



Vins RTK

By Link Robotics

Booklet

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Winners' Booklet Series**



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INTRODUCTION

✓ Overview of Vins RTK

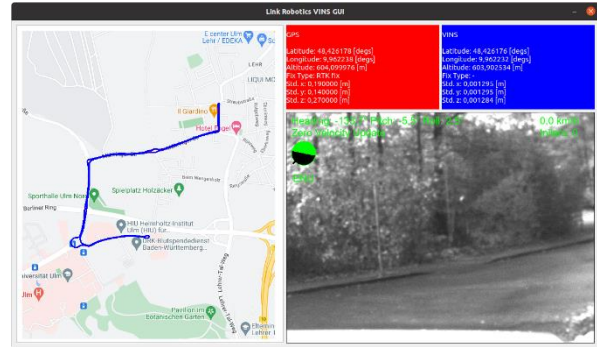


VINS-RTK is a cutting-edge **real-time localization system** that integrates **advanced sensor fusion, AI-driven positioning, and 5G connectivity** to deliver unparalleled accuracy in vehicle tracking and autonomous navigation. By leveraging an **Inertial Measurement Unit (IMU), a monocular camera, and an RTK-enabled GNSS receiver**, VINS-RTK achieves **centimeter-level precision**—even in challenging environments where GNSS signals may be degraded.

- **10Hz real-time localization output**
- **1-2 cm accuracy in RTK mode**
- **50ms average latency**
- **Seamless 5G connectivity & data flow**

Industry Relevance and Applications. VINS-RTK plays a crucial role in:

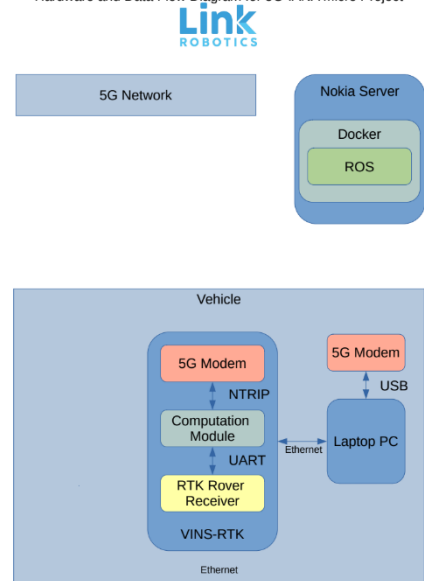
- **Autonomous Vehicles** – Enabling high-precision localization for self-driving systems.
- **Fleet Management & Logistics** – Providing reliable vehicle tracking and navigation data.
- **Infrastructure Monitoring** – Supporting robotic and drone-based inspections.
- **Advanced Driver Assistance Systems** – Enhancing real-time positioning for safety applications.
- **Smart City Applications** – Facilitating intelligent traffic and transportation monitoring.



Integration with 5G-IANA for Enhanced Performance. VINS-RTK leverages **5G-IANA** to enhance data processing, communication, and network function efficiency:

- **Low-Latency Data Transmission:** The localization data is transmitted over a **private 5G network** to **Nokia servers** for real-time processing and storage.
- **Cloud-Based Data Utilization:** Other applications can seamlessly access **position and orientation data** for analytics, visualization, and decision-making.
- **Network Function (NF) Optimization:** The sensor software establishes a **secure NTRIP protocol connection** over the **5G GSM network**, ensuring RTCM correction data continuous reception. If connection drops, it autonomously reconnects.
- **Application Function (AF) in AI & Sensor Fusion:** The **computer vision software** processes IMU, camera, and GNSS inputs using MSCKF algorithms to generate refined localization data. This enhances navigation accuracy when integrated with autonomous vehicle platforms.
- **Edge Computing Efficiency:** The software runs on **Jetson hardware with ROS Noetic**, optimizing real-time processing, while the **sensor software operates on the MPU of the 5G interface card**, managing high-frequency IMU (200Hz) and GNSS (4Hz) data acquisition.

