國立臺北大學資訊工程學系 114 學年度專題

Longitudinal Localization Optimization via Visual and Navigation Route Information Fusion for Vehicle Route Generation

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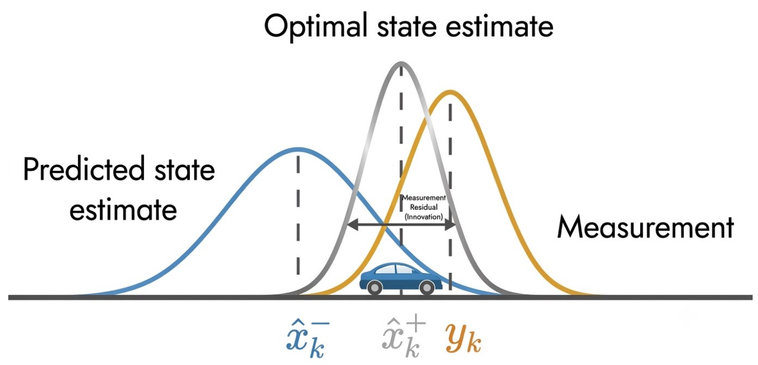
1. Abstract

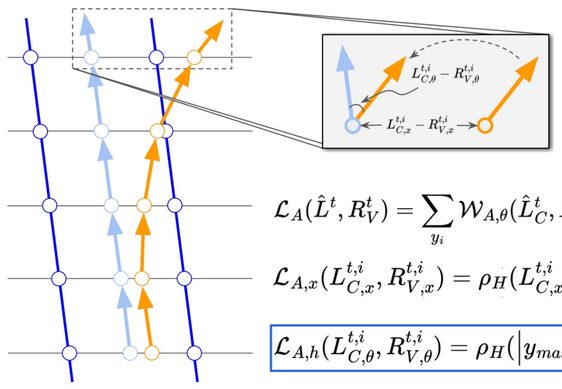
This study presents LLOV, a driver-perspective route generation system that integrates front-facing camera images, low-cost sensor data, and standard navigation routes to generate intuitive navigation guidance without relying on high-definition maps. Built upon the previous OLRA framework, LLOV incorporates an Extended Kalman Filter (EKF), Route Tangent Difference, and Cross Edge Loss to improve localization, heading estimation, and route generation accuracy for practical real-world navigation.

2. Method

- **Initialization & Stabilization** : We employ an **Extended Kalman Filter (EKF)** to fuse raw GPS data with vehicle motion sensors (Yaw Rate and Speed). This stabilizes the initial pose.



- **Route Tangent Difference** : Minimizes the angular and lateral gaps between the planned route and detected lane lines.

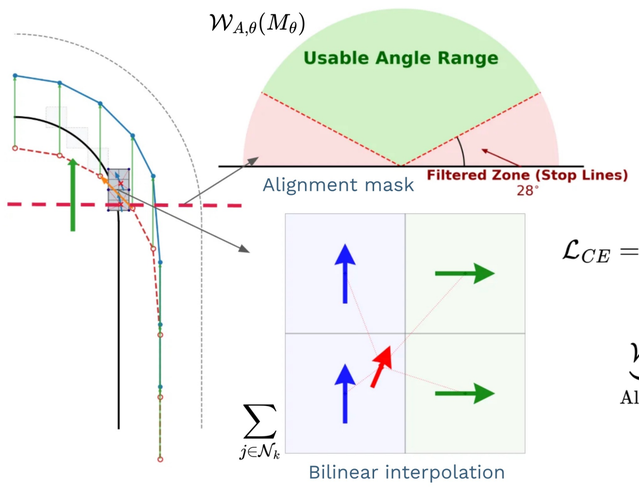


$$\mathcal{L}_A(\hat{L}^t, R_V^t) = \sum_{y_i} \mathcal{W}_{A,\theta}(\hat{L}_C^t, R_V^t) \left[\mathcal{L}_{A,x}(\hat{L}_{C,x}^{t,i}, R_{V,x}^{t,i}) + w_{A,h} \mathcal{L}_{A,h}(\hat{L}_{C,\theta}^{t,i}, R_{V,\theta}^{t,i}) \right]$$

$$\mathcal{L}_{A,x}(L_{C,x}^{t,i}, R_{V,x}^{t,i}) = \rho_H(L_{C,x}^{t,i} - R_{V,x}^{t,i})$$

$$\mathcal{L}_{A,h}(L_{C,\theta}^{t,i}, R_{V,\theta}^{t,i}) = \rho_H(\left| y_{max} \sin(L_{C,\theta}^{t,i} - R_{V,\theta}^{t,i}) \right|)$$

- **Cross Edge Loss (CEL)** : A novel loss function designed to prevent the route from crossing road boundaries.

