Mathematical Models of Human Operators Using Artificial Risk Fields

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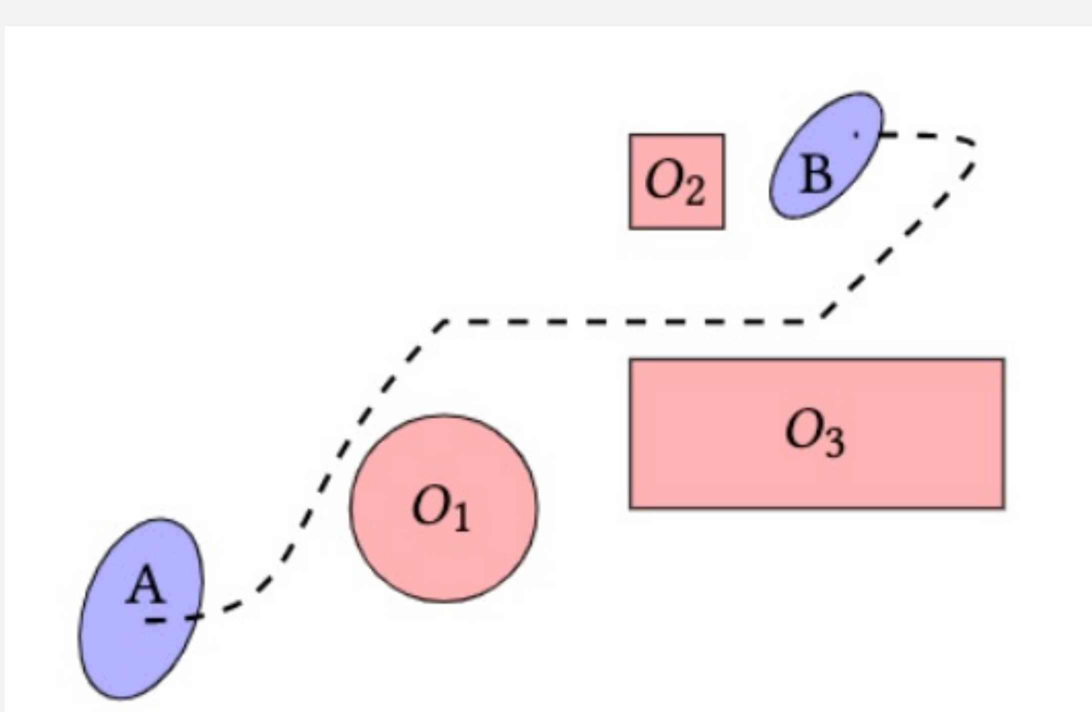
Artificial Risk Fields

Goal: Describe a concise model of a human operating a robot in an uncertain environment. We should be able to learn the model given (state, control) pairs.

Problem Formulation: A risk field includes the following:

- A set of obstacles to avoid
- A set of task specifications (target velocity, time limit)
- Start and Goal states
- A set of environment states x
- A set of possible controls u
- A model of human decision making – P(u | x)



Future Work

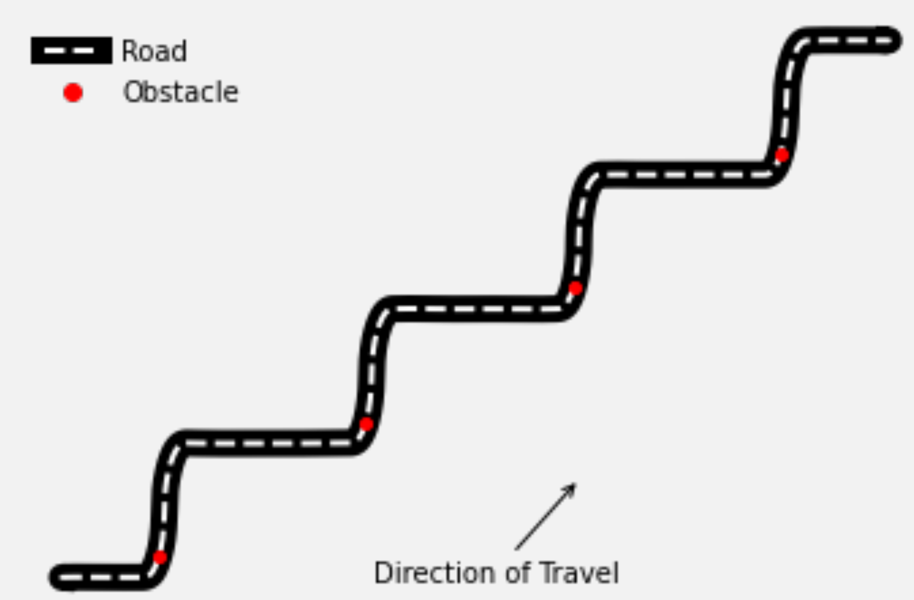
- Predict driver situational awareness
- Provide driver interventions based on runtime monitoring
- Develop more nuanced method of tracking velocities
- Apply models to more complex datasets

Driving Task

Participants: 6 total, 3 male + 3 female
Mean age 21.33 years

Data Collected: 19 total trials on driving course
Trial length is about 4 minutes
Data sampled at 60 Hz

Objectives: Be safe and stay in lane
Avoid colliding with the 4 obstacles
Maintain speed of 45 mph



Driving Risk Field

$$\texttt{risk}(x) = \begin{cases} A \cdot \texttt{dist}(x,\ \text{centerline})^2 + \\ B \cdot \exp(-\texttt{dist}(x,\ \text{obstacle})^2 / d_{obs}^2) + \\ C \cdot (v - v_{tgt})^2 \end{cases}$$

Each state is associated with a risk from a variety of factors. We model that drivers will prefer lower risk.

$$\texttt{cost}(u) = \begin{cases} D \cdot \texttt{acceleration}^2 + \\ E \cdot \texttt{steering rate}^2 \end{cases}$$

Each control input is associated with a cost. We model that drivers will prefer lower cost with a more constant range of inputs.

$$\mathbb{P}(u|x) \propto \exp(-\texttt{risk}(x'(u, \delta)) - \texttt{cost}(u))$$

We model drivers as Boltzmann rational; they are exponentially more likely to choose a control input if they think it will lead to lower risk and cost.

Fitting the Model

- Maximize log-likelihood of decision model using convex optimization tools
- Fitting model using parameters A – E
- Generated trajectories using 5th and 95th percentile parameter values
- Qualitatively different trajectory and control behavior by changing parameters
- Trajectories are accurate to reference up to 5 seconds later