

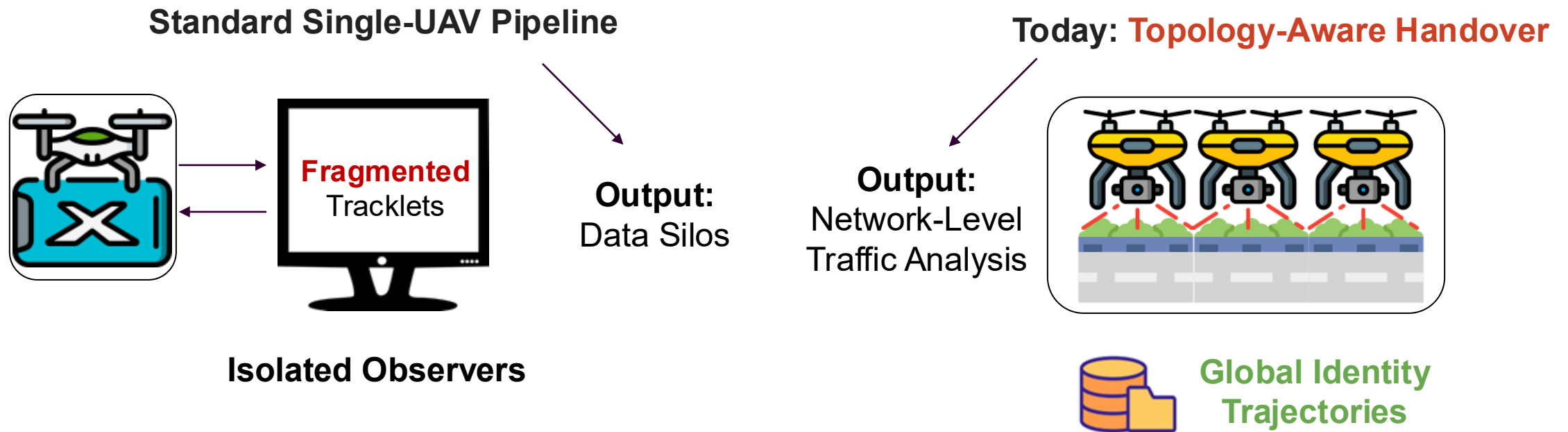
A Topology-Aware Spatiotemporal Handover Framework for Continuous Multi-UAV Tracking

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Traffic-Monitoring Needs Identity Persistence

Multi-UAV Aerial Surveillance

How do we extract continuous, network-level traffic metrics across multiple drone Fields of View (FoV)?



Background: Existing Association Approaches

1. **Geometric & Geo-Referencing Methods:** Align trajectories by transforming pixels into global geodetic coordinates.
2. **Appearance-based Re-ID:** Extract high-dimensional visual embeddings to match vehicles via appearance similarity.



Bottleneck 1: Nadir-View Ambiguity.

