Portable Building Blocks for LiDAR and Camera Sensor Fusion

A modular, scalable GStreamer-based solution for synchronized LiDAR and MIPI camera sensor fusion

At a glance

Domain	Automotive ADAS, Robotics, Advanced Content Streaming, Video Monitoring & Control, Environmental Mapping
Challenge	Synchronize and fuse LiDAR and MIPI camera data in real time, enabling accurate timestamp alignment and point cloud visualization across diverse perception applications.
Solution	A modular GStreamer-based sensor fusion framework plugin engineered by MosChip, integrating LiDAR and camera streams with precise synchronization, SEI data embedding, and real-time point cloud overlay.
Platform	Xilinx UltraScale+ MPSoC, GStreamer, Ubuntu/Linux, C

Executive Summary

MosChip designed a sensor fusion platform for use cases such as Automotive ADAS, Robotics, environmental mapping, video monitoring and control, and advanced content streaming domains. The solution was built to accurately synchronize LiDAR and MIPI camera inputs, overcoming challenges associated with varying sensor frequencies while delivering precise perception data alignment for both edge and cloud-based applications.
MosChip developed a portable GStreamer-based framework with custom plugins for LiDAR data capture, timestamp synchronization, SEI-based embedding and extraction of LiDAR point cloud data within H.264 and H.265 video streams, and real-time overlay of LiDAR data onto live video feeds. Built on the Xilinx UltraScale+ platform, the framework was designed for portability and scalability, enabling seamless integration with different sensors, codecs, and deployment environments.

The result was a reusable and high-performance sensor fusion platform that eliminated data synchronization mismatches, enabled accurate depth perception and terrain mapping, reduced integration effort through reusable building blocks, and accelerated deployment across automotive, robotics, multimedia, and smart vision applications.

The Challenge

The core challenge was to design and implement a solution for capturing and synchronizing data from a MIPI camera, a LiDAR sensor, and multiple additional sensors simultaneously. The use case spanned depth acquisition, LiDAR-based terrain mapping, and incremental ADAS enhancements, each placing different demands on the data pipeline.
To make this work across all these applications, the solution needed to address three specific technical requirements:

- MIPI CSI-2 and LiDAR hardware integration, including mechanical adjustment and calibration to ensure the two sensors were spatially aligned and operating within the same reference frame.
- Precise timestamping and synchronization of video frames and LiDAR point cloud data, so that every captured frame and every point cloud scan could be accurately matched in time regardless of their different native frequencies.
- Real-time overlay of LiDAR point cloud data on a live video stream, enabling operators and downstream systems to see spatial depth data superimposed directly on the visual feed.

