Modeling two-vehicle interaction at freeway - on ramp merging section with game theory

ゲーム理論を用いた高速道路合流部での二車相互作用のモデリング

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1. Introduction

- Accurate modelling of merging interactions is important for designing freeway on-ramps and developing traffic management policies.
- Previous studies of merging behaviour either did not consider the impact of the merging and through drivers on each other or did not capture the mechanism of drivers' decision making.
- This study introduces a model of merging behaviour that aims at realistically reproducing the mechanism of drivers' decision making.

2. Model formulation

- **Game:** non-cooperative, complete information.
- **Set of actions** of Driver i:

$$\mathcal{A}_1 = \{merge, wait\}, a_1 \in \mathcal{A}_1;$$
$$\mathcal{A}_2 = \{yield, block\}, a_2 \in \mathcal{A}_2.$$

- **Vector of actions:** $\boldsymbol{a} = (a_1\ a_2)$;
- **Decision time:** the earliest moment when Vehicle 1 is located on the ramp and Vehicle 2 enters the interaction interval.

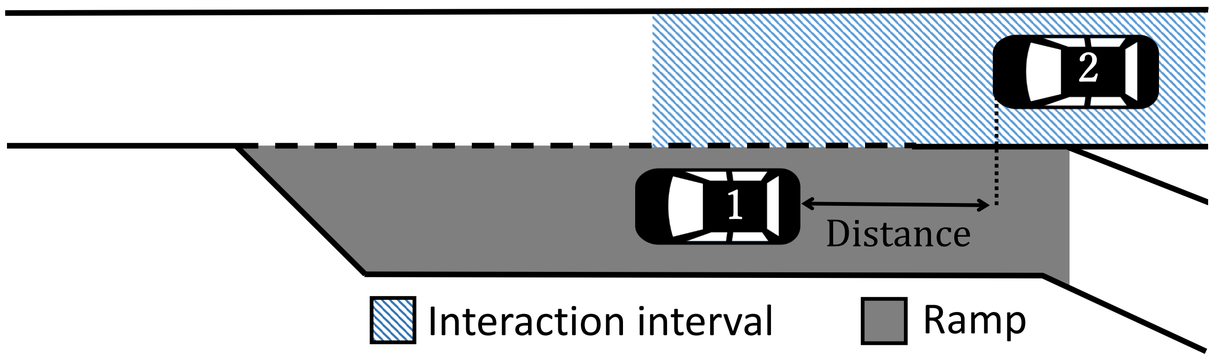


Fig. 1 Freeway on-ramp merging section

			Driver 2	
			Yield	Block
		Probability	$\pi_2(y)$	$\pi_2(b)$
Driver 1	Merge	$\pi_1(m)$	$(u^1_{(my)}, u^2_{(my)})$	$(u^1_{(mb)}, u^2_{(mb)})$
	Wait	$\pi_1(w)$	$(u^1_{(wy)}, u^2_{(wy)})$	$(u^1_{(wb)}, u^2_{(wb)})$

Table 1 The table of utilities for each driver

3. Parameter Estimation

- The utility function for Driver i is formulated as:

$$u_a^i = \beta_a^{i0} + \beta_a^{i1}\Delta x + \beta_a^{i2}\Delta v + \epsilon_a^i$$

(*Distance*, *Speed difference*, *Parameters*, *Error term*)

- The parameters are estimated with the method proposed by Bajari et al. that has theoretical guarantee.
- We suppose that drivers would perform the actions that form Nash equilibrium and we implement the equilibrium selection mechanism.

