Using Goal Structure to Perform Risk Assessment during Driving Maneuvers

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Proactive Risk-Bounded Driving Systems
Will estimate, alert and adapt to potential threats before they become a crisis.
Geordi: A Risk-aware Driving Aid

Highway On-Ramp Scenario:
Agent vehicle (red): moving on ramp.
Ego vehicle (yellow): slow down and change to the left lane.

Geordi:

1. Probabilistically estimates vehicle trajectories, maneuvers and driver styles.
2. Generates risk-bounded vehicle trajectories, given estimates.
3. Proactively generates policies for safe maneuvering, for likely driving situations.

Driving Problem

Find the fastest path to the goal, while limiting the chance of crashing to a tenth of a percent.

Driver goals specified by an:
1. initial pose,
2. goal pose,
3. safety constraint, and
4. bound on probability of failure (chance constraint).
Risk-bounded Trajectories are Generated by Solving a Stochastic Program

E.g., using Algorithmic Risk Allocation [Ono & Williams, AAAI 08]
Risk Assessment is Rooted in Probabilistic Predictions of Vehicle Trajectories

Vehicle paths deviate due to uncertainty.

The influence of uncertainty is described by probability distributions over vehicle states and trajectories.
Trajectory Prediction uses Probabilistic Vehicle and Sensor Models

**Continuous State Space Model**

\[ x_{k+1} = f(x_k, u_k, \omega_k) \]

- **States**: position and velocity
- **Control inputs**: Steering angle, Torque
- **Dynamics** may be non-linear.
- **Sensor and actuation noise** may be non-Gaussian.
Proactive Driving Systems Need Predictions Over Longer Horizons

**Problem:** Uncertainty increases dramatically over time, influenced by:

- Driver goals,
- Vehicle maneuvering,
- Driver styles.

**Idea:** Probabilistically Estimate

- Maneuver sequence of each vehicle.
- Vehicle motion, given maneuver sequence.
- Vehicle state, driver type, driver goal.

- Use to assess risk and to plan.
Probabilistic Maneuver Models Predict Vehicle Trajectories for Each Driver Type

Qualitative:
- Maneuvers are "actions" that specify poses over time.
- Switch left, switch right, exit

Quantitative:
- A maneuver is a bundle of trajectories, called a probabilistic flow tube.
- Maneuver risk corresponds to trajectories in its flow tube that are blocked.
Risk-assessment and Planning of Maneuver Sequences is Framed as a Stochastic Game

$p(s_0)$: Probability distribution over states of ego vehicle e.g., $[x_0, y_0, v_{x_0}, v_{y_0}]$

Geordi generates policies for maneuvering by solving a stochastic shortest path problem that is:

- Chance-constrained
- Concurrent
- Hidden state,
- Hybrid discrete / continuous

➢ Risk-bounded A0* [Santana, Thibeaux, Williams]
Questions?