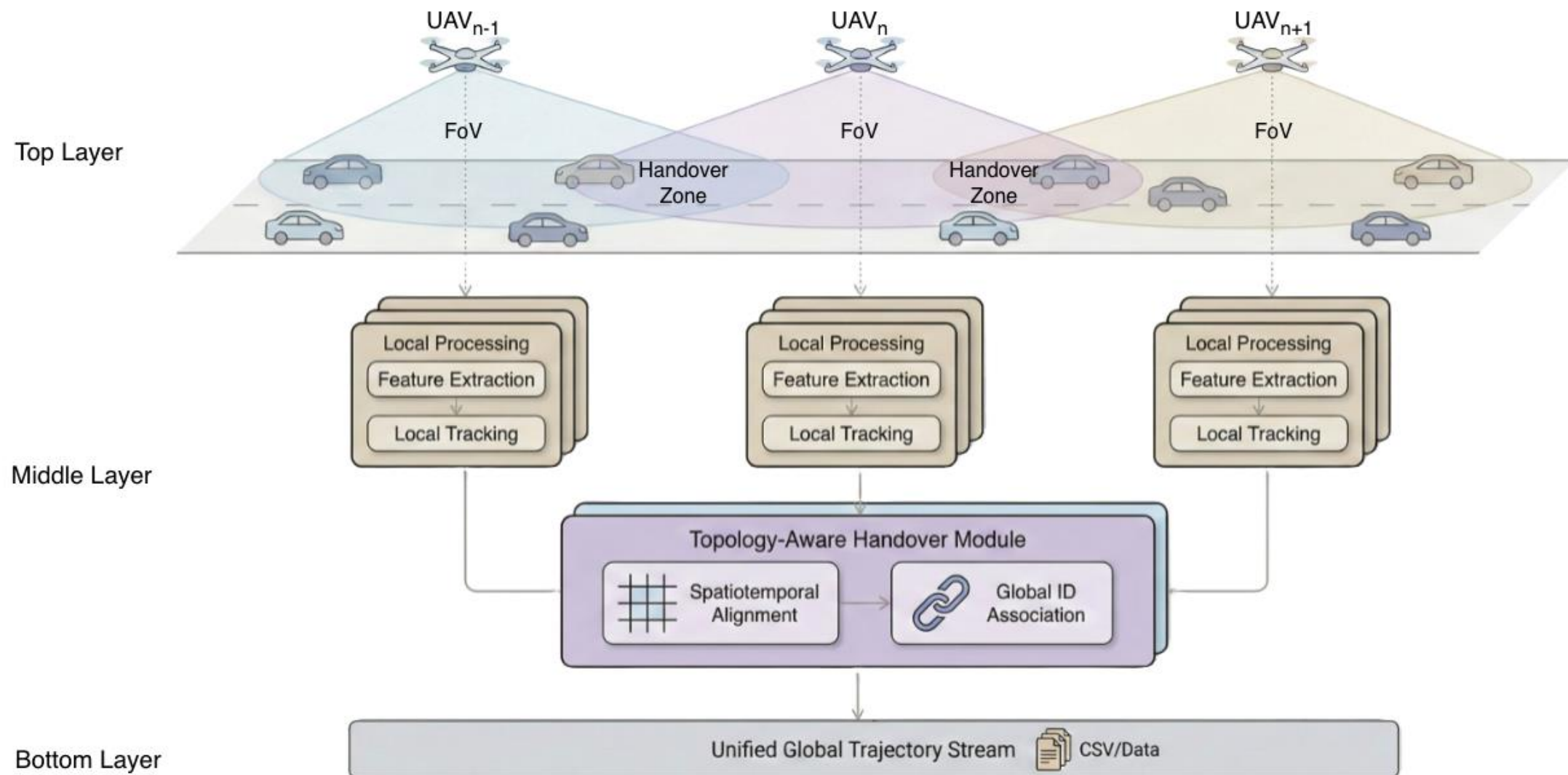
Inter-class Similarity

Bottleneck 2: Illumination Variation.

