# Using Goal Structure to Perform Risk Assessment during Driving Maneuvers

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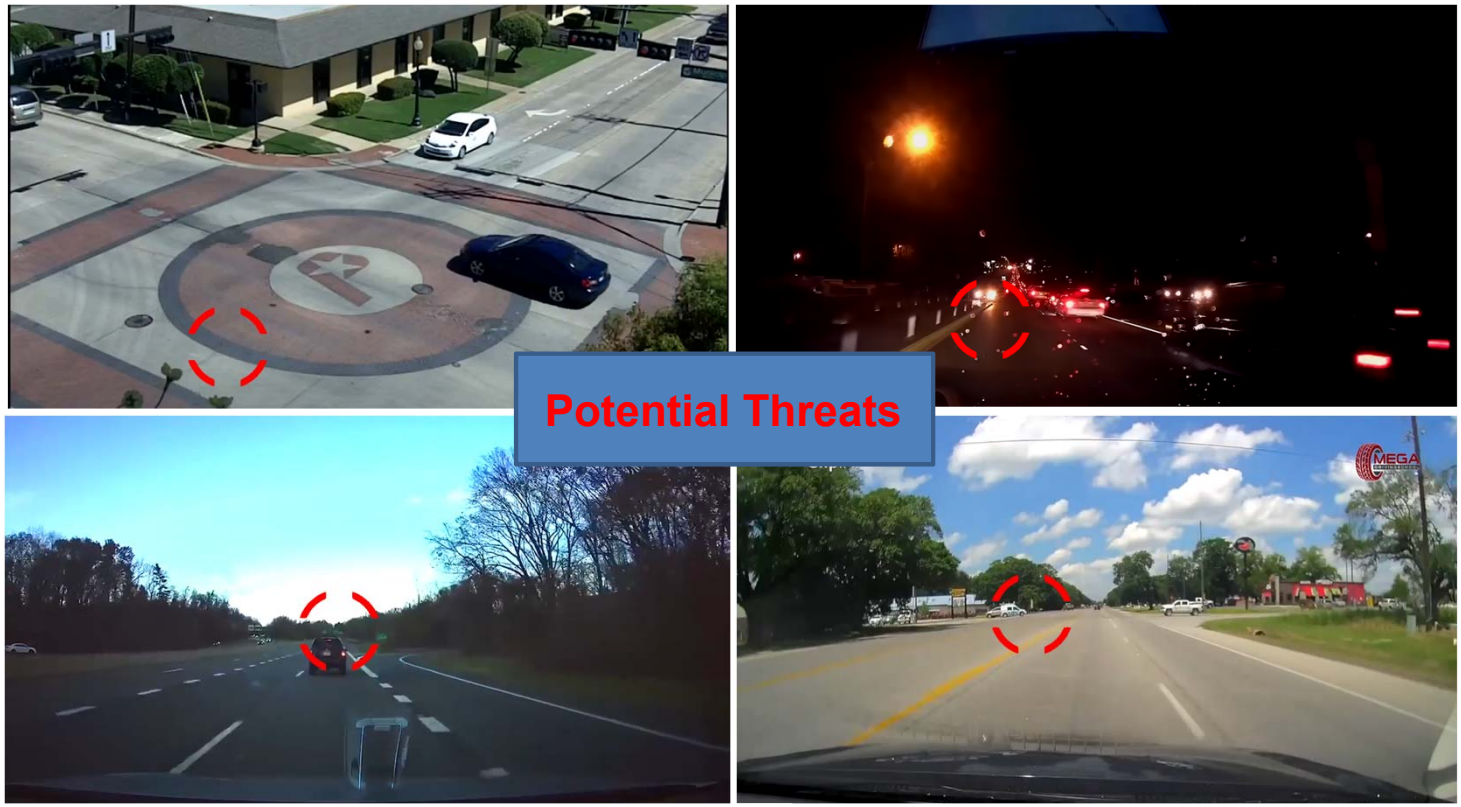
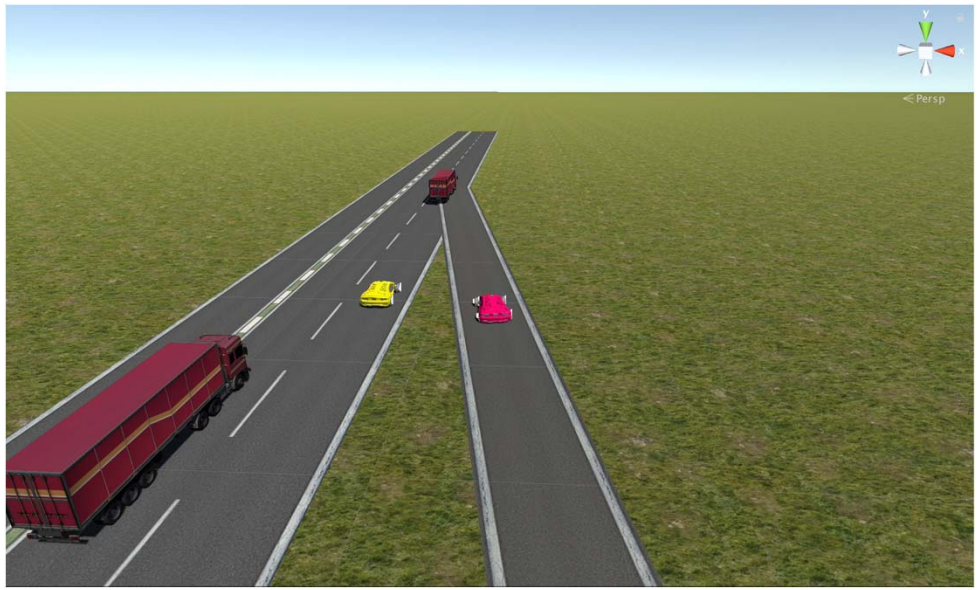
# Proactive Risk-Bounded Driving Systems

