes suffers accuracy and availability problems. INS provides self-contained high-frequency positioning information by integration of accelerations and rotation rates. During the integration process, any bias and errors in IMU sensors will be amplified over time. This results in the unbounded growth of positioning errors in the entire real-time computing process (Xiaoying Kong, 2012).

GNSS has been integrated with the Inertial Navigation System (INS). With this integration, INS has been updated with velocity and position to refine the navigation and measurement of gravity especially deflection of vertical. The complementary characteristics of the two systems made the integration of GNSS and INS viable and widely used for a variety of positioning, navigation, and geo-referencing applications. Depending on the type of applications and other factors, GNSS /INS integration can be developed in three modes, viz.: loose, tight, and ultra-tight integrations. The integration Kalmar filter is at the heart of integrated GPS/INS systems. The widely used integration Kalmar filter is based on the INS error dynamic model, including both navigation states and sensor error states. Precise GPS measurements are used to estimate the INS errors and thus the calibrated INS can provide precise position, velocity and attitude information for the user platform.

1.9.5. Satellite – to - Satellite Tracking

The orbit of a low orbiting satellite is much affected by gravitational pull; air drag and other effects. Low orbiting satellite may be integrated with GNSS (a high orbiting) satellite for satellite –to- satellite tracking method in gravity determination. The low orbiting satellite will have the capability of taking gravimetric data from the Earth's surface, which can be sent to GNSS satellite of high altitude, which then determines the position accurately. The two data can be supplied simultaneously to the users.

The theory of satellite –to- satellite tracking was applied in Gravity Recovery and Climate Experiment (GRACE) and Gravity Field and Ocean Circulation Experiment (GOCE). Presently, the system is called the Global Earth Observation System of Systems.

Apart from the above, this integration has been extensively applied in the mapping of the gravity field. The integration also made it possible to precisely determine the following:

- Velocities
- Gravity anomalies
- Deflection of vertical.

In this integration, it is possible to include deflection of vertical in the post-mission analysis and also the feasibility of conventional gravimetry from the aeroplane and other vehicles. To enhance the capabilities of this integration, the University of New South Wales developed both commercial systems and in-house software packages for operations of integrated GPS/INS systems through real data analysis.

1.10. Global Earth Observation System of Systems (GEOSS)

GEOSS is an international effort to build a public infrastructure that interconnects a diverse and growing array of instruments and systems for monitoring and predicting changes in the global environment (Ezeigbo, 2010). Among the major instruments, which belong to the GEOSS system are the Global Navigation Satellite System (GNSS), Very Long Baseline Interferometer (VLBI), Interferometric Synthetic Aperture Radar (InSAR), Challenging Mini-Satellite Pay-load (CHAMP), Gravity Recovery and Climate Experiment (GRACE), Gravity Field and Steady-State Ocean Circulation Explorer (GOCE).

1.10.1. Gravity Recovery and Climate Experiment (GRACE)

On the 17th of March 2002, GRACE was launched under the Earth System Science Pathfinder Program (ESSP) by the National Administration of Space Agency (NASA). The GRACE mission has 2 identical space crafts (the twin GRACEs) at 220km apart in a polar orbit at an altitude of 500km above the Earth's surface. It does consist of satellite range rate measurements, accelerometer GPS and altitude measurement from each satellite. This program enables the accurate mapping of the Earth's gravity every 30 days over its five years lifespan with a spatial resolution of 400km (half wavelength).

The results of the gravity mapping have been an unprecedented view of the local gravity conditions. Another area of gravity use is the detection of groundwater. Water has the value of mass, and "GRACE can detect differences in groundwater with outstanding accuracy, along with improvements in the precision of the geoid (a model of the Earth's gravity field) of between 10- to 100-fold. Measurements of ocean bottom pressure obtained from GRACE are of high accuracy, which surprised oceanographers, and GRACE even profiles the global water vapour content of the Earth's atmosphere". The GRACE satellites have changed the way people look at the water. It was shown that the changes in the Earth's atmosphere provide different data on melting rates of the world's ice. For example, it was GRACE that determined that ice loss from the high Asian mountain ranges, which was only 4 billion tons a year, compared to the 50 billion tons of ground-based estimates. GRACE pegs global ice loss over the period from 2003 to 2010 at about 4.3 trillion tons, adding about 0.5 inches to the global sea level in eight years.

