



Cooperative Localization & Crossview Geolocalization

By AViSense.AI

Booklet

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Winners' Booklet Series**



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INTRODUCTION

✓ *Cooperative Localization & Crossview Geolocalization*



Cooperative Localization enhances 4D situational awareness by integrating multi-modal data—self-position, distance, azimuth, and inclination—into a unified framework. A swarm of Connected and Automated Vehicles (CAVs) is modeled as an undirected graph with star topologies for efficient communication. Using the Graph Laplacian operator, the system fuses data in real-time over 5G networks, ensuring low-latency updates. Designed for scalability, it extends to indoor robots, underwater vehicles, and drones, addressing challenges like data association, dynamic topologies, and network constraints. The approach avoids iterative measurement exchanges, optimizing computational and communication efficiency while maintaining accuracy.

Crossview Geolocalization precisely estimates vehicle-mounted camera positions by matching ground-level images with satellite maps. Unlike traditional image retrieval methods, it employs deep learning to refine pose estimation for improved localization accuracy.

Telekom Slovenia Testbed. The Telekom Slovenia testbed validated Cooperative Localization and Crossview Geolocalization, leveraging its advanced 5G infrastructure for real-time, high-bandwidth applications. Simulated data was used to replicate real-world conditions, optimizing localization precision in CAVs. The system architecture includes:

1. **Feature Extraction:** Two Convolutional Neural Networks (CNNs) process ground and satellite images, extracting robust, multi-scale features for effective correspondence.
2. **Geometry Projection:** Deep satellite features are mapped to the ground view using a geometric transformation based on relative camera pose.
3. **Differentiable Pose Optimization:** A Levenberg-Marquardt (LM) algorithm iteratively refines pose estimates, progressively integrating finer details for enhanced accuracy.

✓ Objectives



Cooperative Localization

- **Enhanced Situational Awareness:** Expands perception beyond individual sensors using **5G-powered V2V communication**, ensuring **accurate 3D localization** for autonomous driving.
- **Real-Time Precision:** Utilizes **5G's ultra-low latency** for continuous, high-speed data exchange, enabling **instant localization updates** in dynamic traffic.
- **Optimized Network Efficiency:** Transmits **high-fidelity sensor data** while **maximizing 5G bandwidth efficiency**, ensuring seamless connectivity.
- **Fast Processing:** Maintains an **end-to-end response time of under 100 ms**, integrating data transmission and localization updates.

Crossview Geolocalization

- **High-Precision Pose Estimation:** Combines **feature extraction and geometry projection** for accurate localization across varied environments.
- **Smart Bandwidth Management:** Compresses and transmits **high-resolution imagery** without compromising localization quality.
- **Cloud-Optimized Refinement:** Offloads intensive processing to the **cloud via 5G**, ensuring continuous **real-time pose adjustments**.

5G-IANA Deployment and Technical Objectives:

- **Scalable Deployment:** Uses **Docker for ARM devices**, ensuring flexible, **efficient integration** in the testbed.
- **Seamless System Validation:** Conducts real-time testing in a **5G-enabled environment** for robust localization performance.
- **Improved Localization Accuracy:** Achieves a **30% error reduction** over baseline SLAM in **two-vehicle clustering scenarios**.
- **Enhanced Positioning Precision:** Minimizes **lateral and longitudinal errors** for reliable **pose estimation** in dynamic conditions.

Testing Setup & Results



✓ Testing & Qualitative Evaluation

The deployment was conducted at the **Telekom Slovenia research lab**, utilizing the **Edge server** directly connected to the **User Plane Function (UPF)** for seamless integration. Containers were deployed on an **eMBB-type slice** supporting **100 Mbps uplink throughput**, ensuring high-performance execution. Within the **5G n78 band**, the **average Round-Trip-Time (RTT) between the User Equipment (UE) and Edge server** was **15 ms**, despite no actual UE being used. The network environment remained fully operational, optimized for low-latency performance. Most operations were conducted remotely, with an **on-site visit to Telekom Slovenije on October 1–2** for a rehearsal. This allowed direct collaboration to fine-tune the setup and ensure project alignment.

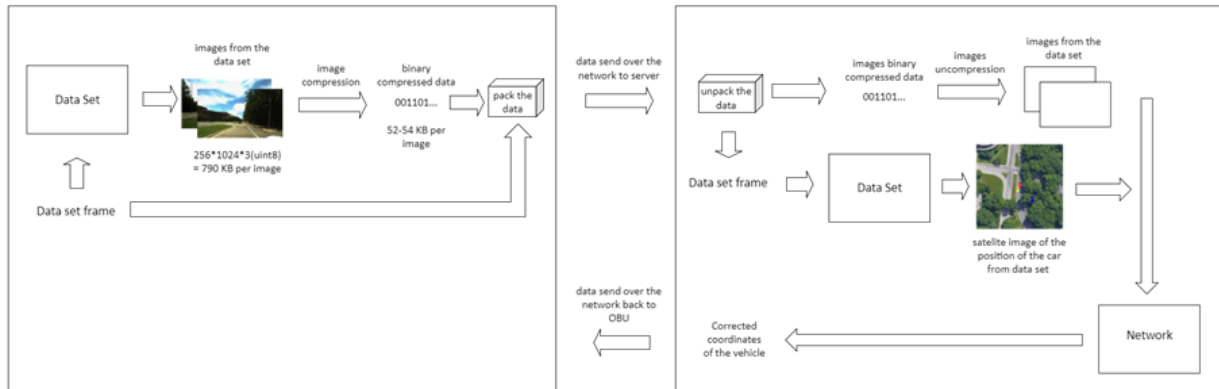
Cooperative Localization

Simulated data from **CARLA** was used to analyze **two vehicles traveling at moderate speeds** on a highway while maintaining visibility and a fixed distance. Each vehicle featured a **64-channel LiDAR, IMU, and GNSS receiver**, generating comprehensive sensor outputs.