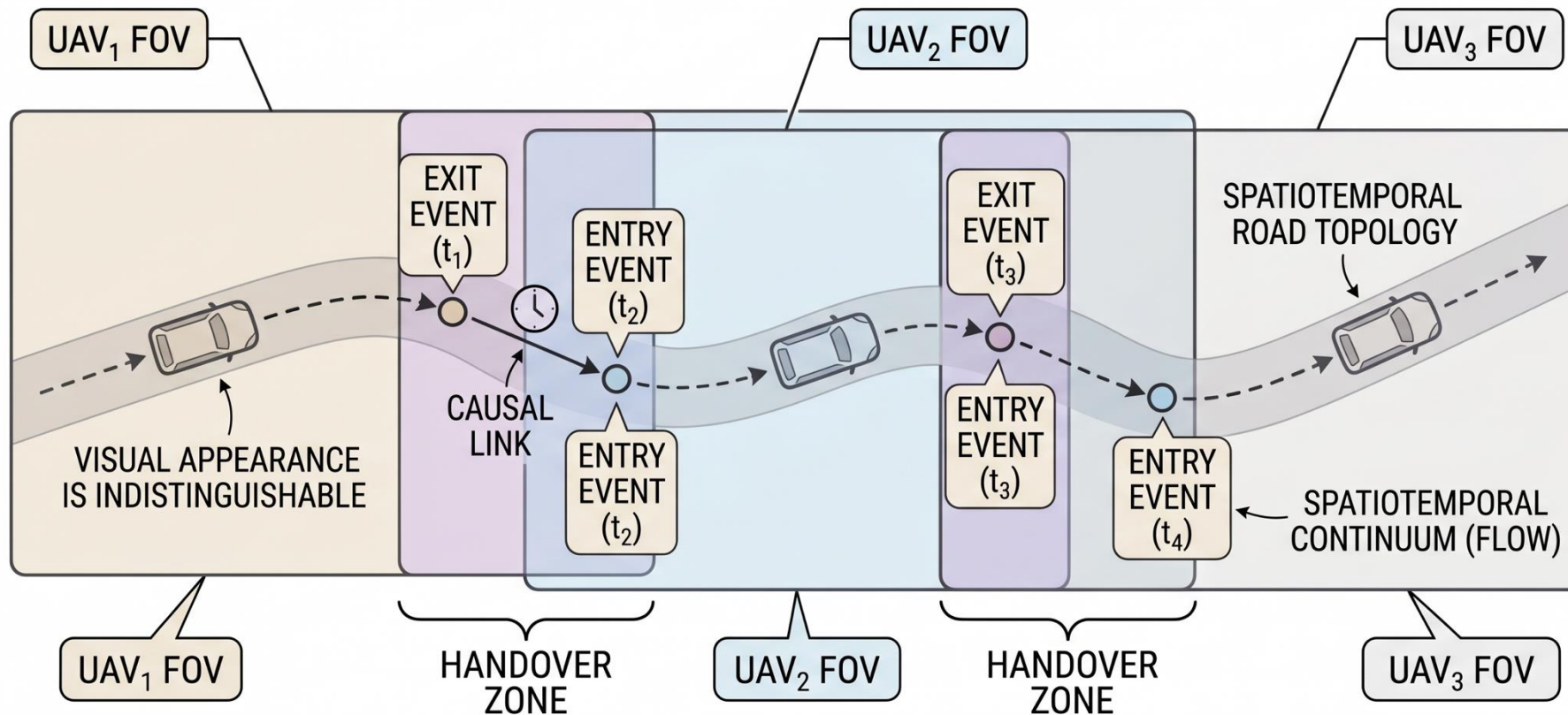
Intra-class Variation

[1] Fonod, Robert, et al. "Advanced computer vision for extracting georeferenced vehicle trajectories from drone imagery." *Transportation Research Part C: Emerging Technologies* 178 (2025).

Approach: System Architecture



Methodology: A Paradigm Shift in Association



Core Contribution:
Guarantees global identity persistence *without* relying on visual features.

The Spatiotemporal Continuum:

Exits and entries across overlapping FOVs are causally linked events.

Experiments & Evaluation Setup

Training Dataset: VisDrone2019

Evaluation Dataset: Custom Multi-UAV Urban Corridor

- 600m continuous span with 3 synchronized 4K **nadir-view** streams.
- Features a complex intersection and realistic **"Merge & Diverge"** behaviors.

Traffic Scenarios Evaluated:

Set A (Free-Flow): Low density & high speeds (>50 km/h).

