

Dynamic Occlusion Reasoning for Dense Urban Autonomous Driving

1. Mathematical Formulation

1.1 Probabilistic Occupancy

Each grid cell maintains a probability of being occupied:

$$P(c_i = 1 | z_{\{1:t\}})$$

where c_i represents occupancy of cell i and z denotes sensor observations.

1.2 Bayesian State Estimation

Hidden agents are modeled using recursive Bayesian filtering:

$$P(x_t | z_{\{1:t\}}) \propto P(z_t | x_t) \int P(x_t | x_{\{t-1\}}) P(x_{\{t-1\}} | z_{\{1:t-1\}}) dx$$

This allows belief propagation even when agents are occluded.

1.3 Collision Risk Estimation

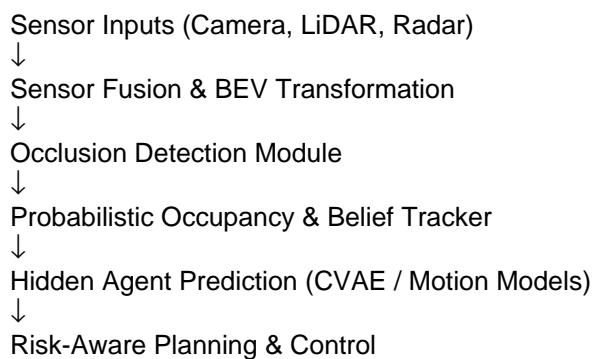
Expected collision risk is computed as:

$$R = \sum P_e \cdot P_i$$

where P_e is the probability of existence of a hidden agent and P_i is the probability of trajectory intersection.

2. System Architecture Design

Overall Pipeline



Module Responsibilities

- Perception Module: Detects visible agents and occluders
- Occlusion Reasoner: Identifies hidden regions and assigns priors

- Prediction Module: Generates multi-modal trajectories
- Planner: Optimizes safety-aware cost functions under uncertainty
- Controller: Executes smooth, defensive maneuvers

3. Integration with Autonomous Stack

The occlusion reasoning module interfaces directly with the prediction and planning layers, influencing speed profiles, lane changes, and stopping behavior in dense urban scenarios.

4. Conclusion

Incorporating mathematical reasoning and structured architecture enables autonomous systems to anticipate unseen hazards. Dynamic Occlusion Reasoning bridges the gap between perception uncertainty and safe decision-making.