The system ran on **two virtual OBUs**, hosting **ROS-based components** for real-time cooperative localization:

- **3D Object Detector:** Processes LiDAR point clouds to estimate object bounding boxes.
 - **3D Object Tracker:** Tracks detected objects over time, maintaining object identities.
 - **LiDAR Odometer:** Estimates vehicle pose and movement using LiDAR data.
 - **Data Aggregator:** Integrates data from **GNSS, IMU, LiDAR, and object tracking** for state estimation.
 - **MQTT to ROS Bridge:** Facilitates V2V communication, handling **Cooperative Awareness Messages**.
 - **Cooperative Localization Module:** Merges data from both vehicles, refining **ego vehicle positioning** for greater localization accuracy.
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Crossview Geolocalization



CVGL System Overview

The figure below illustrates the **Crossview Geolocalization workflow**, detailing image-based localization between the **On-Board Unit (OBU)** and a **Cloud Server**. Due to the absence of a **GPU-enabled server** in the testbed, deployment occurred in a **third-party cloud infrastructure**.

OBU Processing Pipeline:

- **Data Frame Extraction:** Captures images ($256 \times 1024 \times 3$, ~790 KB) from vehicle-mounted cameras.
- **Image Compression:** Reduces image size, optimizing transmission efficiency.
- **Binary Conversion:** Encodes compressed images into a **52–54 KB binary format**.
- **Data Packing:** Prepares data for **network transmission** to the cloud.

Cloud Processing Pipeline:

- **Data Reception & Unpacking:** Retrieves and decodes binary images.
- **Image Decompression:** Restores the original format for processing.
- **Dataset Matching:** Compares received images with **satellite maps** to determine precise location.
- **Coordinate Correction:** Computes position adjustments to enhance localization accuracy.
- **Updated Position Transmission:** Sends refined coordinates back to the OBU, ensuring **real-time geolocation accuracy**.

By leveraging **5G-powered cloud processing**, this system enables **precise vehicle localization**, enhancing situational awareness for autonomous mobility.

Demonstration & System Validation

The demonstration at **Telekom Slovenije Testbed** showcased the **Cooperative Localization** and **Crossview Geolocalization** systems, focusing on deployment, data integration, and performance evaluation. Logged outputs validated the methods' effectiveness in real-world conditions.

System Performance

- **Cooperative Localization:** Achieved **~10Hz 3D situational awareness**, utilizing **5G-powered V2V communication** for real-time position, distance, and angle updates with minimal latency.

- **Crossview Geolocalization:** Integrated **ground-level imagery with satellite data** via a **cloud-based server**, ensuring accurate **pose estimation and position correction** despite the absence of a **GPU-enabled testbed server**.

Network & Latency Evaluation

- Maintained a **15ms average round-trip time (RTT)** over **5G**, meeting real-time **localization and situational awareness** requirements.
- Operated on an **eMBB-type slice (100 Mbps uplink)**, enabling **high-fidelity sensor data transmission** between vehicles and the cloud with minimal delay.

System Responsiveness

- **Cooperative Localization** adapted dynamically to **speed and directional changes**, maintaining precise tracking.
- **Crossview Geolocalization** processed **image-to-map integration** efficiently, ensuring **accurate position corrections** in various simulated traffic scenarios.

By leveraging **5G connectivity**, both systems demonstrated **real-time adaptability, accuracy, and efficiency**, reinforcing their potential for advanced autonomous mobility.

✓ Results



The **5G-IANA initiative** has significantly strengthened **AviSense's business model** by:

- **Enabling real-world testing** of advanced localization and situational awareness technologies.
- **Providing technical guidance** to refine key innovations.
- **Facilitating strategic partnerships** within the communication sector.

Technology Validation & Commercialization

The **5G testbed** played a crucial role in advancing **AviSense's core technologies** from **TRL4 to TRL5**, including **crossview geolocalization, cooperative localization, and multimodal data fusion**. Rigorous testing ensured **safety, reliability, and scalability**, laying the groundwork for successful commercialization.

Business & Market Positioning

5G-IANA's **business guidance** has sharpened AviSense's **competitive edge**, emphasizing **safety, transparency, and innovation**—three pillars that resonate in both **consumer and industrial markets**. The collaboration also bolstered **credibility**, reinforcing AviSense's position as a **leader in sustainable and safe transportation solutions**.

Challenges & Support

Integrating the **Open Application Experimentation Platform** posed initial challenges due to **limited familiarization time**. AviSense relied on **support** for deployment and execution within the testbed, ensuring a **smooth transition** despite the constraints.

By leveraging **5G-IANA's infrastructure and expertise**, AviSense continues to drive **cutting-edge advancements** in next-generation mobility.



Key Conclusions & Future Plans

AviSense discovered the **5G-IANA Second Open Call** through **industry networks, online platforms, and CAV-focused newsletters**. The call's emphasis on **5G-powered automotive solutions** aligned perfectly with AviSense's mission to enhance **situational awareness in Connected and Automated Vehicles (CAVs)**.

Driven by the opportunity to **advance and validate** its **Cooperative Localization and Crossview Geolocalization use cases**, AviSense eagerly pursued participation, leveraging **5G technology** to refine its innovations.

Online & Multimedia Material

Video content, including a recorded live demonstration and explanation, is available on the 5G-IANA YouTube channel.
Scan the QR code on the right to watch:

SCAN ME



SCAN ME



Discover more about Avisense' and other success stories available on the 5G-IANA website by scanning the QR code on the right:

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