Berkeley
Artificial Intelligence Research

How Robots Influence Our Actions

Anca Dragan

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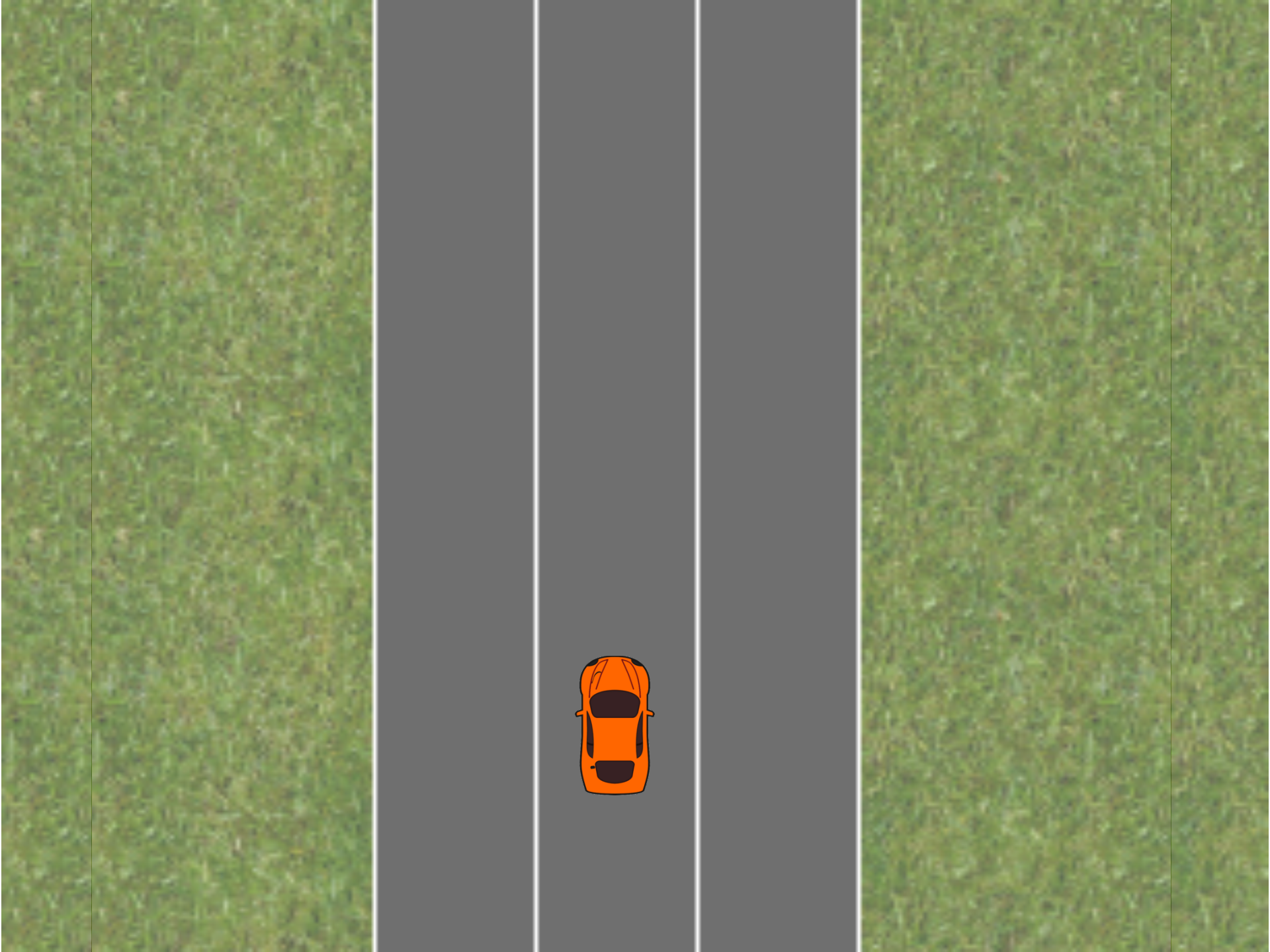
