Evaluation Form – Technical Background Review

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_______ / 30 Technical Content

- Current state-of-the-art and commercial products
- Underlying technology
- Implementation of the technology
- Overall quality of the technical summary

_______ / 30 Use of Technical Reference Sources

- Appropriate number of sources (at least six)
- Sufficient number of source types (at least four)
- Quality of the sources
- Appropriate citations in body of text
- Reference list in proper format

_______ / 40 Effectiveness of Writing, Organization, and Development of Content

- Introductory paragraph
- Clear flow of information
- Organization
- Grammar, spelling, punctuation
- Style, readability, audience appropriateness, conformance to standards

_______ / 100 Total - Technical Review Paper

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GPS Integration for Autonomous Surface Vessel

Introduction

Global Positioning System (GPS) is a crucial source of position estimation for outdoor robots since data from the odometer constantly drift from the actual position. This is especially true when applied to Autonomous Surface Vessels (ASV) as the erratic nature of aquatic environments introduces significant noise to local sensors. This paper examines some commercially available GPS products fit for ASVs, explains the underlying technology, and provides methods of GPS integration for position estimation.

Commercial Application of GPS

Application for GPS ranges from military operations to tracking runaway dogs, therefore the quality and price of GPS devices vary drastically. Electronic retail companies such as Sparkfun and Adafruit sell hobbyist-grade GPS modules priced under $100. MTK3339 breakout board ($40) from Adafruit is a 66 channel GPS module with an update rate of 10 Hz and has the advantage of drawing low power and having mounting holes and a USB port for easy prototyping and interfacing [1]. Technology conglomerates like Garmin sell a wider range of products including a slightly higher-end GPS 16x ($100) that is fully waterproof and has an integrated antenna, which is ideal for the aquatic environment [2]. Most GPS products are marketed as multipurpose devices and the distinction between marine and land use are not clear, although some products such as Reach RS+ ($800)/ M+ ($300) module are divided between a base and a mobile “rover” component and require the operating environment to be terrestrial [3].

Technology

A typical GPS module receives signals from satellites that not only include GPS satellites operated by the U.S. Air Force, but also from other systems that are part of the Global Navigation Satellite System (GNSS) such as GLONASS (Russia), BEIDOU (China), and GALILEO (Europe) [4]. A GPS device receives radio signals from multiple satellites and uses a simple mathematical process called trilateration [5]. Trilateration measures the distances between a receiver and satellites and calculates the only possible position on the globe. This requires a solid signal from at least four satellites since the Earth is three-dimensional and one more satellite is required than the number of position dimensions. The distance between a receiver and a satellite is easily derived by multiplying the speed of light by the amount of time it took for a radio signal to travel from a satellite to a receiver [5].

Implementation

Sensor data of the position of a robot are typically fed into a mathematical model that outputs a single state estimation based on multiple input sources. The most widely used state estimation model for robotics is called Kalman Filter. There are two popular variants called Extended Kalman Filter (EKF) and Unscented Kalman Filter (UKF). UKF is more accurate but requires more computation power whereas EKF is less accurate but is sufficiently accurate that it is favored over UKF when the computation is handled by limited computational resources such as an embedded system [6]. A budget ASV may be equipped with a computer with limited performance but a sufficiently powered embedded computer such as Nvidia Jetson TX2 might have no problem using EKF instead. For data from a GPS module to be fed into a Kalman filter, it first needs to be transformed into a frame called Universal Transverse Mercator (UTM) coordinate system which divides the Earth into 60 zones and projects each to a two-dimensional plane [7]. In ROS, a package called robot_localization takes this UTM data and transforms it to a map frame which can be fed into a Kalman filter [8]. Since a typical GPS module's update rate ranges from 1 to 25 Hz, two Kalman filters are required for effective path planning, one for short, precise local plans that rely on frequently updated odometry and IMU and one for long, but accurate global plans that utilize sparsely updated GPS position to calculate a general path.

A potential source of error for position estimation is the magnetic interference introduced by motors that require a large amount of current to operate. This might result in an inaccurate reading of magnetic heading in IMU which could invalidate the data acquired using GPS which requires ROS packages to adopt a certain axes convention like East North Up (ENU) or North East Down (NED) [9]. A complementary magnetic compass may need to be installed far away from motors or parts that draw significant power.

1. “Ultimate GPS Module,” *adafruit*. [Online]. Available: https://www.adafruit.com/product/790. [Accessed: 08-Mar-2021].
2. “Garmin GPS 16x™,” *Garmin*. [Online]. Available: https://buy.garmin.com/en-US/US/p/13194. [Accessed: 08-Mar-2021].
3. “Introduction,” *Emlid*. [Online]. Available: https://docs.emlid.com/reachrs/. [Accessed: 08-Mar-2021].
4. “Satellite Navigation - GPS - How It Works,” *Federal Aviation Administration*, 22-Jul-2020. [Online]. Available: https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/gps/howitworks/#:~:text=GPS%20satellites%20carry%20atomic%20clocks,time%20the%20signal%20was%20broadcast.&text=Thus%2C%20the%20receiver%20uses%20four,longitude%2C%20altitude%2C%20and%20time. [Accessed: 08-Mar-2021].
5. “Trilateration Exercise,” *GPS.gov*. [Online]. Available: https://www.gps.gov/multimedia/tutorials/trilateration/. [Accessed: 08-Mar-2021].
6. S. Yang and H. Li, "Application of EKF and UKF in Target Tracking Problem," *2016 8th International Conference on Intelligent Human-Machine Systems and Cybernetics (IHMSC),* Hangzhou, China, 2016, pp. 116-120, doi: 10.1109/IHMSC.2016.25. [Accessed: 08-Mar-2021].
7. “What does the term UTM mean? Is UTM better or more accurate than latitude/longitude?,” *U.S. Geological Survey*. [Online]. Available: https://www.usgs.gov/faqs/what-does-term-utm-mean-utm-better-or-more-accurate-latitudelongitude?qt-news_science_products=0#qt-news_science_products. [Accessed: 08-Mar-2021].
8. S. Paepcke, “Tom Moore: Working with the Robot Localization Package,” *Open Robotics*, 17-Jun-2016. [Online]. Available: https://www.osrfoundation.org/tom-moore-working-with-the-robot-localization-package/. [Accessed: 08-Mar-2021].
9. “About Aerospace Coordinate Systems,” *MATLAB & Simulink*. [Online]. Available: https://www.mathworks.com/help/aeroblks/about-aerospace-coordinate-systems.html. [Accessed: 08-Mar-2021].