Using Artificial Potential Fields To Model Driver Situational Awareness

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Background: Risk Fields

For more detail, see our Jensen, et al. paper at ITSC 2022

A risk field includes the following:

Task specifications (target speed, avoid obstacles)
Environment states *x*
Possible controls *u*
Formalized using *risk* and *cost* functions

A model of human decision making:

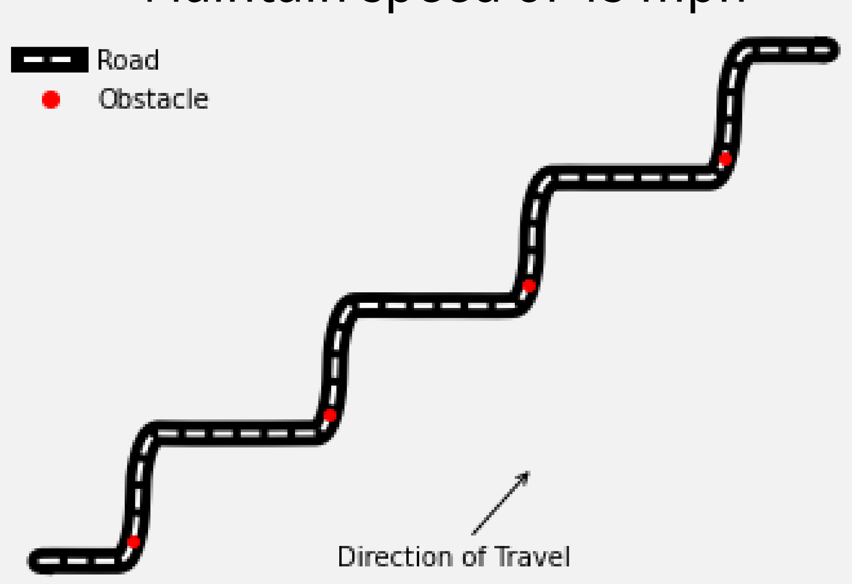
Probabilistic model P(*u* | *x*)
$\mathbb{P}(\mathrm{u}|\mathrm{x}) \propto \exp(-\mathtt{risk}(\mathrm{x}'(\mathrm{u},\delta)) - \mathtt{cost}(\mathrm{u}))$
Drivers will likely choose less risky/costly actions

Driving Task

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

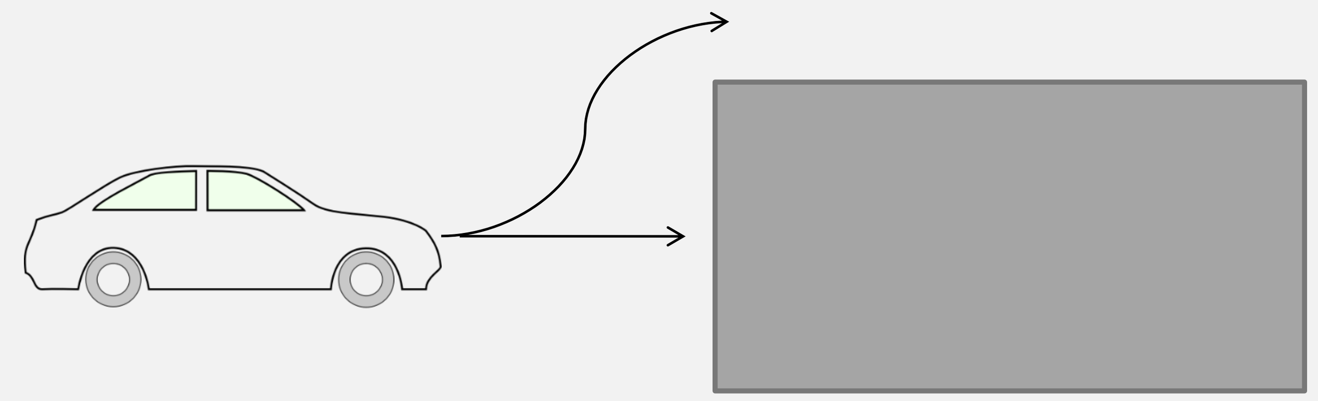
Data Collected: 19 total trials on driving course
Trial length is about 4 minutes
Data sampled at 60 Hz