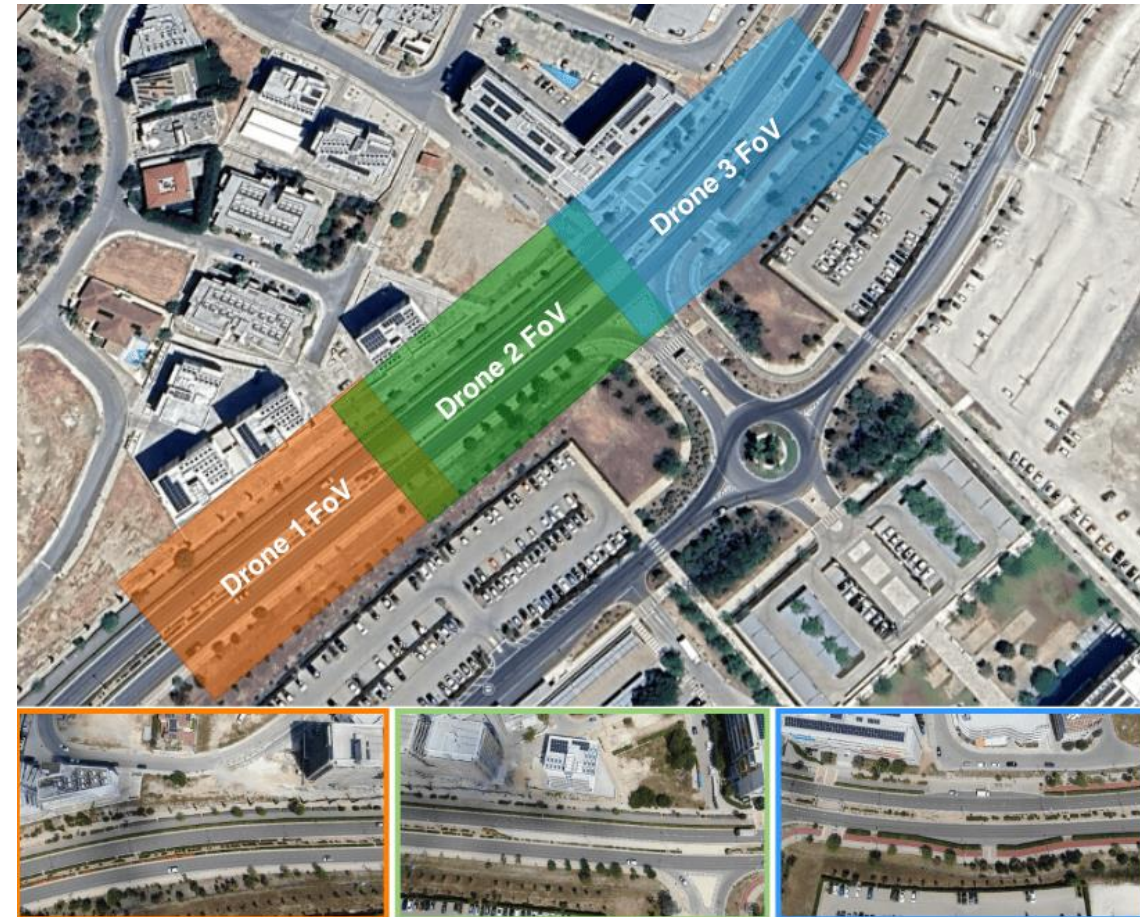
Set B (Congestion): High density with stop-and-go waves.

Set C (Overtaking): Parallel interactions and frequent lane changes.

Hardware Platforms:

Server Node (NVIDIA V100 GPU)

Edge Node (NVIDIA Jetson Orin NX)



[2] Du, et al. "VisDrone-DET2019: The vision meets drone object detection in image challenge results." Proceedings of the IEEE/CVF international conference on computer vision workshops. 2019.