1.10.2. Gravity Field and Steady-State Ocean Circulation Explorer (GOCE)

On March 17, 2009, the European Space Agency launched a satellite-based gravity mission called GOCE into orbit. This mission carries a 3-axis gradiometer and a GPS/GLONASS receiver. The reference orbit is down dust, sun-synchronous at an altitude of 250/270km above the Earth's surface. The combination of high and low altitude satellites that is satellite –to- satellite track and a gradiometer enable an excellent mapping of the Earth's gravitation field (Ezeigbo, 2005).

The mission of GOCE by the European Space Agency is mapping the Earth's gravity field with the same level of accuracy as GRACE and a higher spatial resolution. "GRACE and GOCE are complementary in terms of spectral sensitivity. A series of GOCE and GRACE and GOCE-based global gravity models have been released since 2010. Assessment of these models is commonly based on comparisons with other independent data, that are direct and indirect based on the observations of the Earth's gravity field, including geoid heights from GPS and spirit levelled heights, airborne and surface gravity measurements, marine geoid heights from mean oceanographic sea surface topography models, altimetry observations, orbits from other geodetic and altimetry satellites. In response to the call of having an independent coordinated and inclusive team for the assessment of the new GOCE models, a Joint Working Group (JWG) was approved by IGFS and the IAG Commission 2 during IUGG 2011 in Melbourne, Australia. Its objectives are to develop new standard validation/calibration procedures and to perform the quality assessment of GOCE- GRACE and GOCE-based satellite-only and combined solutions for the static Earth's gravity field".

GOCE was able to gather enough data to map Earth's gravity just after two years in orbit. By 31 March 2011, this satellite was able to produce with unrivalled precision the most accurate model of the 'geoid', while on the 12th March 2012; the first global high-resolution map of the boundary between Earth's crust and mantle – the Moho – was produced based on data from GOCE gravity satellite. The most accurate gravity map of Earth has already been delivered by ESA's GOCE gravity satellite on the 16th November 2012. To obtain even better results, the orbit of the satellite is being lowered. The incredibly low orbit of the satellite kept less than 260km was maintained and responsible by GOCE's innovative ion engine, together with its accelerometer measurements. GOCE was able to provide new insight into air density and wind speeds in the upper atmosphere. It was also planned that GOCE will give dynamic topography and circulation patterns of the oceans with unprecedented quality and resolution in the near future.

Unfortunately, the plan was dusted on the 21st of October, 2013 when the mission came to a natural end as it ran out of fuel and the satellite gradually descended, with most of the 1,100kg satellite disintegrated in the atmosphere, an estimated 25% reached Earth's surface on Monday 11th November, 2013. ESA's GOCE satellite reentered Earth's atmosphere on a descending orbit pass that extended across Siberia, the western Pacific Ocean, the eastern Indian Ocean and Antarctica. Fortunately, there was no damage to the property.

1.10.3. Multi-GNSS Monitoring Network (MGM-Net)

MGM-Net is a multi-constellation GNSS augmentation and assistance system which include a plurality of reference stations across the world. Each of the reference stations may be adapted to receive navigation data from a plurality of different GNSS and to monitor integrity and performance data for each of the GNSS. An operation centre may receive the integrity and performance data transmitted from each of the plurality of all the reference stations in the network. The Japan Aerospace Exploration Agency (JAXA) has established a Multi-Global Navigation Satellites System Monitoring Network under international collaboration as part of the "Multi-GNSS Demonstration Campaign". The receiver used in this system can track any GNSS satellites for various applications.