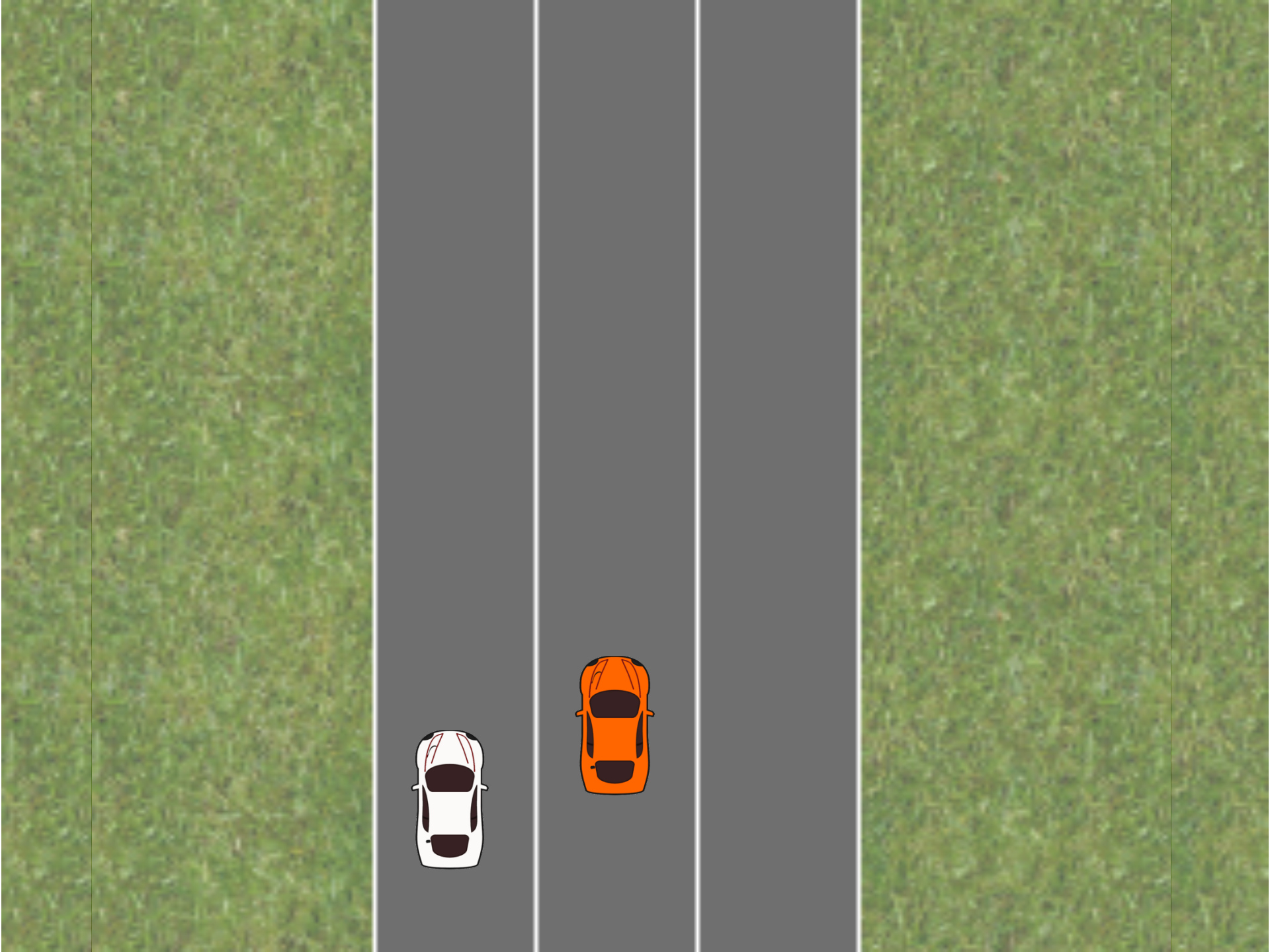
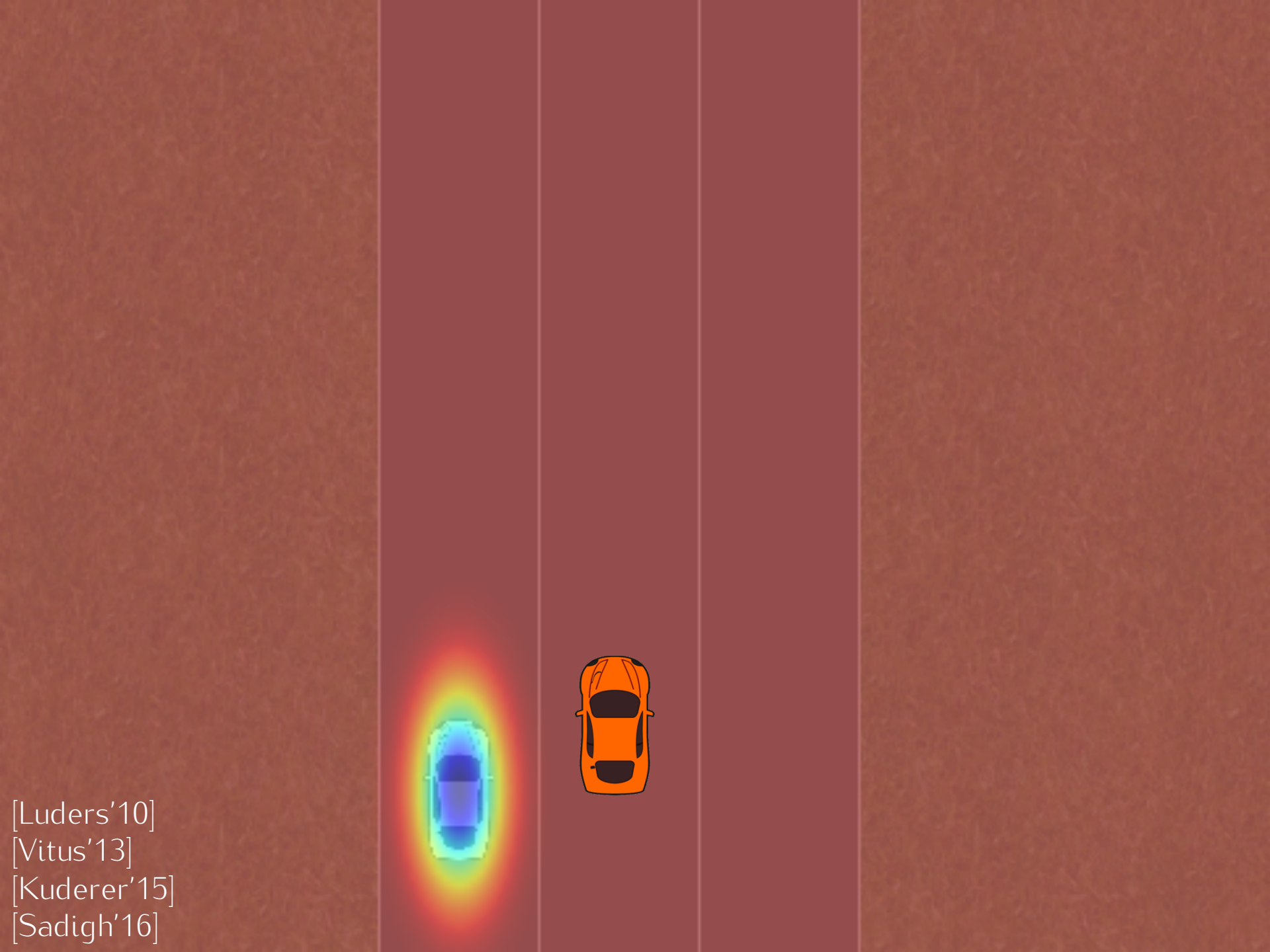
2015/02/06 23:10:06