Will estimate, alert and adapt to potential threats before they become a crisis.



# Geordi: A Risk-aware Driving Aid

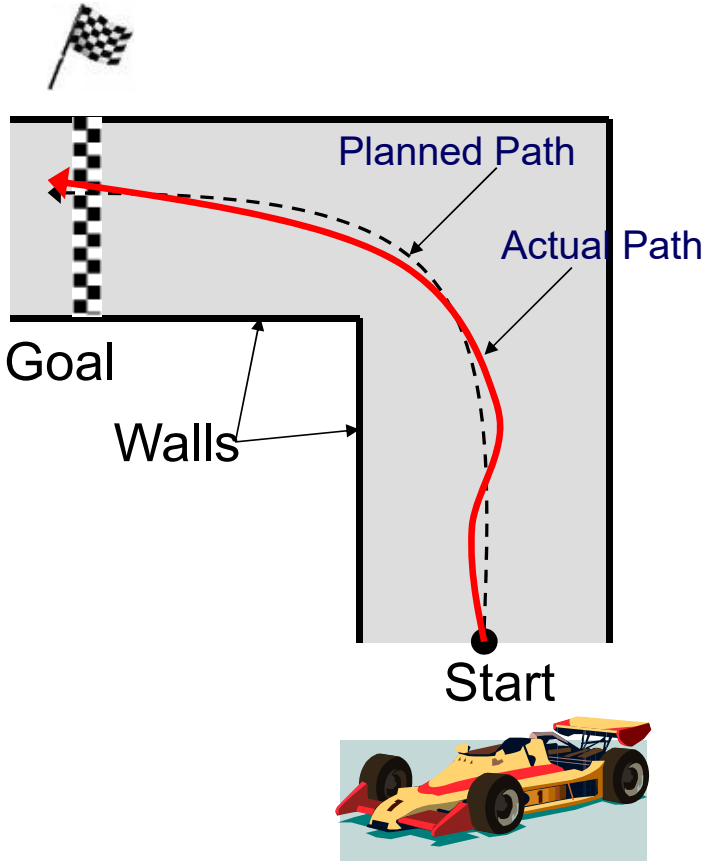


Highway On-Ramp Scenario:
Agent vehicle (red): moving on ramp.
Ego vehicle (yellow): slow down and change to the left lane.

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.

