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RESEARCH ON ROBUST VISUAL-INERTIAL ODOMETRY ALGORITHMS FOR QUADCOPTERS LOCALIZATION

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Introduction. The development of robust and efficient localization systems for quadcopters is a critical challenge in the field of autonomous navigation. Quadcopters are increasingly utilized in applications such as surveillance, search and rescue, and delivery services, where precise and reliable localization is essential. However, traditional visual-inertial odometry (VIO) systems often struggle in challenging environments, such as those with textureless surfaces, repetitive patterns, and sudden lighting changes. These limitations can lead to inaccurate localization, system drift, or even failure. To address these issues, this research proposes a robust monocular VIO system that integrates visual and inertial data, deep learning-based feature extraction and matching techniques, and a hybrid approach combining point and line features. The proposed system aims to enhance localization accuracy and robustness, particularly in dynamic and complex environments.

Main part. To address the challenges faced by traditional VIO systems, this research focuses on the following key steps:

1. Integration of Visual and Inertial Data: The core of the proposed system is a monocular VIO approach that synergistically combines visual data from a camera with high-frequency motion data from an inertial measurement unit (IMU). While IMU data is crucial for estimating the system's state during rapid movements and in low-visibility conditions, it is prone to drift over time. Visual data, on the other hand, provides rich environmental context but can be affected by lighting variations and textureless scenes. The fusion of these two data sources mitigates their individual limitations, resulting in a more robust and accurate localization system.

2. Deep Learning-Based Feature Extraction and Matching: The system incorporates advanced deep learning techniques, including SuperPoint [1] for feature detection and descriptor extraction, and SuperGlue [2] for context-aware feature matching. These models enable accurate and reliable feature matching in challenging scenarios where traditional methods often fail, reducing the risk of system drift or failure.

3. Hybrid Feature Approach: The system leverages both point and line features to enhance localization performance. Line features are particularly robust to illumination changes and provide valuable structural information in human-made environments. However, direct line matching is computationally complex. To address this, the system employs a point-based matching method for lines, simplifying the process while retaining the benefits of line features. This approach was inspired by the work of Airvo [3], which proposed a stereo camera-based visual odometry system using both point and line features to improve accuracy and robustness.

4. Real-Time Optimization Framework: The system employs an optimization framework that minimizes a cost function incorporating point feature reprojection error, line feature reprojection error, and inertial data error based on preintegration theory [4]. The Huber kernel is used to robustly handle outliers, ensuring accurate and reliable state

estimation.

5. Evaluation: The performance of the proposed VIO system is evaluated using benchmark datasets such as Euroc. The results demonstrate that the system outperforms state-of-the-art VIO systems and achieves competitive performance compared to more complex SLAM algorithms, particularly in challenging environments. The evaluation metric used is the absolute translation error.

Conclusions.

This research contributes significantly to the field of autonomous navigation by developing a robust and reliable VIO system for quadcopters. By integrating advanced deep learning techniques, IMU data fusion, and a hybrid feature approach, the system effectively overcomes many limitations faced by traditional VIO methods. This advancement enhances the operational capabilities and reliability of quadcopters in real-world scenarios, paving the way for more precise and consistent state estimation in dynamic and challenging environments. Future work may explore further optimization of the system for specific applications and environments, as well as the integration of additional sensor modalities for enhanced performance.

List of references:

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