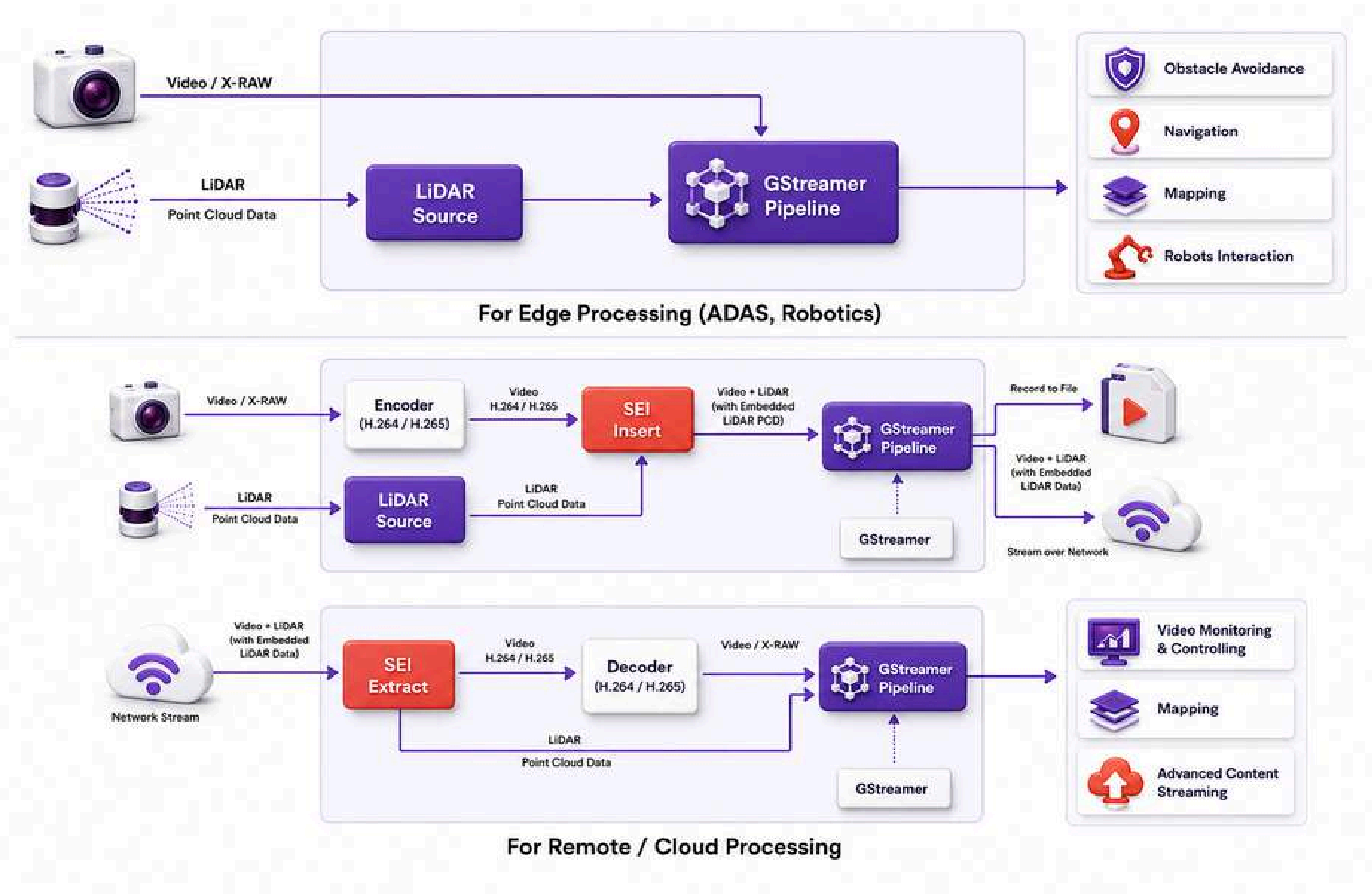
The challenge was not just technical depth in each of these areas individually. It was building a solution that handled all three reliably and continuously.

The Solution

MosChip developed a GStreamer-based sensor fusion solution that can be extended with various sensors, including LiDAR and MIPI, as well as different video encoders. The architecture was built for portability and reuse, making it straightforward to add new sensor types or adapt the pipeline for different deployment environments. The key elements of the solution included:

- LiDAR and MIPI CSI-2 integration covering both hardware and software for seamless compatibility within a unified data pipeline.
- 12Hz scan frequency delivering up to 5KB of point cloud data per scan, providing dense spatial information at a rate suited to real-time applications.
- Precise timestamp synchronization via a custom GStreamer plugin, ensuring accurate data alignment between LiDAR and MIPI frame streams regardless of their independent clocking.
- SEI embedding and extraction through custom GStreamer plugins that carry LiDAR point cloud data inside H.264 and H.265 video streams, eliminating the need for a separate data channel.
- Real-time overlay plugin enabling live superimposition of LiDAR point cloud data onto the video stream for immediate, spatially aware visualization.
- Continuous operation optimization to maintain reliability and stability over extended runtimes, preventing data drift, synchronization degradation, or pipeline failures.

Architecture



Tools & Technologies

Technology	Role in the Solution
Hardware Platform / SoC	Xilinx UltraScale+ MPSoC
Codecs	H.264/H.265 Encoder and Decoder
Stream Resolution	4Kp30
LiDAR Scan Frequency	12Hz scan frequency, 5000Hz range frequency
Framework	GStreamer
Operating System	Ubuntu/Linux
Programming Language	C

Outcomes & Impact

By building on the GStreamer ecosystem and designing for modularity from the ground up, MosChip delivered a solution that goes beyond solving the immediate sensor fusion problem. The architecture was built to keep delivering value over time as requirements evolve and new sensors are added.

- Accelerated time to market by building on the existing GStreamer infrastructure rather than developing a custom pipeline from scratch, reducing development effort and enabling faster feature deployment.
- Reduced integration effort through a reusable, modular design that makes adding new sensor types straightforward without rearchitecting the pipeline.
- Reliable real-time synchronization between LiDAR and MIPI camera streams through precise timestamp alignment, eliminating data mismatches that would otherwise compromise depth perception and terrain mapping accuracy.
- Portable, cross-application solution that works equally well for edge-processed use cases like ADAS and Robotics, and cloud-connected applications including content streaming, video monitoring, and environmental mapping.
- Production-grade stability through continuous operation optimisation, ensuring the pipeline runs reliably over extended periods without synchronization drift or performance degradation.