# Geordi Frames Risk Assessment using Chance Constraints over Driver Goals and Safety Constraints.




## Driving Problem

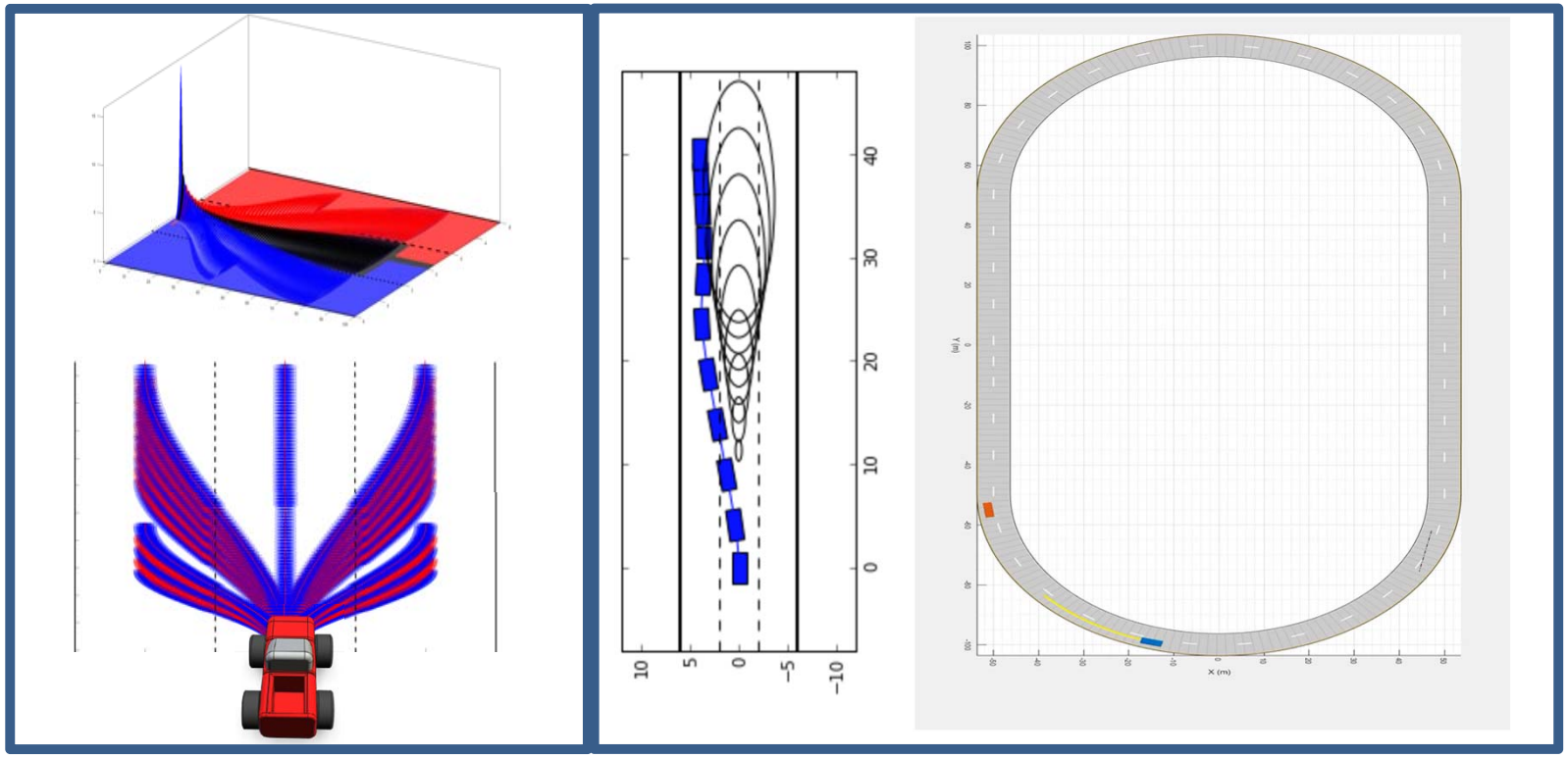
*Find the fastest path to the goal, while limiting the chance of crashing to a tenth of a percent.*

Risk bound

Driver goals specified by an:

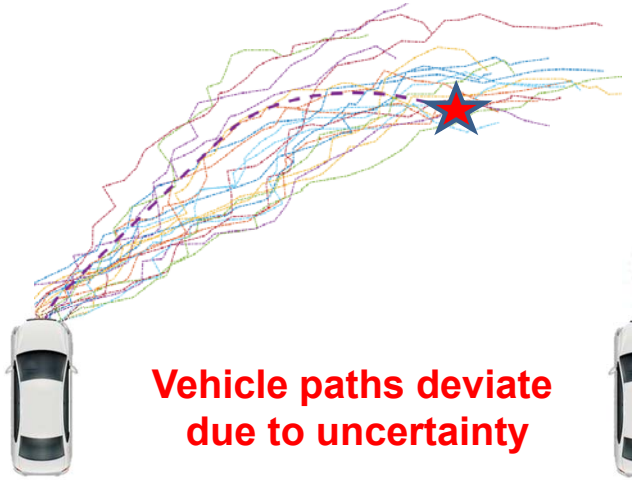
1. initial pose,
2. goal pose,
3. safety constraint, and
4. bound on probability of failure (*chance constraint*).