4. Empirical analysis

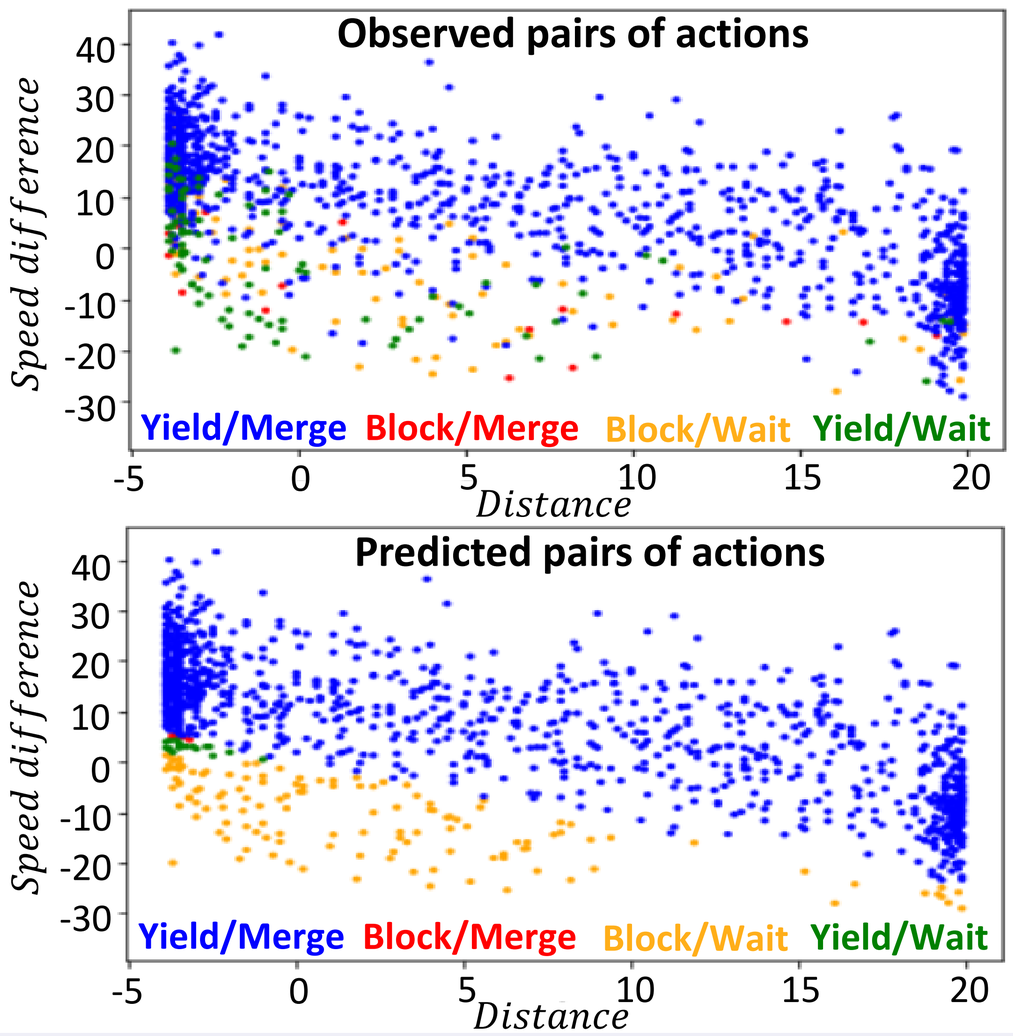
- "Zen Traffic Data" (zen-traffic-data.net) obtained on Hanshin Expressway is used for empirical analysis;
- 200 meters long merging section was selected;
- 1239 cases of merging interaction were found;

Fig. 2 The merging section

		β^0	β^1	β^2
Driver 1	Yield/Merge	0.162	1.527	1.118
	Block/Merge	0.013	-0.169	-0.170
	Block/Wait	-0.128	-1.211	-0.952
Driver 2	Yield/Merge	0.404	1.578	0.964
	Block/Merge	0.149	-0.115	0.125
	Block/Wait	0.036	-0.596	-1.110

Table 2 The estimated parameters

- Actions performed in each case were labelled;
- Parameters of our model were estimated;
- Total accuracy: $MAE = 0.175$;
- Yield/Merge accuracy: $MAE = 0.025$.



5. Conclusion

Our model demonstrates acceptable prediction ability of the merging situations but does not clearly distinguish between the non-merging cases. Prediction of these cases can be improved in the future through extension of the model to dynamic version and adoption of a gap selection mechanism.