Hyungtae **Lim**

ROBOTICS RESEARCHER · FILED ROBOTICS ENGINEER

30, Mannyeon-ro 18beon-gil, Seo-gu, Daejeon, Republic of Korea

(+82) 10-4494-5143 | shapelim@kaist.ac.kr | limhyungtae.github.io/aboutme/ | limhyungtae | hyungtae-lim

"Towards Pervasive Robotics and Artificial Intelligence"

Research Statement

What I aim for is to make terrestrial robots, including wheeled mobile robots, self-driving vehicles, and quadruped robots, be actively employed in real-world environments and I believe that these technologies have the potential to revolutionize the way we live and work. To this end, as a robotics researcher, I have focused on developing robust algorithms that work well even in the presence of noise and other disturbances that potentially degrade the performance of the tasks of our interest. Thus, the overarching goal of my research is to help robots perceive the surroundings and perform localization in a robust manner even when robots encounter objects or situations that robots have not modeled (here, the term *modeling* includes both conventional pattern finding and data-driven approaches). In addition to the robustness, I pursue – and advocate to improve – the reproducibility of my approaches in real-world applications, enabling other researchers and developers to easily utilize my proposed methods to tackle their problems.

Specifically, I divide my research topics into three main categories to achieve the long-term autonomy of robots. The first is to make the robots' perception robust from the egocentric perspective [1-5]. The second is to achieve robust simultaneous localization and mapping (SLAM), overcoming the imprecise measurements or spurious association between multiple sensor data acquired from different viewpoints [6-13]. Third, by using the estimates and prediction from the first and second steps, I've studied how to manage a robocentric map that can be exploited to perform localization and navigation [14-15]. I believe that long-term multi-session SLAM and map management, particularly, static map building [14-15], are the ultimate goals of SLAM, and this will allow robots to perform long-term operations.

G 1. Robust Perception From the Egocentric Perspective I focus on enhancing the perception capabilities of terrestrial robots from an egocentric perspective to leverage this predicted (or estimated) information for better obstacle avoidance and occupancy checks. First, I studied deep learning-based 3D depth prediction using a 2D LiDAR sensor and monocular camera, which are a combination of inexpensive sensors, to help the cleaning robot avoid unavoidable 3D obstacles when using only the range data observed from a 2D LiDAR sensor [5]. Based on the assumption that terrestrial objects inevitably come in contact with the ground, I've studied robust and fast ground segmentation that can be easily employed in various robot platforms and sensor configurations [1-3]. Then, after rejecting ground points from a 3D point cloud as a preprocessing step, I've studied robust instance and moving object segmentation [4]. Recently, I'm interested in how to manage the sparsity issue of a 3D point cloud captured by an omnidirectional LiDAR sensor and how to leverage semantic information for better scene understanding and feature association.

G 2. Outlier-Robust and Degeneracy-Robust Simultaneous Localization and Mapping On the other hand, it is important for a robot to localize itself by estimating the relative pose using the spatial correlation of landmarks in the surroundings between multiple sensor data acquired from different viewpoints, called *correspondences*. However, undesirable spurious correspondences always exist due to the sensors' characteristics [7-9], ambiguity of the surroundings [6, 11], bad weather [7], and moving objects [10, 12]. These outliers are not specific to a particular sensor, but can occur with any sensor. Thus, I've conducted research to make the odometry or SLAM systems robust against these outliers. In addition, while participating in competitions [16-17], I observed that LiDAR inertial odometry (LIO) methods tend to diverge when going through very narrow and constrained spaces, so I am struggling with developing a robust LIO that can manage such degenerate environments effectively [13].

G 3. Multi-Session Mapping and Long-Term Map Management Finally, using the estimated poses and sensor data, I've studied techniques for static map building [14-15] and multi-session SLAM. Real-world environments are dynamic and undergo changes over time; thus, I've developed algorithms that allow robots to update and maintain their maps across a single session or multiple sessions. To this end, recently, I've noticed instance-aware static map building significantly increases the mapping quality. I also proposed robust loop closing for multi-session SLAM. By improving multi-session mapping quality and effective static map management, I aim to enhance the long-term autonomy of terrestrial robots in complex urban environments. Currently, I am working on a project to improve the performance of moving object segmentation at a perception level by reusing the output of static map building [14] , which indicates that I do not think my three goals are just independent; rather, I believe my research goals are inter-coupled.

References (Selected Publications Highly Relevant to My Research Statement)

* denotes the authors are co-first authors

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