Results – Handover Success Rate (HOSR)



TABLE I

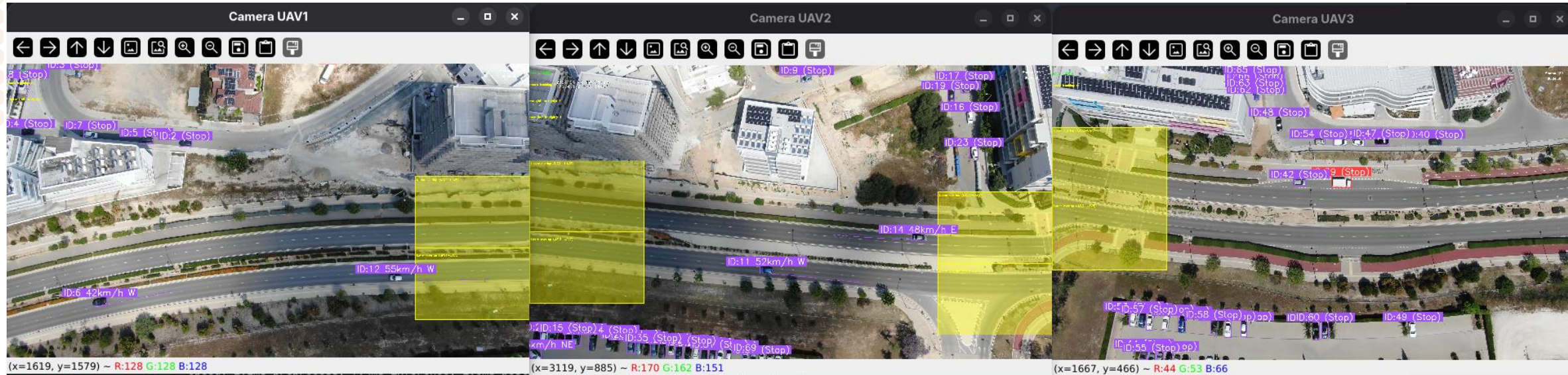
COMPARATIVE ANALYSIS ON THE UAV-CHAIN DATASET.

Method	Mechanism	HOSR (%)	IDF1 (%)	FPS (Server)
ByteTrack (Naive)	Motion IoU	12.4	34.2	65.2
DeepSORT	Re-ID (CNN)	68.3	55.1	22.8
FastReID (ResNet)	Re-ID (Large)	74.1	62.8	8.4
Ours (Proposed)	Topology + Meta	99.8	96.5	62.1

TABLE II

SYSTEM ROBUSTNESS ANALYSIS ACROSS TRAFFIC REGIMES

Regime	Primary Challenge	HOSR	Latency (ms)
Set A (Free-Flow)	High Velocity Blur	99.8%	14.2
Set B (Congestion)	Queue Timeout	92.4%	18.5
Set C (Overtaking)	Parallel Handovers	98.6%	15.1

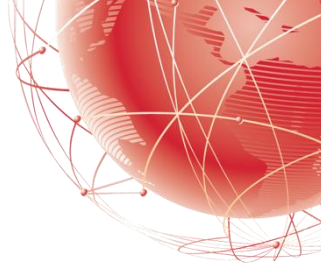


[3] Zhang, Yifu, et al. "Bytetrack: Multi-object tracking by associating every detection box." European conference on computer vision. Cham: Springer Nature Switzerland, 2022..