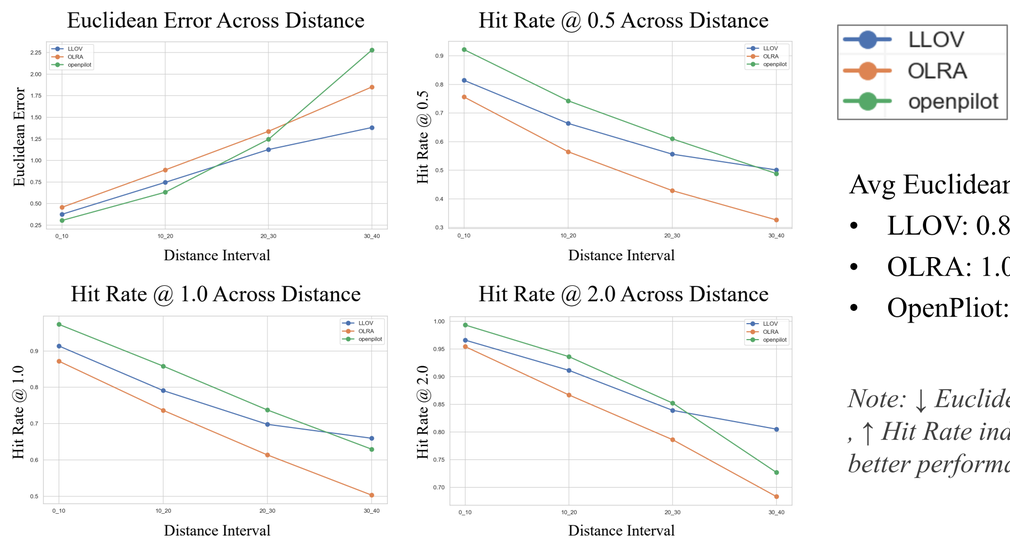


$$\mathcal{L}_{CE} = \sum_{k=1}^{K} \sum_{j \in \mathcal{N}_k} \Bigg(\underbrace{\mathcal{W}_{dist}(d_k)}_{\text{Spatial Weight}} \cdot \underbrace{\|\Delta R_V\| \cdot \eta_j}_{\text{Distributed Step}} \cdot \underbrace{\mathcal{W}_{A,\theta}(M_\theta)}_{\text{Alignment Mask}} \cdot \underbrace{\mathcal{L}_{A,\theta}(R_{V,\theta}, M_\theta)}_{\text{Heading Loss}} \cdot \underbrace{\mathcal{I}_{grad}}_{\text{Intensity}} \Bigg)$$

3. Comparison with SOTA

OpenPilot fails to correctly identify turns at intersections.

LLOV reduces longitudinal errors.



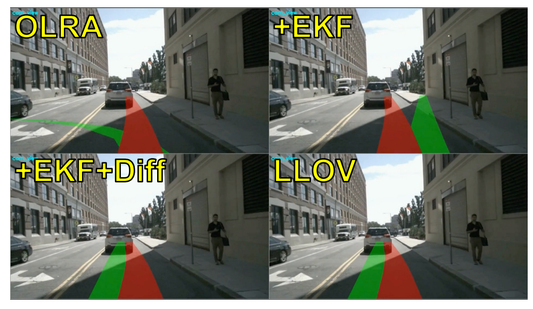
Avg Euclidean Error:

- LLOV: 0.84
- OLRA: 1.05
- OpenPliot: 0.89

Note: ↓ Euclidean Error , ↑ Hit Rate indicate better performance.

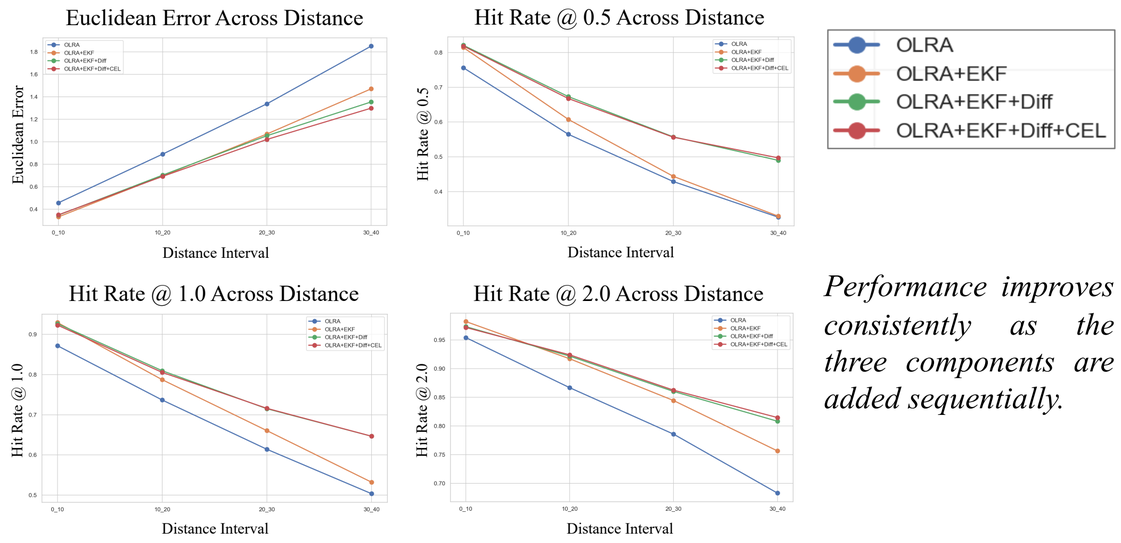
LLOV achieves better overall performance than OLRA and outperforms OpenPilot near route endpoints, where intersections are more likely to occur.

4.Abaltion Study



EKF reduces longitudinal errors, while Route Tangent Difference improves heading accuracy.

Route Tangent Difference improves heading estimation, while CEL refines longitudinal localization.



Performance improves consistently as the three components are added sequentially.

5. Conclusion

In this work, we proposed LLOV, a driver-perspective route generation framework that fuses visual and navigation route information. By integrating EKF, Route Tangent Difference, and Cross Edge Loss, LLOV reduces localization errors and improves heading estimation accuracy. Experimental results show that it generates routes more consistent with actual driving trajectories than OLRA.

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