Deception for Advantage in Connected and Automated Vehicle Decision-Making Games*

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Abstract

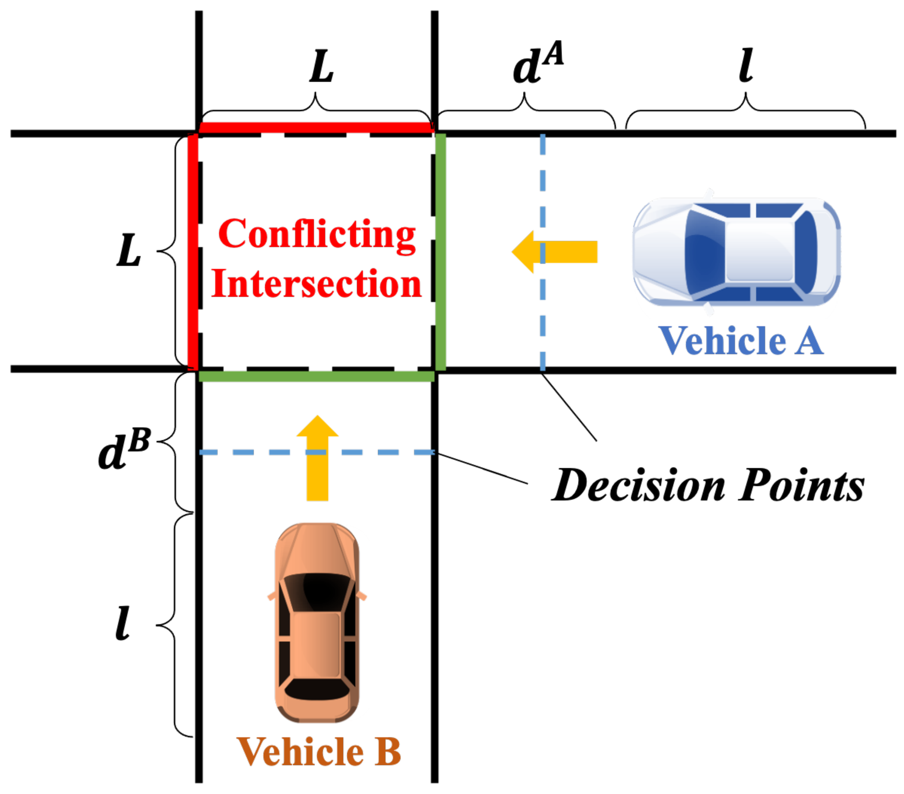
Connected and Automated Vehicles (CAVs) have the potential to enhance traffic safety and efficiency. In contrast, aligning both vehicles' utility with system-level interests in scenarios with conflicting road rights is challenging, hindering cooperative driving. This paper advocates a game theory model, which strategically **incorporates deceptive information within incomplete information vehicle games**, operating under the premise of imprecise perceptions. The equilibria derived reveal that CAVs can exploit deceptive strategies, not only gaining advantages that undermine the utility of the other vehicle in the game but also posing hazards to the overall benefits of the transportation system. Vast experiments were conducted, simulating diverse inbound traffic conditions at an intersection, validating the detrimental impact on efficiency and safety resulting from CAVs with perception uncertainties, and employing deceptive maneuvers within connected and automated transportation systems. Finally, the paper proposes feasible solutions and potential countermeasures to address the adverse consequences of deception in connected and automated transportation systems. It concludes by calling for integrating these insights into future research endeavors and pursuing to fully realize the potential and expectations of CAVs in enhancing the whole traffic performance.

Scenario

Two vehicles **compete for the right to pass** through the same roadblock, typically a signal-free intersection.

Single decision process to represent the game.

Decision point with the same distance, similar to the decision point set by FHWA for human drivers in MUTCD.



Base Game

Two decisions can be planned for each vehicle: keeping speed to **pass** or slowing down to **yield**.

(U^A,U^B)	A: Pass	A: Yield
B: Pass	$(-R,-R)$	$(\frac{d^A}{v}-\frac{L+d^B+l}{v},0)$
B: Yield	$(0,\frac{d^B}{v}-\frac{L+d^A+l}{v})$	$(-D,-D)$

Similar to a simple chicken game, this game will produce four different playoffs, **considering both safety and efficiency**.