# Risk-bounded Trajectories are Generated by Solving a Stochastic Program



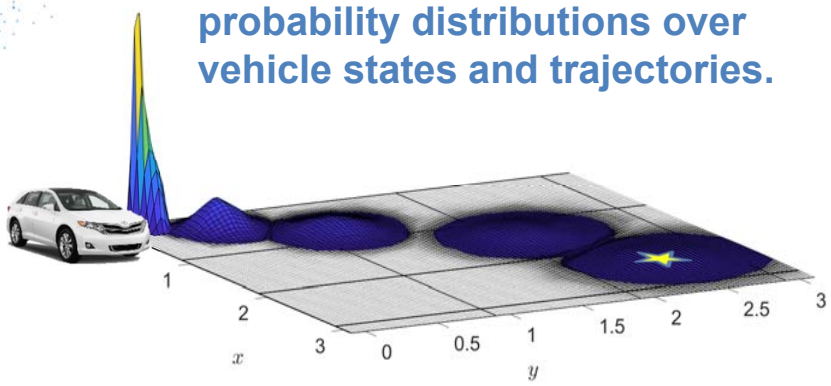

E.g., using **Algorithmic Risk Allocation** [Ono & Williams, AAAI 08]

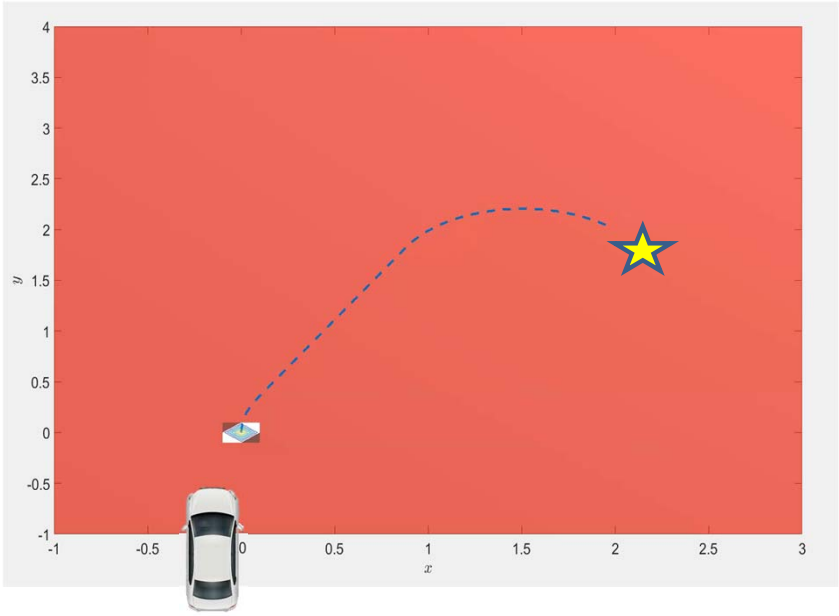
# Risk Assessment is Rooted in Probabilistic Predictions of Vehicle Trajectories

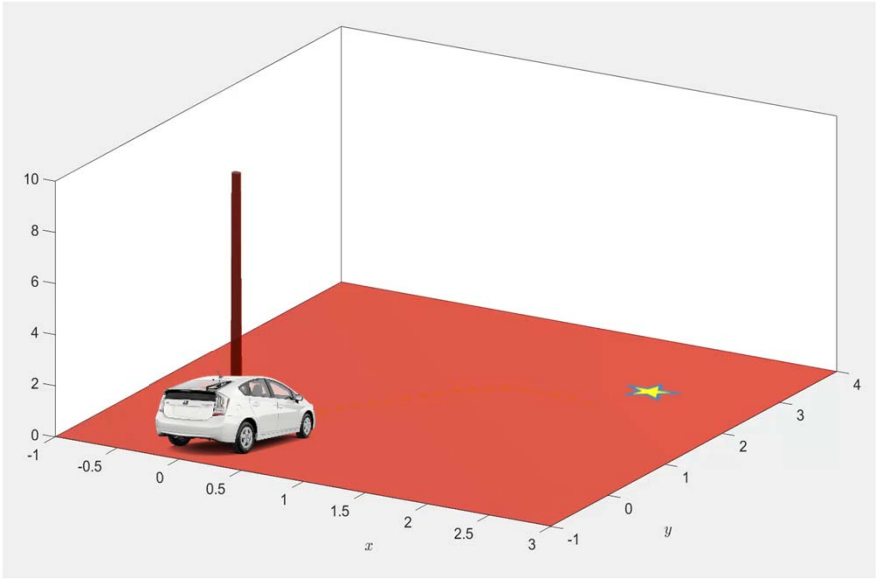


Vehicle paths deviate due to uncertainty

The influence of uncertainty is described by probability distributions over vehicle states and trajectories.