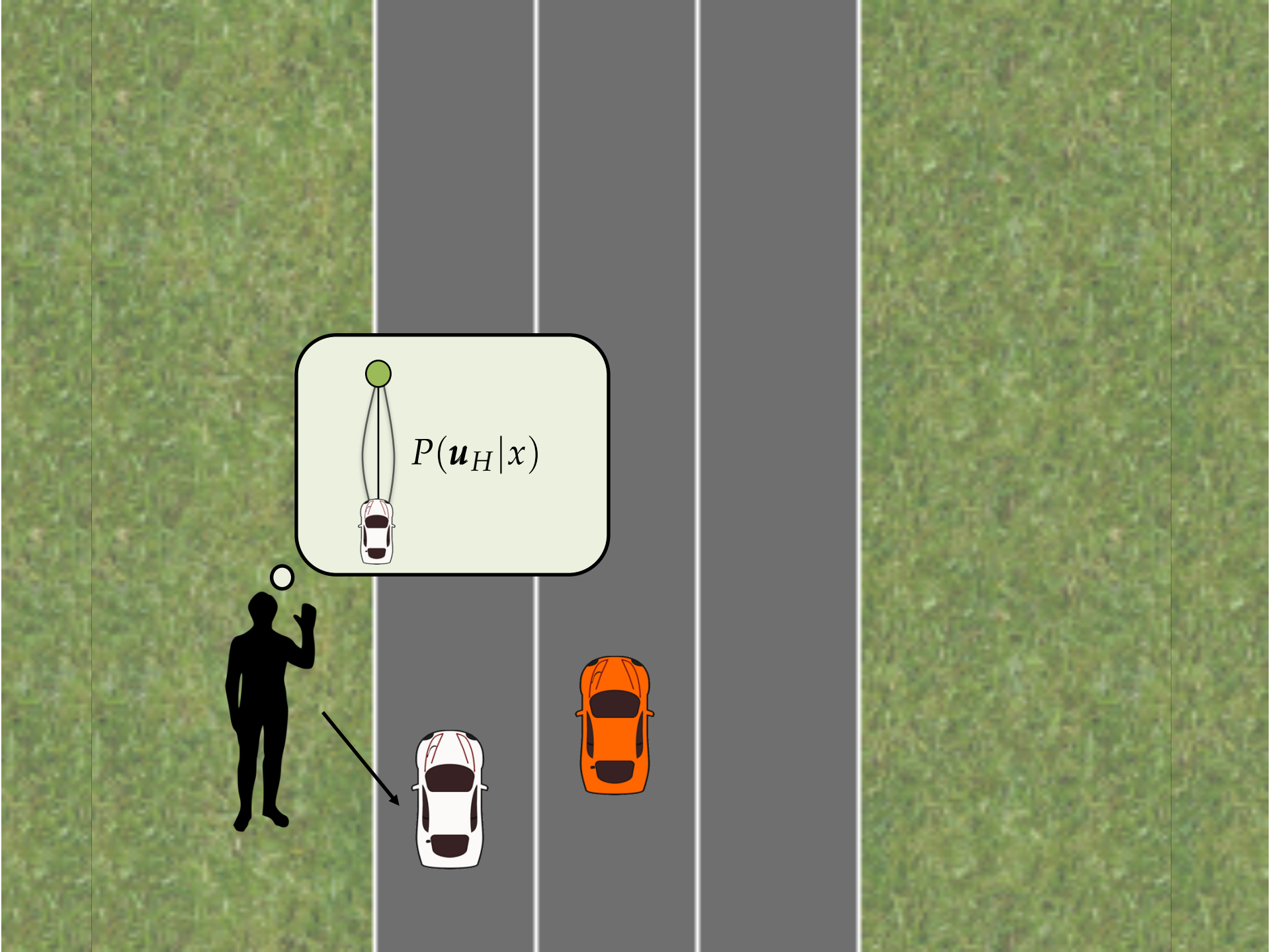
Robots expect humans
to act like this truck driver.

