Enhancing Trajectory Accuracy of Airborne and Ground-Based Vehicles in GIS Applications with Integrated GNSS-IMU Technology

R RAMBABU, SC22M075, Geoinformatics, Department of Earth and Space Sciences, Indian Institute of Space Science and Technology

Objectives

- Explore the potential benefits of integrating GNSS (Global Navigation Satellite System) and IMU (Inertial Measurement Unit) technologies for enhancing the trajectory accuracy of airborne and ground-based vehicles in GIS (Geographic Information System) applications.
- Evaluate the performance, challenges of the integrated GNSS-IMU system in terms of trajectory accuracy, and to compare it with traditional navigation systems.
- Exploring the advanced Techniques for Improving Trajectory Estimation and Mapping Accuracy.
- Exploring the practical applications of the integrated GNSS-IMU system in various GIS scenarios, such as mapping, surveying, and monitoring.

Introduction

The accurate and precise positioning of vehicles is critical in various applications such as Light Detection and Ranging (LiDAR), high-resolution aerial mapping and other various applications of surveying and mapping. Global Navigation Satellite System (GNSS) is widely used for positioning and navigation of vehicles. However, the accuracy of GNSS can be significantly affected by various factors such as signal blockage, multipath, and atmospheric conditions. Inertial Measurement Unit (IMU) technology can provide information on vehicle motion, which can be used to improve the accuracy of GNSS. Therefore, the integration of GNSS and IMU technologies can enhance the trajectory accuracy of airborne and ground-based vehicles in GIS applications

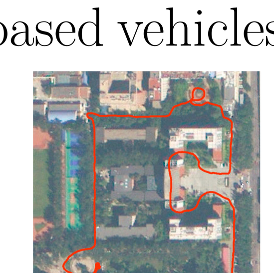

Figure 1:Trajectory of LiDAR Mobile mapping survey

The integrated system allows for more accurate maps and models, improved surveying results, and better monitoring of environmental changes and also allows for faster and more efficient data collection, reducing costs and increasing productivity.

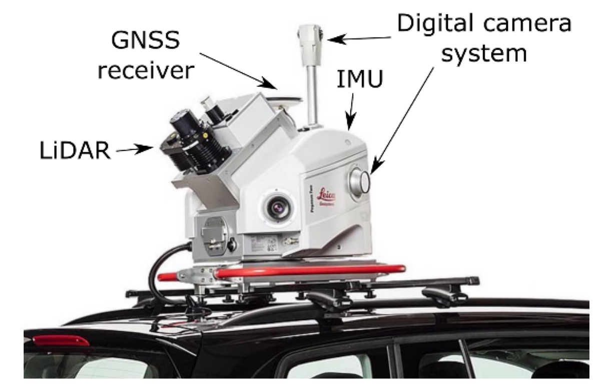

Figure 2:LiDAR integration of GNSS IMU

Integrated GNSS-IMU systems have been shown to outperform traditional navigation systems in terms of trajectory accuracy for both airborne and ground vehicles in GIS applications, because GNSS-IMU systems are able to compensate for the weaknesses of GNSS signals, such as multipath and signal blockage, using inertial measurements from the IMU. The result is a more accurate and reliable trajectory estimation. In contrast, traditional navigation systems rely solely on GNSS signals and are therefore more susceptible to errors in challenging environments, such as urban canyons or under tree canopies.

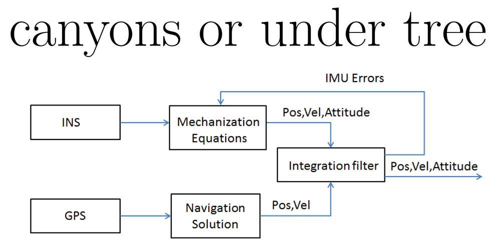

Figure 3:Block diagram of GNSS-IMU integration

the challenges posed by the integration is proper calibration and synchronization which will achieved through rigorous testing and high precision timing synchronization techniques. In addition to that overcome the challenges of position errors of GNSS and bias (gyro drift/acclerometers bias) in IMU should have high quality equipment with advanced filtering capabilities

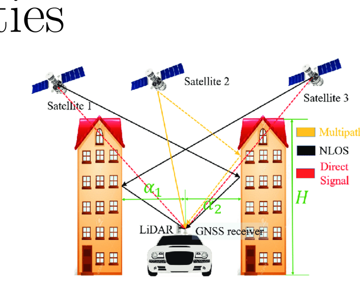

Figure 4:Blockage of signals in urban environment

Techniques/Methods

Deep Learning: Deep learning algorithms have been used to automatically detect and classify objects in LiDAR and aerial images, such as buildings, trees, and vehicles. This information can be used to improve mapping accuracy and identify potential obstacles for autonomous vehicles.

Multi-Sensor Fusion Combining data from multiple sensors such as cameras, radar, and sonar in addition to IMU, GNSS, and LiDAR to improve accuracy, especially in challenging environments.

Nonlinear Filtering: This techniques uses particle filtering and unscented Kalman filtering to estimate the state of a dynamic system based on noisy measurements,nonlinearities and uncertainties for improved accuracy.

Loop Closure: A technique that identifies points in the trajectory where a vehicle or drone revisits a previously scanned area using LiDAR data. By adjusting the trajectory at these loop closures, accumulated errors can be removed, improving trajectory accuracy.

SLAM (Simultaneous Localization and Mapping): A technique that creates a map of the environment while simultaneously estimating the location and orientation of the LiDAR sensor. By incorporating LiDAR data into the trajectory estimation process, SLAM improves trajectory accuracy and the resulting point cloud.

3D city models: Incorporating detailed 3D models of urban environments into the navigation systems, the effects of multipath and signal blockage can be mitigated. This approach has proven effective in improving the accuracy and reliability of GNSS-IMU systems in urban environments since there are high levels of signal blockage.

Figure 5:Enhanced Trajectory for mobile LiDAR survey in Urban Environment using 3D city model

Applications

Aerial surveys: Accurate trajectory information is essential for aerial surveys that use LiDAR and high-resolution aerial imagery. The integrated GNSS-IMU system can provide precise positioning and orientation data for accurate data collection and analysis.

Precision agriculture: Precision agriculture involves the use of geospatial data to optimize crop yields and reduce waste. Accurate trajectory information can be used to precisely map crop areas and monitor crop growth. The integrated GNSS-IMU system can provide precise positioning and orientation data for accurate crop mapping and analysis.

Disaster response: Accurate trajectory information is critical for emergency response efforts during natural disasters. The integrated GNSS-IMU system can provide precise positioning and orientation data for efficient search and rescue operations, damage assessment, and other emergency response activities.

Infrastructure planning: Infrastructure planning involves the use of geospatial data to plan and design infrastructure projects such as roads, bridges, and buildings. Accurate trajectory information can be used to precisely map existing infrastructure and identify areas that require improvements. The integrated GNSS-IMU system can provide precise positioning and orientation data for accurate infrastructure mapping and analysis.

Infrastructure planning: Environmental monitoring involves the use of geospatial data to monitor changes in the environment such as deforestation, land-use change, and water quality. Accurate trajectory information can be used to precisely map environmental features and monitor changes over time. The integrated GNSS-IMU system can provide precise positioning and orientation data for accurate environmental mapping and analysis.