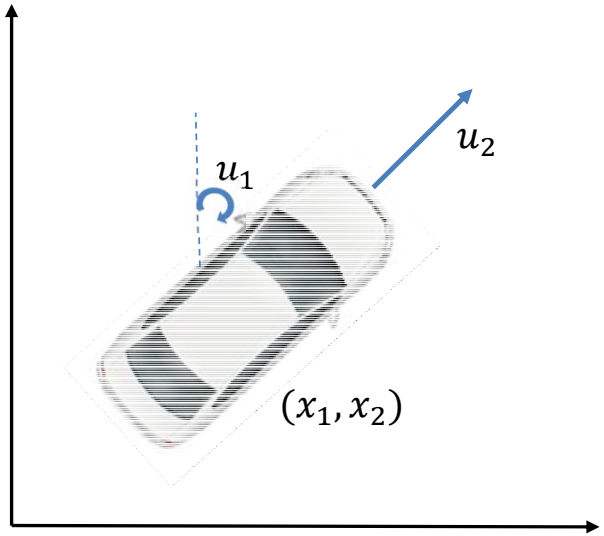



# Trajectory Prediction uses Probabilistic Vehicle and Sensor Models

**Continuous State Space Model**

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

states — inputs — Uncertainty ~ p($\omega_k$):probability distribution



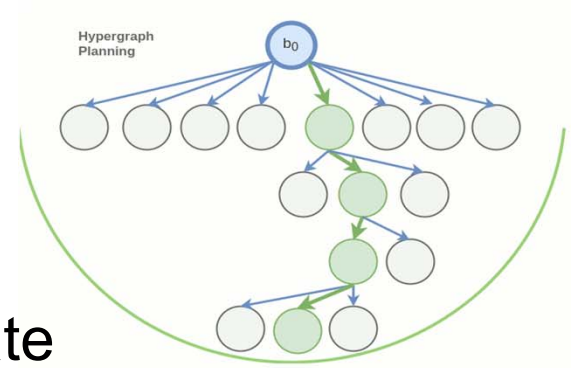

$states$: position and velocity
$control\ inputs$: Steering angle, Torque

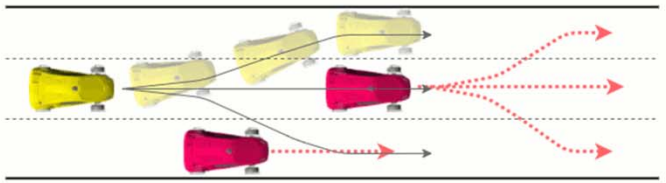
- Dynamics may be non-linear.
- Sensor and actuation noise may be non-Gaussian.

# 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.

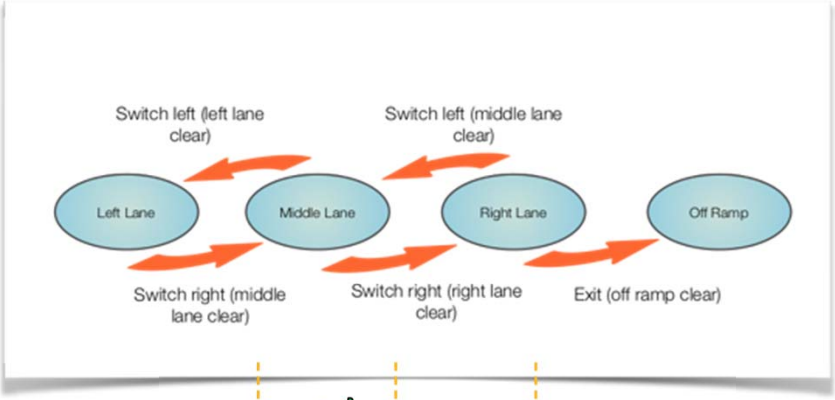
- Vehicle state, driver type, driver goal.

- Use to assess risk and to plan.