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



Modeling Situational Awareness

- Situationally-aware drivers have expected risk fields
- Unaware drivers will act like they don't register the obstacle
- This gives two hypothesized risk field models based on user's mental state



Hypothesized Driver Risk Fields:

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

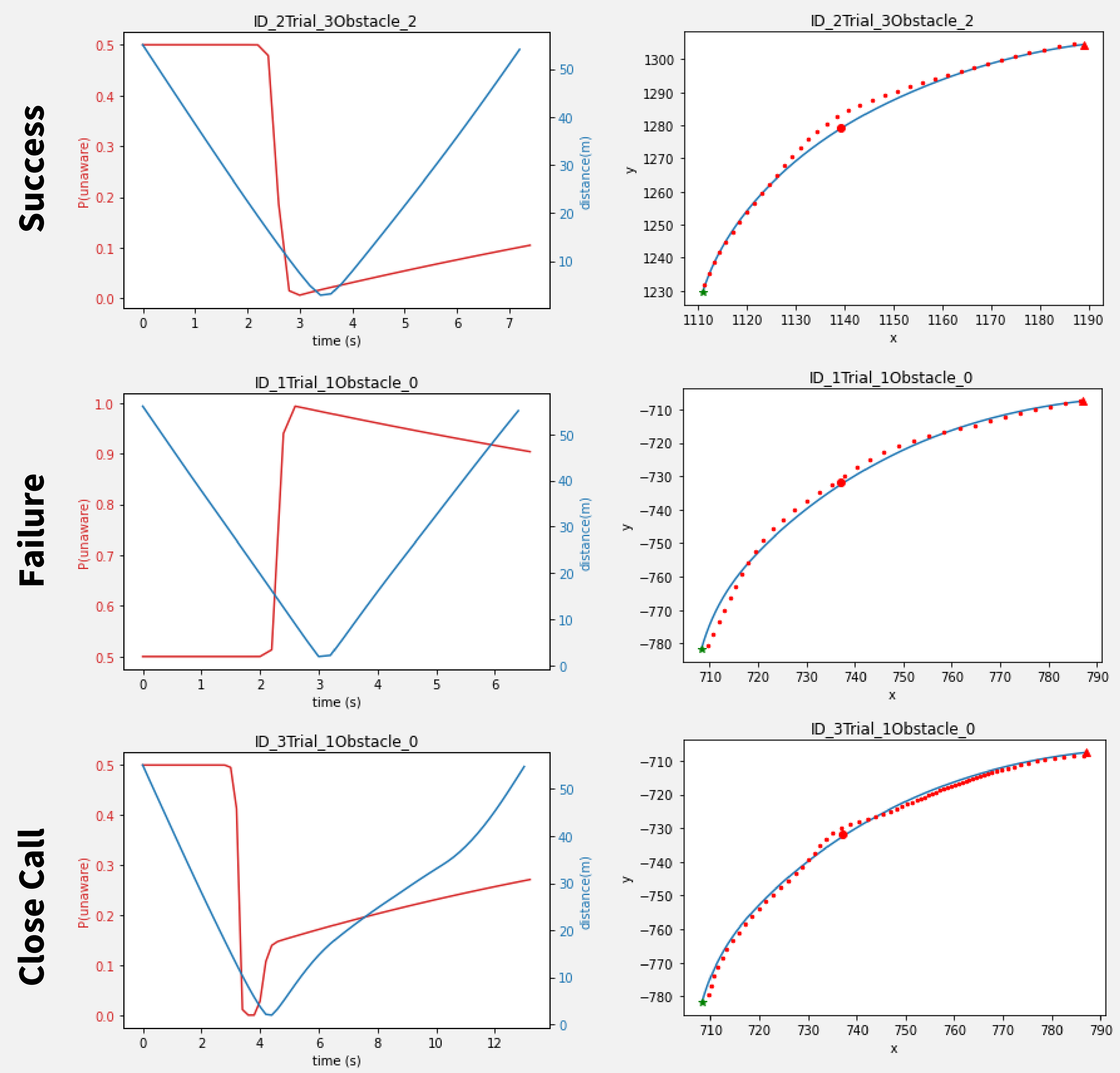
$$\mathtt{cost}(\mathrm{u}) = \begin{cases} D \cdot \mathtt{acceleration}^2 + \\ E \cdot \mathtt{steering\ rate}^2 \end{cases}$$

