Ph.D. in Information Technology
Thesis Defense

October 30th, 2025
at 9:00 am
Beta Room - building 24

Paolo CUDRANO – XXXVI Cycle

Road Representations for Autonomous Navigation: Offline Mapping, Online Detection and Dynamic Adaptation

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Abstract:

Autonomous vehicles rely on accurate perception of the road environment to operate effectively. Perception systems transform raw sensor data into meaningful representations of road features, enabling vehicles to interpret their surroundings and plan maneuvers. These representations must be accurate enough to ensure safe navigation while remaining computationally tractable in real-time environments. Different operational scenarios therefore call for specifically tailored representations in order to meet these conflicting requirements.
This thesis systematically investigates this design challenge, studying the development and maintenance of road representations across key operational contexts: offline mapping with abundant computational resources, online detection under strict real-time constraints, and adaptive strategies for dynamic environments. We focus predominantly on road line markings, distinctive features of road environments and essential for navigation, yet our analysis generalizes to broader road feature challenges.
First, we explore offline mapping of road lines using compact geometric models based on clothoid curves. These models achieve high accuracy and provide interpretable trajectory information for real-time control, making them suitable for integration into High-Definition (HD) maps, yet they exhibit limited convenience in complex urban scenarios, such as intersections and roundabouts.
Second, we address these limitations and further advance offline mapping by adopting a complementary model-free approach characterized by higher expressiveness. Capturing and aggregating dense line segmentation masks and distilling them into topological graphs, we obtain compact and accurate road line maps especially where geometric models are more limited.
Next, recognizing that HD maps may be absent or outdated in certain areas, we investigate online road line detection. By improving frame-by-frame accuracy and incorporating short-term detection aggregation, we enhance robustness against noise and occlusions while satisfying real-time constraints.
Finally, we address the dynamic nature of road environments, which requires adaptive perception. We discuss strategies for map maintenance and propose continual deep learning approaches to handle appearance variations.
Through this comprehensive analysis, we highlight the fundamental trade-offs faced by road representations and provide concrete solutions for their efficient offline mapping, robust online detection, and adaptive long-term maintenance.

PhD Committee

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