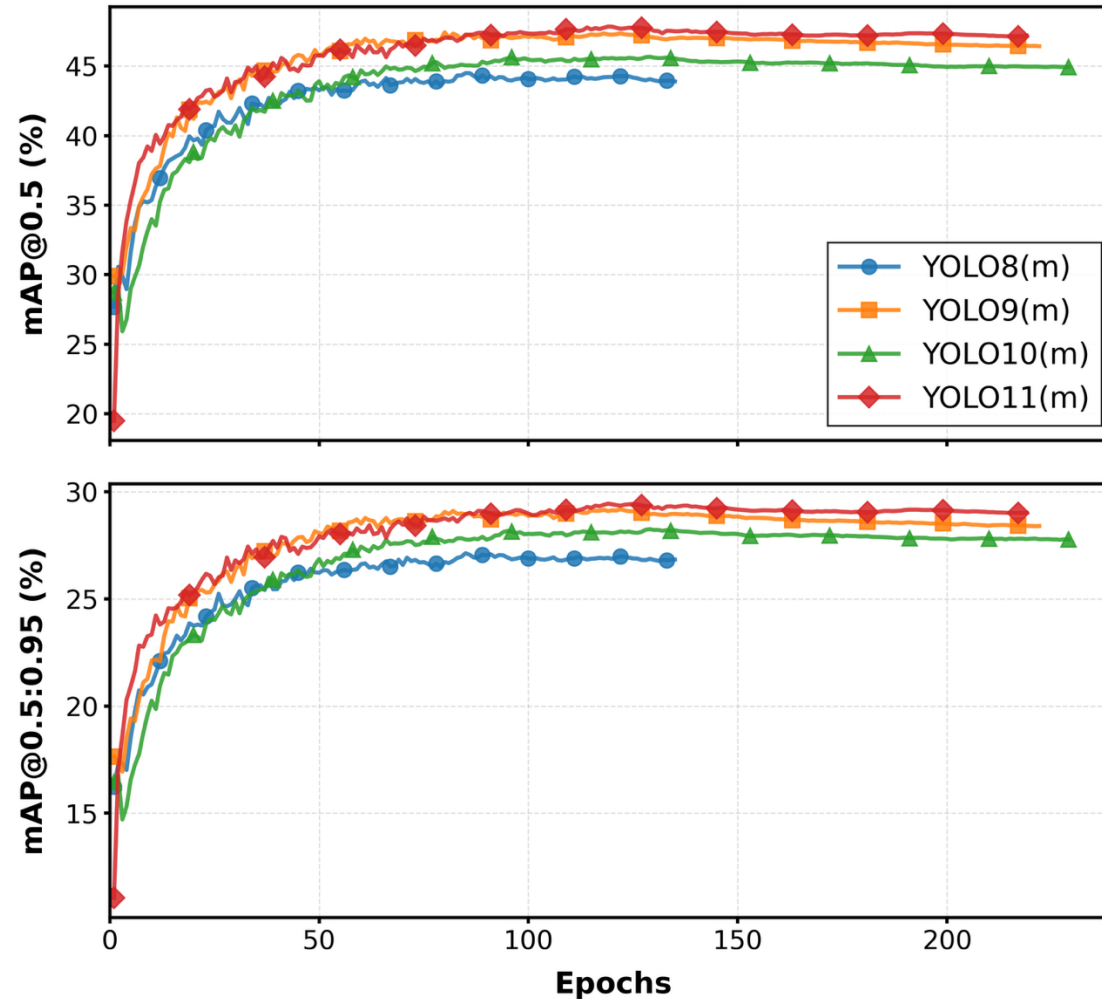
[4] Wojke, Nicolai. et al. "Simple online and realtime tracking with a deep association metric." 2017 IEEE international conference on image processing (ICIP). IEEE, 2017.

[5] He, Lingxiao, et al. "Fastreid: A pytorch toolbox for general instance re-identification." Proceedings of the 31st ACM international conference on multimedia. 2023.