1.10.4. Augmentation Systems

These are the navigational aid developed for different functions to improve the accuracy, integrity, and availability of satellites. There are several such systems worldwide, some are satellites based while others are ground-based:

1.11. Ground-Based Augmentation Systems (GBAS)

GBAS is a satellite-based precision approach established at an airport, aimed to provide an accurate landing system to the aeroplane. GBAS provides aircraft with very precise positioning guidance, both horizontal and vertical, which is especially critical during the approach and landing phase of flight. This allows for a safer, more efficient and descent landing operation.

1.12. Satellite-Based Augmentation Systems (SBAS)

Satellite-Based Augmentation Systems deliver error corrections, extra ranging signals (from the geostationary satellite) and integrity information for each GPS satellite being monitored. Augmentation Systems includes the US WAAS Wide Area Augmentation System (WAAS) a navigational aid designed to enable aircraft to rely on GPS for taking off, en routing, landing operations and any other phases of flight, including precision approaches to all airports within its coverage area. Examples of WAAS are the: European EGNOS Japan's MSAS, India's GAGAN, Russia's SDCM and China's COMPASS

Researches are still ongoing on the applications of the Global Navigation Satellites System and integrating it with other methods of positioning to solve geospatial problems.

1.13. Integrating Unmanned Aerial Vehicle with Ground Penetrating Radar (GPR)

An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft with no pilot onboard or an aircraft with remote control from a ground station. One of the major components of Frone is the GNSS device that enables its accurate location. UAVs have been integrated with other tools e.g a ground-penetrating radar (GPR) mounted on a drone enables users to see through the surface of ground, ice, rocks, freshwater and buildings or structures. This is a good way to map flooding and other natural disasters.

1.13.1. Applications

Global Positioning System is a fast, accurate and efficient tool in positioning, navigation and time measurement. Hence, it is basic to various operations and powerful equipment for many professions. To the surveyors, it is an accurate survey tool, defensive guidance to the military and an indispensable tool for navigation on land, sea and air. Other professionals use GPS for various purposes; including Military, Aviation, Communication, and several other applications. it is on these notes that GPS is tagged "general invention"

Global Positioning System is revolutionising all professions involved in data gathering by combining the high accuracy of the conventional method of data acquisition with the convenience of satellite surveying, removing the rigorous of intervisibility between the stations and its ease of measurement coupled with high productivity which results in low cost which has made its applications viable to various professions. Some of the applications of GPS are enumerated below:

1.14. GPS APPLICATIONS IN SURVEYING AND GEOINFORMATICS

GPS has been applied in Geodesy, Cadastral, Engineering, Mining surveying, attitude determination and any other area of geo-spatial information. It is suitable for Digital Terrain Modelling (DTM), pre-marked and post-marked in Photogrammetry, Ground truthing and other data gathering exercises in Remote Sensing. It is equally applied in positioning on the sea for Marine Information System (MIS) in Hydrography and so on in the field of surveying and geo-informatics.

2. Cadastral surveying

One of the basic technical requirements for a multipurpose cadastre is the production of a complete and up to date map which required a monumental network of controls. Global Positioning System has been applied in surveys associated with the establishment of a coordinated cadastre. Also, GPS is applied in the accurate fixing of geo-data and land data such as air rights, oil wells, flood hazard zones; and fixing of individual, family, Local, State, national and international boundaries.

The accuracy required and reliability of coordinates are satisfied. Therefore, GPS can replace the conventional method in cadastral surveying.

3. Geodetic surveying

GPS has been applied in establishing maintaining and densifying a geodetic network of controls for various use. This required high accuracy as they serve as the skeleton for lower-order controls. Also, one of the objectives of Physical geodesy is the determination of the mathematical figure of the earth called the geoid. This has been achieved with a global positioning system. The geoid is a very important concept in the practical determination of orthometric height which is the height system to which most measurements of height on the earth's surface are being referred. Mean Sea Level has been recognised as a good approximation of the geoid (Aleem, 2013). The difference between the ellipsoidal height measured by the GPS and orthometric height which is related to the geoid is geoidal undulation.