Hardware and Data Flow Diagram for 5G-IANA Micro Project



By leveraging **5G-IANA's high-bandwidth, low-latency capabilities**, VINS-RTK significantly enhances:

- **Real-time vehicle localization for autonomous systems**
- **Edge computing efficiency for sensor fusion applications**
- **Reliable data transmission with minimized latency (~50ms average)**
- **Scalability for deployment across multiple industry use cases**

This integration ensures **greater precision, efficiency, and adaptability**, making VINS-RTK a **cutting-edge solution for next-generation mobility and AI-driven localization systems**.

✓ Objectives



VINS-RTK is a **real-time localization software prototype** designed to provide accurate position, orientation, and velocity data for vehicles by integrating **IMU, monocular camera, and RTK-GNSS receiver**. The system is crucial for applications such as **autonomous driving and vehicle tracking**, where precise and reliable localization is a key enabler. Its core objectives include:

- Achieving **1-2 cm localization accuracy with RTK fix** for high-precision vehicle navigation.
- Ensuring **real-time and robust localization**, even in challenging environments (e.g., RTK-float, GNSS-fix, dead-reckoning).
- Supporting **low-latency (50ms average) and high-frequency output (20Hz for localization, 20Hz for IMU data, 4Hz for GNSS data)** to meet the demands of time-sensitive applications.
- **Seamless integration with the 5G-IANA platform**, enabling real-time data sharing and remote access.

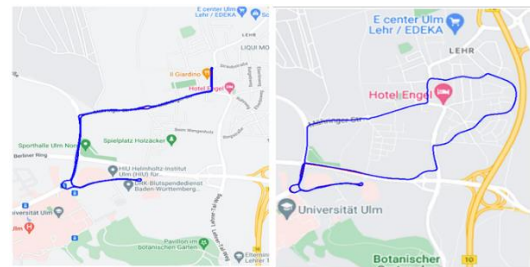
Testing Setup & Results



✓ Testing & Qualitative Evaluation

Setup & Demonstration

The **robot localization system** was tested outdoors near the **University of Ulm**, using the **Nokia private GSM network** for reliable **5G coverage**. The robotic platform featured **sensor fusion technology for high-precision localization**. The **5G-enabled RTK-GNSS system** integrates a **monocular camera** for real-time visual tracking, an **IMU** for motion/orientation sensing, and an **RTK-GNSS receiver** leveraging **Hexagon Smartnet** for centimeter-level accuracy. Data is processed on the **Nvidia Jetson Xavier NX**, executing **visual-inertial navigation algorithms**. The **5G interface card** with an **STM32MP1 MPU** and **Simcom 5G modem** ensures **low-latency RTK communication**.



Driven paths for the two experiments

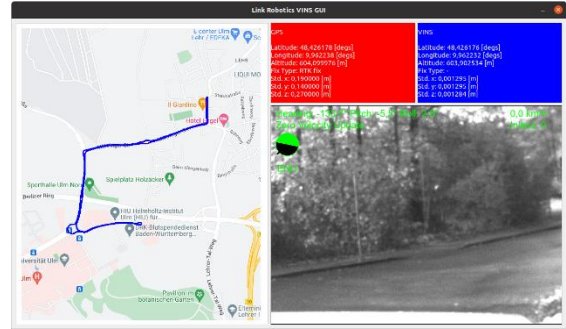
The software, running on **ROS Noetic**, fuses **camera, IMU, and GNSS data** via a **Multi-State Constraint Kalman Filter (MSCKF)**. The **sensor software** processes **IMU (200Hz) and GNSS (4Hz) data**, sending localization updates to **Nokia cloud servers**. A **Network Function (NF)** ensures **continuous RTCM correction retrieval** over **5G**, maintaining **uninterrupted connectivity** even in low-signal areas.