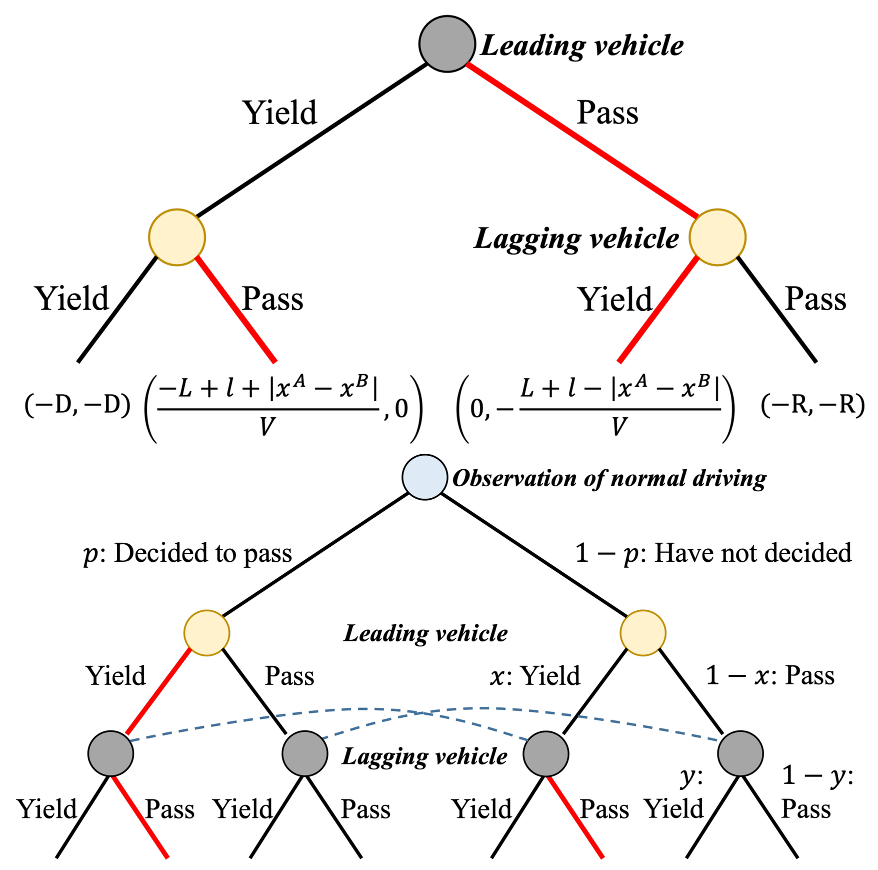
- Both passes lead to a significant collision risk ($-R$)
- One pass and one yield cause no cost for the passing vehicle (0), but a time delay ($\frac{d^Y}{v}-\frac{L+d^P+l}{v}$) for the yielding one.
- Both yields lead to a moderate negative number ($-D$) given to both.

Analyses

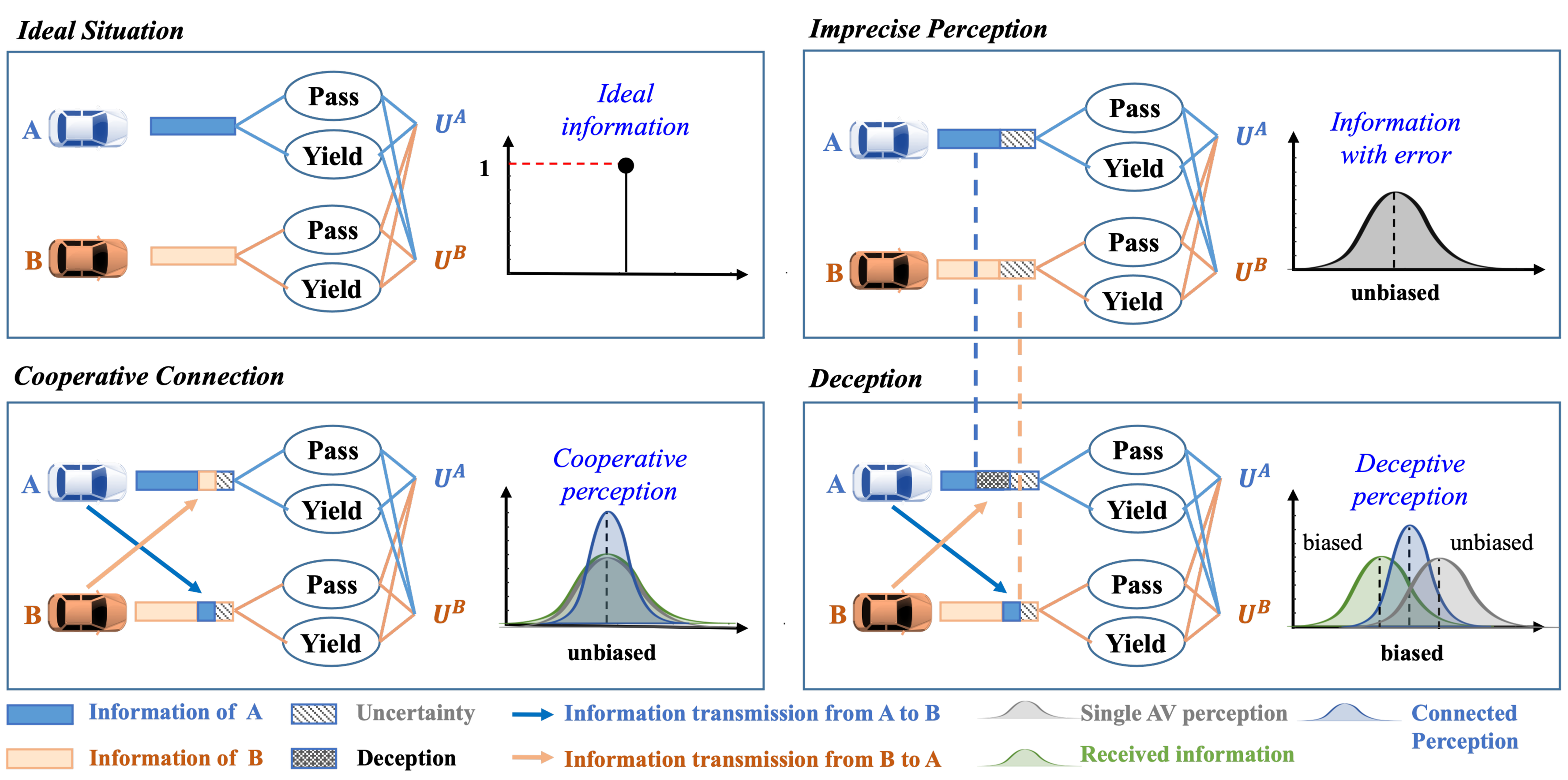
Ideal situation: both vehicles have complete information. The vehicle makes the decision first will choose to pass. *This can also maximize the overall efficiency of intersections.*

