Pose Graph Adjustment for LiDAR-SLAM with Boat Motion Characteristics in Urban Rivers

Naoto Kimura[*1], *Masafumi Nakagawa*[1], *Takeshi Komori*[2], *Nobuaki Kubo*[2], *Etsuro Shimizu*[2]

[1] *Shibaura Institute of Technology*

[2] *Tokyo University of Marine Science and Technology*

An autonomous boat estimates self-position, attitude, and surrounding environment with satellite positioning, IMU, cameras, and LiDAR, to control its speed and behavior. In research on autonomous boats, many topics are discussed related to navigation in open seas and automatic berthing and un-berthing under open sky environments. However, in narrow waterways in urban areas, dense buildings along the waterways degrade the GNSS positioning environment. Therefore, the authors have focused on the combination of PPP-RTK positioning and LiDAR-based SLAM to improve the robustness of GNSS positioning along narrow waterways. Through the preliminary experiments, the combination of PPP-RTK positioning and LiDAR-based SLAM was examined to confirm the effectiveness of positioning mode switching between PPP-RTK and LiDAR-SLAM.

In research on redundant trajectory methods for satellite positioning environments, for autonomous ground robots that perform terrestrial locomotion, non-satellite positioning environments can utilize wheel odometry as a supplementary sensor for self-positioning and attitude estimation. However, for autonomous boats, wheel odometry cannot be used. On the other hand, in the case of UAV, a combination of RTK-GNSS and Visual odometry has been validated as an effective solution for seamless indoor-outdoor flight capabilities in infrastructure inspections. However, for boat, the measurement environment varies significantly, from open water with good overhead visibility to dimly lit areas under bridges with no lighting, making the application of image-based measurements challenging. The authors focus on a cancellation method of accumulated errors in sections of non-satellite positioning without loop closure constraints. Specifically, the proposed approach is based on the motion characteristics of the boat to perform pose adjustments to avoid SLAM degradation.

Keywords: 3D mapping, PPP-RTK, SLAM, Indoor-outdoor seamless positioning, Mobile Laser Scanning