Field tests demonstrated **real-time localization accuracy**, with **RTK-Fix mode** achieving **1-2 cm precision**. Localization remained stable in **RTK-Float and GNSS-Fix modes**, while the system maintained **50ms latency at a 10Hz update rate**, ensuring seamless performance.

Validation trials involved mounting the **sensor enclosure** on a test vehicle, initializing **RTK-GNSS**, and calibrating accuracy via **GUI interface (<10 cm covariance)**. Real-world navigation trials, supported by **ROS data logging**, verified system performance.

The results demonstrate that **5G enhances localization responsiveness**, ensuring **robust autonomous navigation**. Future developments will focus on **optimizing data transmission**, **expanding fleet tracking applications**, and **refining autonomous vehicle navigation**. The system's adaptability and **real-time processing capabilities** make it a **scalable solution for next-generation mobility**.

Qualitative Evaluation



Two ground experiments using a **Nokia test vehicle** validated **real-time 5G-enhanced localization**. The system demonstrated **high accuracy, reliability, and real-time data transmission**, confirming its suitability for autonomous vehicle applications. Field tests near the university campus assessed system performance under varying 5G coverage conditions. Most areas had full 5G connectivity, enabling the GNSS receiver to operate in RTK mode, achieving centimeter-level accuracy. However, in regions without 5G, RTK corrections were unavailable, and GNSS-Fix mode maintained accuracy around one meter. As seen in the **figure on the right**, in areas with obstructed GNSS signals—due to buildings, trees, or satellite visibility limitations—RTK accuracy varied but remained below one meter in optimal conditions. Even where 5G and RTK corrections were absent, the system continued providing reliable position-orientation data.

✓ Results



The **VINS-RTK system** has proven to be highly reliable, delivering **centimeter-level accuracy** even in challenging conditions such as rain and 5G outages. Its ability to operate effectively without RTK service highlights its adaptability, making it a robust solution for real-world applications. Successful trials at the **Nokia Research Center in Ulm** have confirmed its precise localization capabilities under demanding conditions.

Advancing Business Scalability with 5G Integration The integration of **5G-IANA** has significantly enhanced business scalability and operational efficiency by enabling **real-time localization** over a private **5G network**. A **TCP server in a Docker environment** ensures seamless **cloud-based localization**, facilitating **remote analysis, path tracking, and sensor fusion**—critical components for **autonomous driving applications**.

Reliable Connectivity and Network Function The system's **Network Function (NF)** ensures stable connectivity, transmitting **NTRIP protocol requests** over 5G to obtain **RTCM correction data** from an **Internet-RTK server**. **Automatic reconnection mechanisms** maintain uninterrupted network communication, ensuring consistent performance in varying network conditions.

Real-Time Localization for Next-Generation Mobility Operating on **ROS Noetic on NVIDIA Jetson hardware**, the system integrates **custom GNSS and IMU drivers**, enabling **real-time localization fusion**. By leveraging **5G technology**, it enhances **accuracy, reduces latency**, and lays the foundation for **scalable, next-generation mobility solutions** in autonomous and connected vehicle applications.

Key Conclusions & Future Plans



Future developments will enhance the system's **real-time data transmission**, enabling **position and orientation updates** to **Nokia servers** for improved **remote monitoring**. The prototype will integrate into **test vehicle navigation stacks**, advancing its role in **autonomous driving**. Additionally, it will function as a **vehicle**

tracking solution, supporting **real-time fleet monitoring** via a **graphical interface** for streamlined visualization and management.

Further **industry and research collaborations** will refine performance, expand use cases, and optimize **large-scale deployment**. The system's continued evolution will drive **next-generation localization solutions**, strengthening its impact on **intelligent transportation systems**. Currently Link Robotics also works on Digital Twin Generation using Vins RTK and a LIDAR addition into the sensor stack, which is developed under a 6G-SNS cascade fund and will be tested in IDIADA Test site in Spain in late March 2025.

Online & Multimedia Material

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



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

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