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3D Surveying of Mining Environments using Simultaneous Localization and Mapping

Abstract

In the 21st century, Mobile Mapping Systems (MMSs) have undergone substantial advancements, driven by progress in sensors, software, and robotics. Although nowadays they are being successfully deployed in diverse scenarios, some sectors' conditions still pose a challenge to reliably obtain high-quality 3D data. One of the most promising industries for benefiting from mobile mapping is mining, where complex and GNSS-denied environments are common. Despite gaining more momentum in recent years in the scientific community, the surveying-related aspects of underground applications of such systems have not yet been well researched. Thus, this thesis aims to fill the gap by developing and validating a low-cost mobile mapping system capable of robustly performing 3D reconstructions in mining environments. The study adopts an iterative approach, evaluating various aspects of the system's performance against state-of-the-art methods, including comparisons with traditional surveying techniques like TLS (Terrestrial Laser Scanning). Different measures were explored to assess the quality of point clouds in subterranean conditions to ensure resilient and reliable operation.

Based on a scientific literature meta-analysis, several research objectives were established, addressing the identified scientific gaps. They include carrying out comprehensive quantitative evaluations of 3D reconstruction quality in mining conditions, establishing an open dataset for further development in mobile mapping methods, and improving open-source SLAM solutions while tailoring measurement approaches for mining environments and 3D reconstruction requirements.

A series of six scientific articles presents the progression from basic measurement systems to advanced SLAM implementations and comprehensive data quality analyses. Each publication provides unique insights and advancements to the field, tackling issues ranging from 3D data quality assessments at various underground sites to publishing an open dataset, and developing several diverse mobile mapping systems. In the final study, these efforts resulted in the creation of a universal and robust handheld mapping system capable of producing high-quality 3D reconstructions. The performance of the system was validated in diverse environments, including underground tunnels, where it matched or outperformed the quality of the results provided by commercial solutions.

The findings contribute to the broader field of research on mobile mapping technologies, particularly in challenging GNSS-denied, unstructured environments like mining areas. Overall, this dissertation not only enhances state-of-the-art SLAM algorithms and develops open-source datasets but also demonstrates the feasibility and effectiveness of using SLAM-based low-cost MMSs in mining surveying, providing a versatile, transparent, reliable and affordable solution for acquiring accurate 3D spatial data for various needs of the mining industry.

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