Design and Implementation of a Low-Cost GNSS-Synchronized Multi-Camera System for a UGV

Master Project 2

Student

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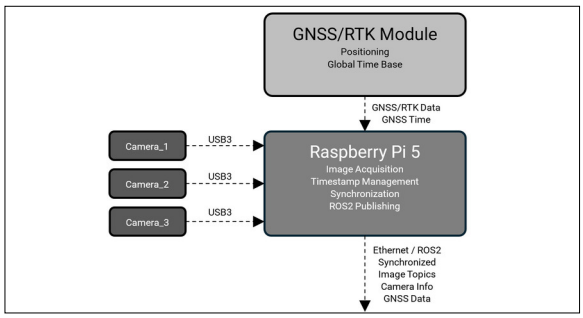
Definition of Task: This project presents the design, implementation, and evaluation of a low-cost synchronized multi-camera perception system for a mobile robotic application. The objective of the project was to develop a modular embedded sensor system capable of providing temporally coordinated image acquisition and GNSS-referenced timing using commercially available hardware components and a ROS2-based software architecture.

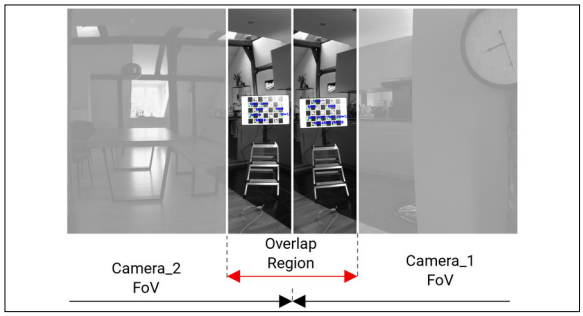
Approach / Technology: The developed system integrates three FLIR Firefly USB3 global-shutter RGB cameras, a GNSS/RTK receiver, and a Raspberry Pi 5 into a compact sensor enclosure mounted on a Husarion Panther unmanned ground vehicle. A custom ROS2-based acquisition framework implemented in C++ using the Teledyne FLIR Spinnaker SDK was developed to support deterministic camera management, synchronized frame grouping, calibration integration, and distributed sensor data publication. The project further includes the development of a complete intrinsic and extrinsic calibration pipeline based on OpenCV.

Result: Experimental validation demonstrated sub-pixel intrinsic calibration accuracy, along with physically consistent extrinsic calibration results, for the evaluated camera configuration. The synchronization behaviour and temporal stability of the acquisition framework were evaluated under varying resolutions, frame rates, pixel formats, and recording workloads. The results show that stable synchronized acquisition at 30 Hz using full-resolution BayerBG8 image streams is achievable under nominal operating conditions with almost no timing jitter and zero missing synchronized frame sets. Although the current implementation relies on software-coordinated synchronization, the hardware and software architecture were designed to support future GNSS-triggered camera acquisition using a shared timing signal. Overall, the presented system establishes a reproducible and extensible foundation for future synchronized multi-camera perception and embedded robotic sensor integration.

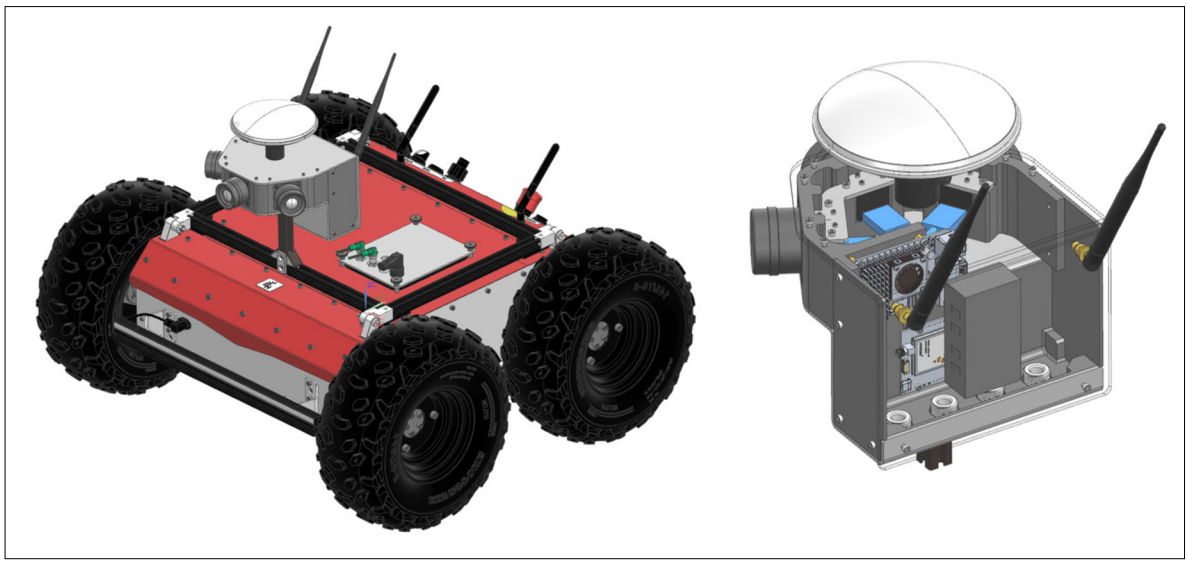
High-Level System Architecture Overview
Own presentment



Visualization of Overlapping Fields of View (FoV) Between Cameras During Extrinsic Calibration
Own presentment



UGV Robotics Platform with Integrated Sensor Suite
Own presentment



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Subject Area
Mechatronics & Automation