# Probabilistic Maneuver Models Predict Vehicle Trajectories for Each Driver Type

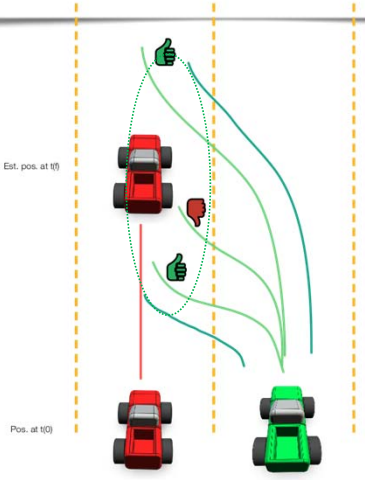
Qualitative:

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

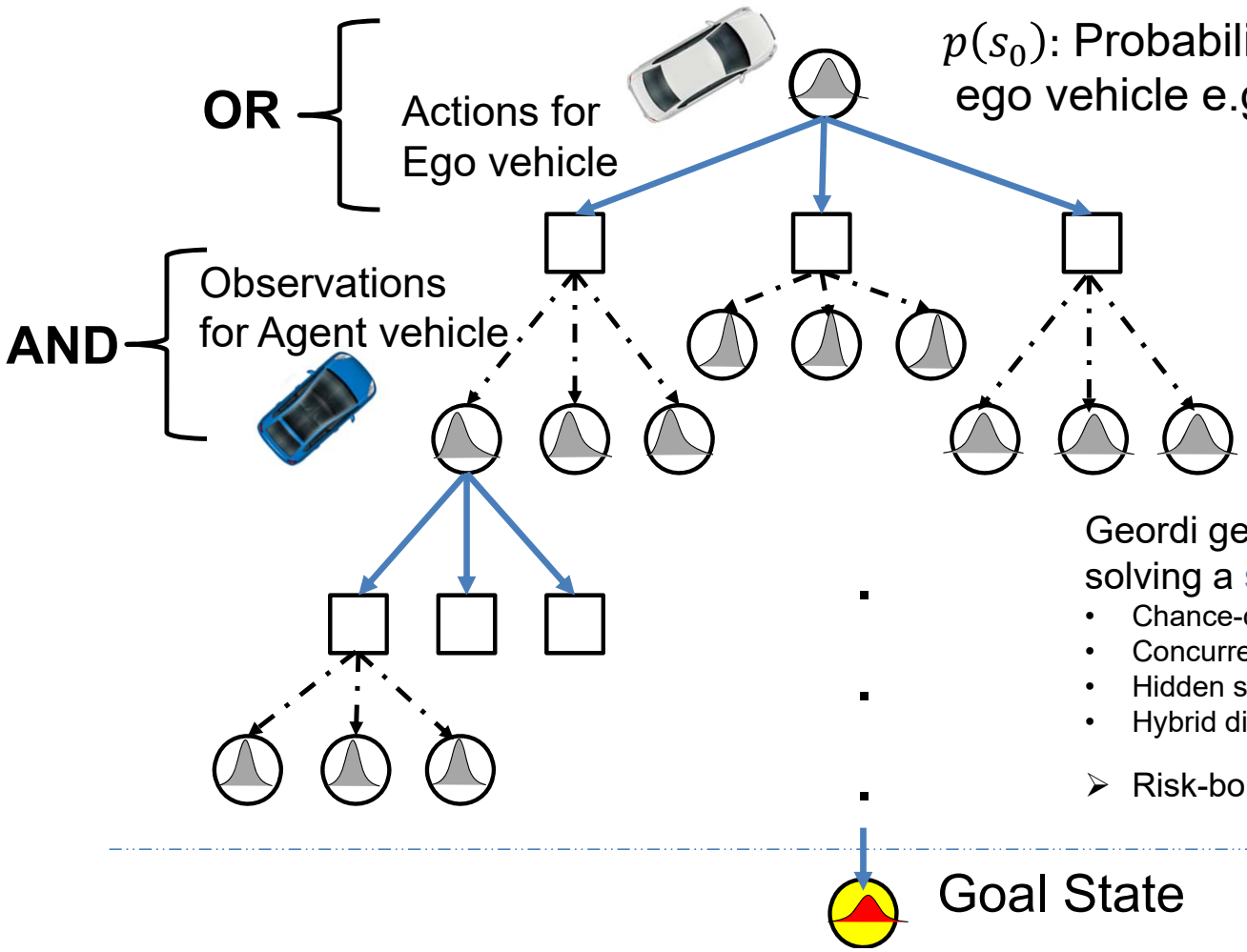



Quantitative:

- 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?