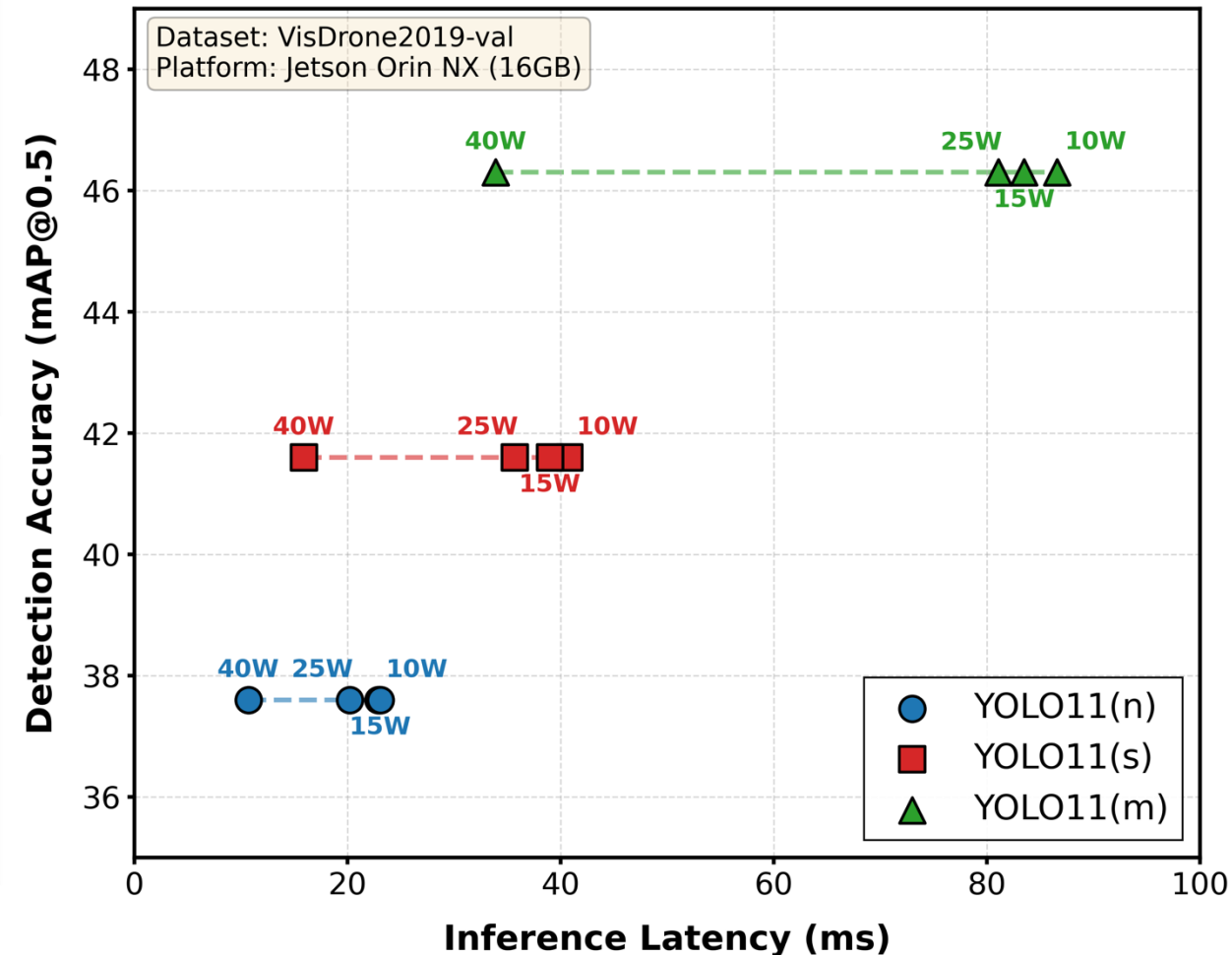
Results – Edge Performance



VisDrone Validation Performance



Efficiency Trade-off on Nvidia Jetson Orin NX

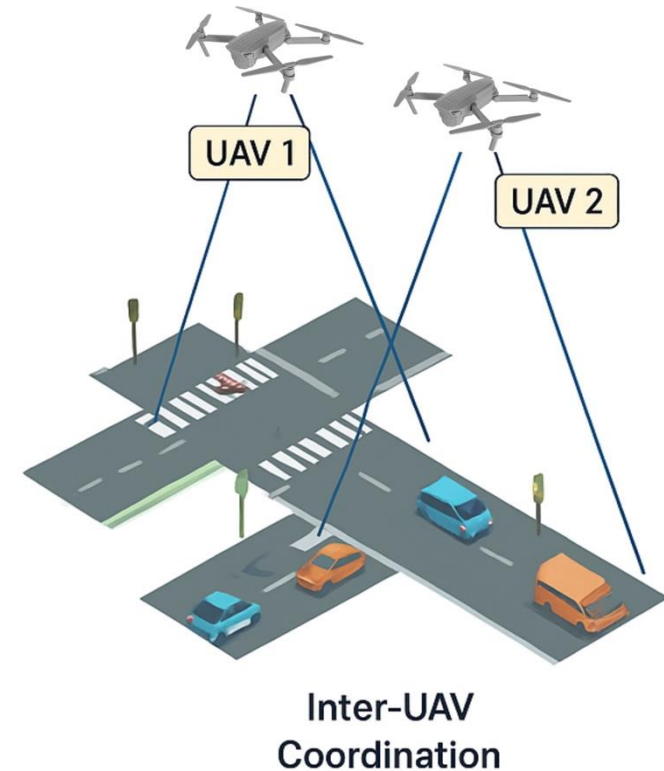


Key Contributions

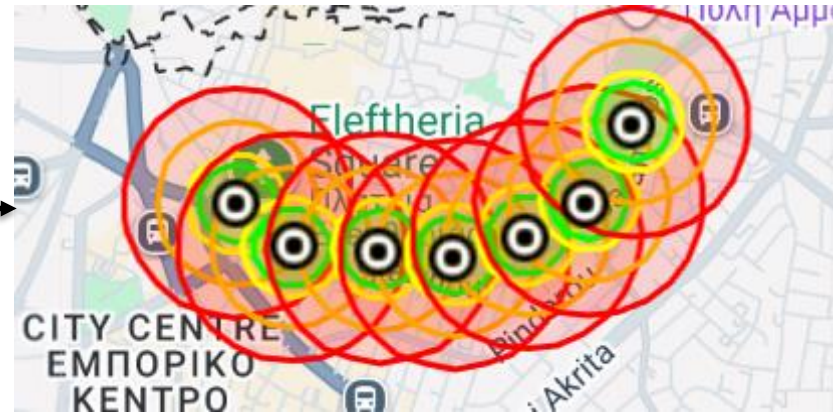
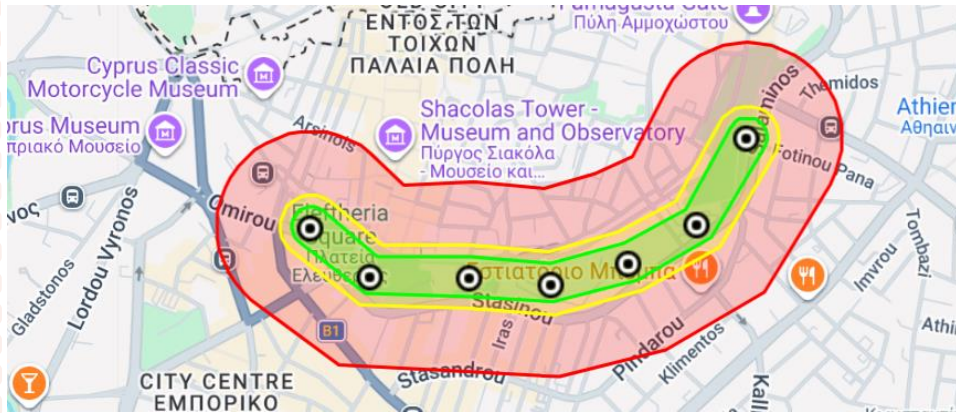
Resolved "**Nadir-View Ambiguity**": Replaced inefficient visual matching with a robust, queue-based topological algorithm.

High-Precision Flow Tracking: Applied physical roadway constraints to ensure highly reliable **identity persistence**, effectively tracking platoons of identical vehicles.

Edge-Computing Ready: Enabled real-time decentralized processing directly on UAV hardware, eliminating high-bandwidth video transmission to ground servers.



Future works



Thank you. Questions?

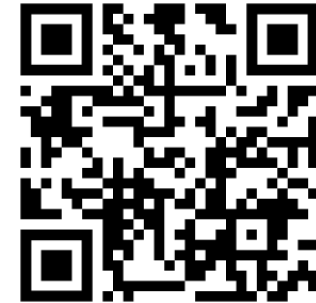
 GitHub



 Hugging Face



 Website



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