4. Photogrammetry

Global Positioning System has been applied in various operations in photogrammetry. These include premarked, postmarked exercises in the establishment of controls in aero-triangulation. Also, GPS has been applied in Digital Terrain Modelling.

5. Hydrographic surveying

GPS is an efficient tool in positioning the sea. Kinematics positioning technique has been applied in hydrographic distance projects where the available Electronics Position Fixing (EPF) instrument surfer range limitations and poor accuracy from the shore. Position established with GPS serves as the control for underwater structures such as well and template; offshore structure such as a lighthouse, oil rig, location buoys, harbour, wharf, shoal and many other applications (Aleem, 1996). Furthermore, Hydrographers have been applying the use of GPS to study waves and tides. Predictions are made from the analyses of the results.

6. Monitoring and deformation surveys

Artificial structures and other engineering construction projects are subject to subsidence and pressure while the measurement of crustal deformation is central to the understanding of earthquake processes, plate-tectonics, rifting, mountain building processes and behaviour of volcanoes. The objective of surveys associated with such monitoring exercise is to measure changes in position, displacement or strain with time. This involves repetitive measurement to identify the changes with high accuracy. GPS has been applied in such exercise.

7. Engineering surveying

The success of most engineering construction works depends on the utilisation of a topographical map which can be produced with data obtained from GPS. The horizontal positions are given directly while the ellipsoidal height can be interpolated to produce the contour on the topographical map, on which the design is made. GPS can also be applied in setting out the design on the ground.

8. Geophysical surveys

GPS is also applied in Geophysical survey in support of pipeline pre-lay route, post lay inspection, rig and dredging survey, drilling hazard assessment and so on.

9. Geographic information system

This involves the management of spatial information. Here, data must be collected. Therefore, there is no GIS without data. One of the basic tools in the acquisition of spatial data is the Global Positioning System. The integration of the two systems will be discussed.

9.1. Applications of GPS in military

The system was initiated and maintained by the military. GPS has been viewed as part of the United State tactical defence system. The most accurate of the navigation service provided by GPS (i. e. Precise Positioning Service) is being reserved for the military, others are being denied assess because of the fear of using it against the US and her allies. Also, military who are to protect the lives and properties of the nation need maps, charts, sketches and diagrams in the performance of their lawful assignment. Special types of maps are being produced for military reconnaissance, such maps can be produced with data acquired from GPS. Other areas of GPS applications in the military are: location of the territorial theatre of war, countermeasures, en-route navigation, low-level navigation, close air support, missile guidance, coordinated bombing, reconnaissance search and rescue operation, enrooted navigation and so on (Aleem, 1996)

9.2. Applications of GPS in agriculture

Agriculture has been the mainstay of various nations' economies. For development to take place or continue, the problem of hunger must be solved. GPS had been applied in agriculture in the following areas:

- Demarcation of land for farming
- Demarcation of some areas in the forest for wild lives
- Other information that assists in erosion control also contributes to the growth of agriculture.

9.3. Applications of GPS in aviation

Aircraft need perfect and reliable navigational devices for successful take-off, enrooting and landing operations. GPS has been applied in many areas of aviation exercises.

9.4. Applications of GPS in navigation

Global Positioning System and other satellites navigation systems supply such information as bearing, distances, 3 Dimensional coordinates, time and other information that are vital in navigation exercises. This will enable the users to navigate on land, sea and air at any time.

10. Conclusion

Global Navigation Satellite System has been integrated with other tools such as geodetic levelling, Remote Sensing, GIS, INS and some other systems that have led to the development and manned of payloads and other satellites application in space. Satellite to satellite tracking methodology produced GOCE. The integration has improved the GNSS applications in so many areas.

Recommendations

GNSS integration is therefore recommended for any applications that require the use of the location.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest

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