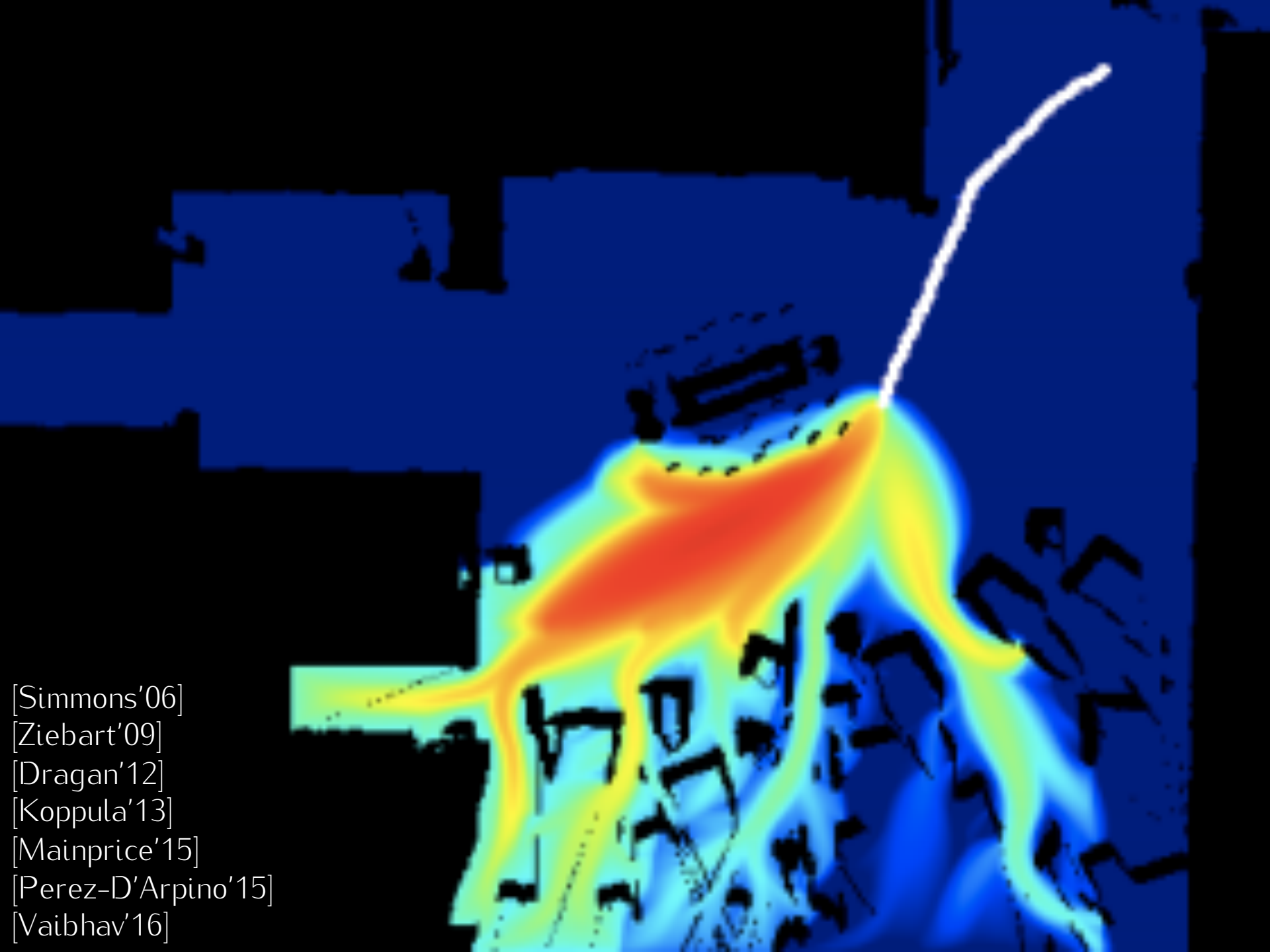






[Luders'10]
[Vitus'13]
[Kuderer'15]
[Sadigh'16]


$P(\boldsymbol{u}_H|x)$



