学 位 論 文 の 要 旨

Design and Implementation of Localization and Navigation Systems for Mobile Robots
(モバイルロボットのための自己位置推定およびナビゲーションシステムの設計と実装)

氏 名　姜 雄文(Jiang, Xiongwen)

The rapid development of robotics has heightened the importance of environmental perception and autonomous navigation capabilities for mobile robots. However, achieving accurate and stable positioning in varied environments presents a substantial challenge. To address these issues, this study introduces a dual-system approach: a GNSS-based navigation system suited for open environments and a tightly coupled LiDAR-Inertial Odometry (LIO) system optimized for GNSS-restricted scenarios.

In expansive outdoor areas with available GNSS signals, GNSS serves as a reliable foundation for mobile robot positioning, using satellite data to determine position within a global coordinate frame. For such scenarios, this study proposes a high-precision GNSS-based navigation system that integrates an optimized Pure Pursuit path-tracking algorithm. The system enhances path-following accuracy and stability by iteratively refining parameters through a genetic algorithm, which are then applied to an improved Pure Pursuit algorithm supplemented with proportional-integral (PI) control. This approach enables smooth and precise navigation even where the standard Pure Pursuit algorithm might oscillate.

For dense urban or GNSS-constrained environments, a tightly coupled LIO system is introduced to address odometry drift in unknown and dynamic settings. The system employs an error-state Kalman filter to fuse data from an inertial measurement unit (IMU) and LiDAR, achieving greater positioning accuracy by combining geometric and intensity-based textural information. In addition, a LiDAR intensity calibration technique is used to correct distortions from environmental changes, further enhancing odometry

precision beyond conventional methods. This adaptable and robust system provides reliable localization in areas with dense infrastructure or severe GNSS interference.

Experimental results validate both systems' robustness and accuracy. The GNSS-based system significantly improves path-following precision when GNSS signals are reliable, allowing smooth navigation across large open spaces. Meanwhile, the LIO system demonstrates robust localization in GNSS-restricted settings, mitigating odometry drift and maintaining reliable positioning. Together, these systems form a comprehensive solution that equips mobile robots with the versatility to operate effectively across diverse environmental conditions. Future work aims to integrate these systems into a cohesive framework, allowing for dynamic switching and data fusion to enhance adaptability and continuity across various real-world environments.