Imprecise perception: CAVs make decisions with uncertainty. Leading vehicle takes a conservative strategy to avoid conflict actively with a probability. *It harms overall utility.*

Cooperation: Two independent and shared observations reduce the variance but keep it unbiased. *Total utility is closer to the ideal situation.*



Deception: Deviated shared location information prompts leading CAV to yield. *The overall utility is even worse than that without connectivity.*



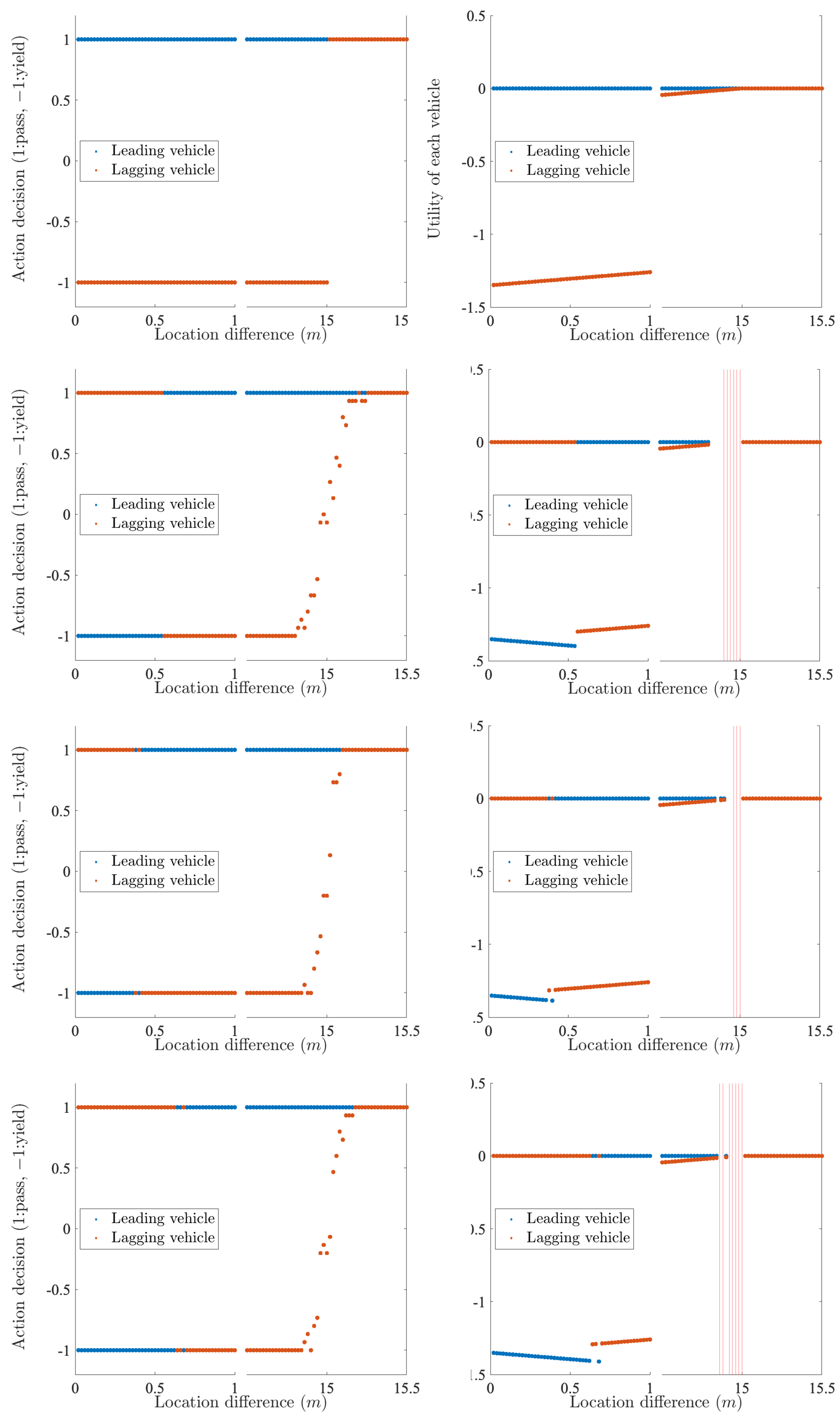
Experiments

We conducted numerical simulation experiments to show the intuitive and quantitative impact of imprecise perception, cooperation, and deception on decision-making games at a conflicting intersection.

A conflict exists in this intersection when there is an $L+l$ difference in distance between two vehicles. We repeated 30 random trials for uncertain scenarios, and the average results are shown.

(⇣)From top to bottom: Ideal Situation, Imprecise Perception, Cooperation, and Deception.

(⇢)From left to right: Decision Made, and Utilities.

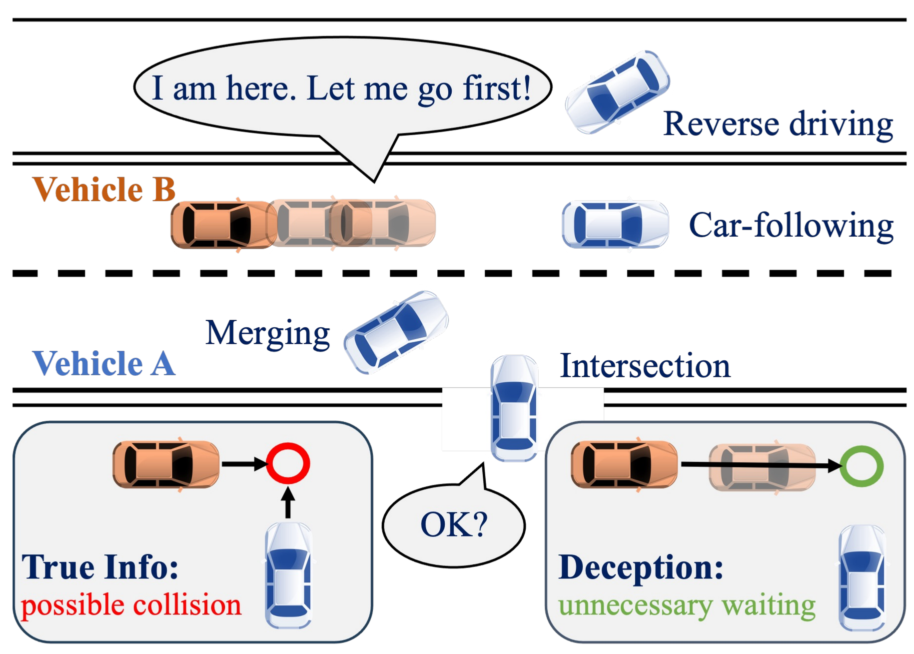


Conclusion

In summary, this paper has **introduced deception into a game theoretical framework** with imprecise perception for analyzing CAV interactions. Since CAVs will always deceive for advantage, each CAV's belief in the other's information will decrease to zero. This is in line with the *cheap talk game*. This paradox highlights the inherent conflict between single-vehicle and the broader system-wide benefits, weakening vehicle-to-vehicle connectivity developments.

- We plan to explore the signaling strategies and reception beliefs through **signaling games** in the future;
- Expanding the scope to **diverse scenarios** will also provide a more comprehensive understanding;
- **Machine learning methods** for accurately **identifying** irrational and cooperative vehicles are expected to be leveraged, even without intentional deception but with similar behaviors like communication delays.

We advocate considering incomplete information in CAV studies, employing verification mechanisms, recognition methods, and robust control to mitigate the adverse effects on intelligent transportation systems.



*This work is supported by the U.S. National Science Foundation under Grant No.2313578.

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