Supplementary Materials : Cooperative Driving Between Human-driven Vehicle and Autonomous Vehicle Considering Stochastic Human Behavior States

Sanzida Hossain[1], Jiaxing Lu[2], He Bai[1] and Weihua Sheng[2]

***Abstract*— This document presents additional information for the formulation of cooperative driving between autonomous vehicles (AVs) and human-driven vehicles (IHVs) considering Considering Stochastic Human Behavior States such as human attention and tendency to follow. The detailed work is presented in [1].**

A. State constraints

The new state variables $\bar{z}_k^1, \bar{z}_k^2, \bar{z}_k^3$ and $\bar{z}_k^4$ formulate the following constraints.

$$\bar{z}_k^1 \leq M_u s_k^1,\ \bar{z}_k^1 \geq m_u s_k^1, \tag{1}$$

$$\bar{z}_k^1 \leq u_k^d - m_u(1-s_k^1),\ z_k^1 \geq u_k^d - M_u(1-s_k^1), \tag{2}$$

$$\bar{z}_k^2 \leq M_u s_k^3,\ \bar{z}_k^2 \geq m_u s_k^3, \tag{3}$$

$$\bar{z}_k^2 \leq s_k^a - m_u(1-s_k^3),\ \bar{z}_k^2 \geq s_k^a - M_u(1-s_k^3), \tag{4}$$

$$\bar{z}_k^3 \leq M_u s_k^2,\ \bar{z}_k^3 \geq m_u s_k^2, \tag{5}$$

$$\bar{z}_k^3 \leq u_k^h - m_u(1-s_k^2),\ \bar{z}_k^3 \geq u_k^h - M_u(1-s_k^2) \tag{6}$$

$$\bar{z}_k^4 \leq M_u s_k^3,\ \bar{z}_k^4 \geq m_u s_k^3, \tag{7}$$

$$\bar{z}_k^4 \leq u_k^a - m_u(1-s_k^3),\ \bar{z}_k^4 \geq u_k^a - M_u(1-s_k^3). \tag{8}$$

The upper and lower bounds of the input acceleration are M_u and m_u respectively.

The state limits of the IHV are enforced by:

$$x_k^h \leq M,\ \ x_k^h \geq m, \tag{9}$$

for upper limit and lower limit M and m respectively.

B. Human state transition probabilities

TABLE I

HUMAN STATE TRANSITION PROBABILITIES

		$P(s_{k+1}^1=1)$	$P(s_{k+1}^2=1)$	$P(s_{k+1}^3=1)$
$u_k^B=1$	$s_k^1=1$	$P(t_k^1)=0.45$	$P(t_k^2)=0.05$	$P(t_k^3)=0.5$
	$s_k^2=1$	$P(t_k^4)=0.2$	$P(t_k^5)=0.1$	$P(t_k^6)=0.7$
	$s_k^3=1$	$P(t_k^7)=0.1$	$P(t_k^8)=0.1$	$P(t_k^9)=0.8$
$u_k^B=0$	$s_k^1=1$	$P(\bar{t}_k^1)=0.5$	$P(\bar{t}_k^2)=0.5$	$P(\bar{t}_k^3)=0$
	$s_k^2=1$	$P(\bar{t}_k^4)=0.5$	$P(\bar{t}_k^5)=0.5$	$P(\bar{t}_k^6)=0$
	$s_k^3=1$	$P(\bar{t}_k^7)=0.5$	$P(\bar{t}_k^8)=0.5$	$P(\bar{t}_k^9)=0$

[1]Sanzida Hossain and He Bai are with Mechanical and Aerospace Engineering, Oklahoma State University, Stillwater, OK 74078, USA. {sanzida.hossain, he.bai}@okstate.edu

[2]Jiaxing Lu and Weihua Sheng are with Electrical and Computer Engineering, Oklahoma State University, Stillwater, OK 74078, USA. {jiaxing.lu,weihua.sheng}@okstate.edu

This work is supported by the National Science Foundation (NSF) Grants CISE/IIS 1910933 and CPS 2212582.

C. The architecture of the ResNet-50 model for distraction detection

TABLE II

RESNET-50 MODEL ARCHITECTURE

layer name	output size	50-layer
conv1	112×112	$7\times7, 64$
conv2_x	56×56	3×3, *max pool* $\begin{bmatrix}1\times1,64\\3\times3,64\\1\times1,256\end{bmatrix}\times3$
conv3_x	28×28	$\begin{bmatrix}1\times1,128\\3\times3,128\\1\times1,512\end{bmatrix}\times4$
conv4_x	14×14	$\begin{bmatrix}1\times1,256\\3\times3,256\\1\times1,1024\end{bmatrix}\times6$
conv5_x	7×7	$\begin{bmatrix}1\times1,512\\3\times3,512\\1\times1,2048\end{bmatrix}\times3$
	1×1	average pool,8-d fc,softmax

REFERENCES

[1] S. Hossain, J. Lu, H. Bai, and W. Sheng, "Cooperative driving between human-driven vehicle and autonomous vehicle considering stochastic human behavior states," 2023, accepted for publication at 2023 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Detroit, Michigan, USA.