Predicted Situational Awareness

- Initially guess P(*aware*) = P(*unaware*) = 0.5
- Use Bayes' Rule to update prediction based on user action

$$\mathbb{P}(\text{UNAWARE}|\mathbf{u},\mathbf{x}) = \frac{\mathbb{P}(\mathbf{u}|\mathbf{x}, \text{UNAWARE}) \times p_U}{\mathbb{P}(\mathbf{u}|\mathbf{x}, \text{UNAWARE}) \times p_U + \mathbb{P}(\mathbf{u}|\mathbf{x}, \text{AWARE}) \times (1 - p_U)}$$

P(*unaware*): **Driver Trajectory:**



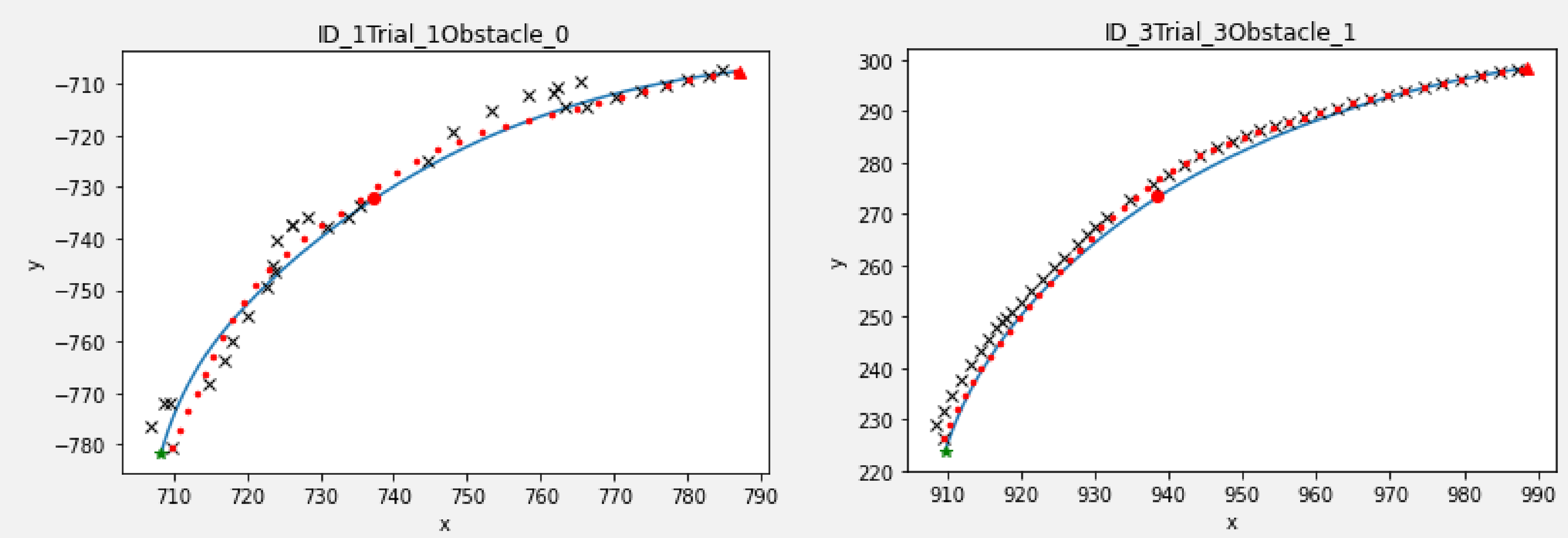
Perceived Position

- Relax the assumption that the driver knows their exact position
- Generate distribution of nearby positions the driver could perceive as their current position
- Use Bayes' Rule to estimate driver's perceived position based on their control actions

Distribution over likely positions

$$\mathbb{P}(\hat{\mathbf{x}}|\mathbf{u}) = \frac{\mathbb{P}(\mathbf{u}|\hat{\mathbf{x}}_j) \times \pi(x_j, y_j)}{\sum_{k=1}^{K} \mathbb{P}(\mathbf{u}|\hat{\mathbf{x}}_k) \times \pi(x_k, y_k)}$$

Control model based on perceived position



Future Work

- Apply approach to more dynamic and complex scenarios, recorded by Purdue team
- Compare situational awareness estimates with other measures such as gaze and self-reports
- Infer situational awareness from other factors besides steering inputs