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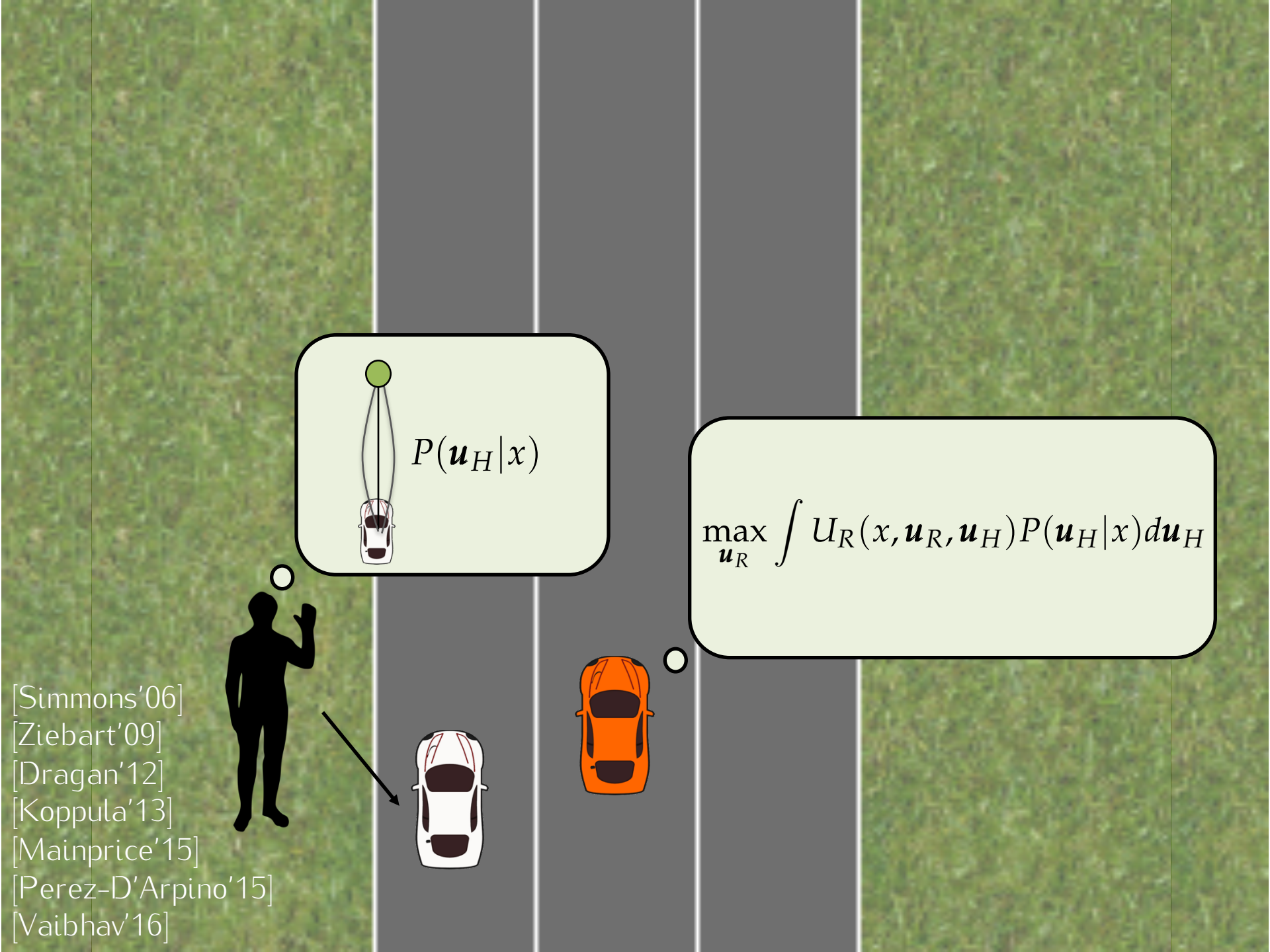
[Dragan'12]
[Koppula'13]
[Mainprice'15]
[Perez-D'Arpino'15]
[Vaibhav'16]

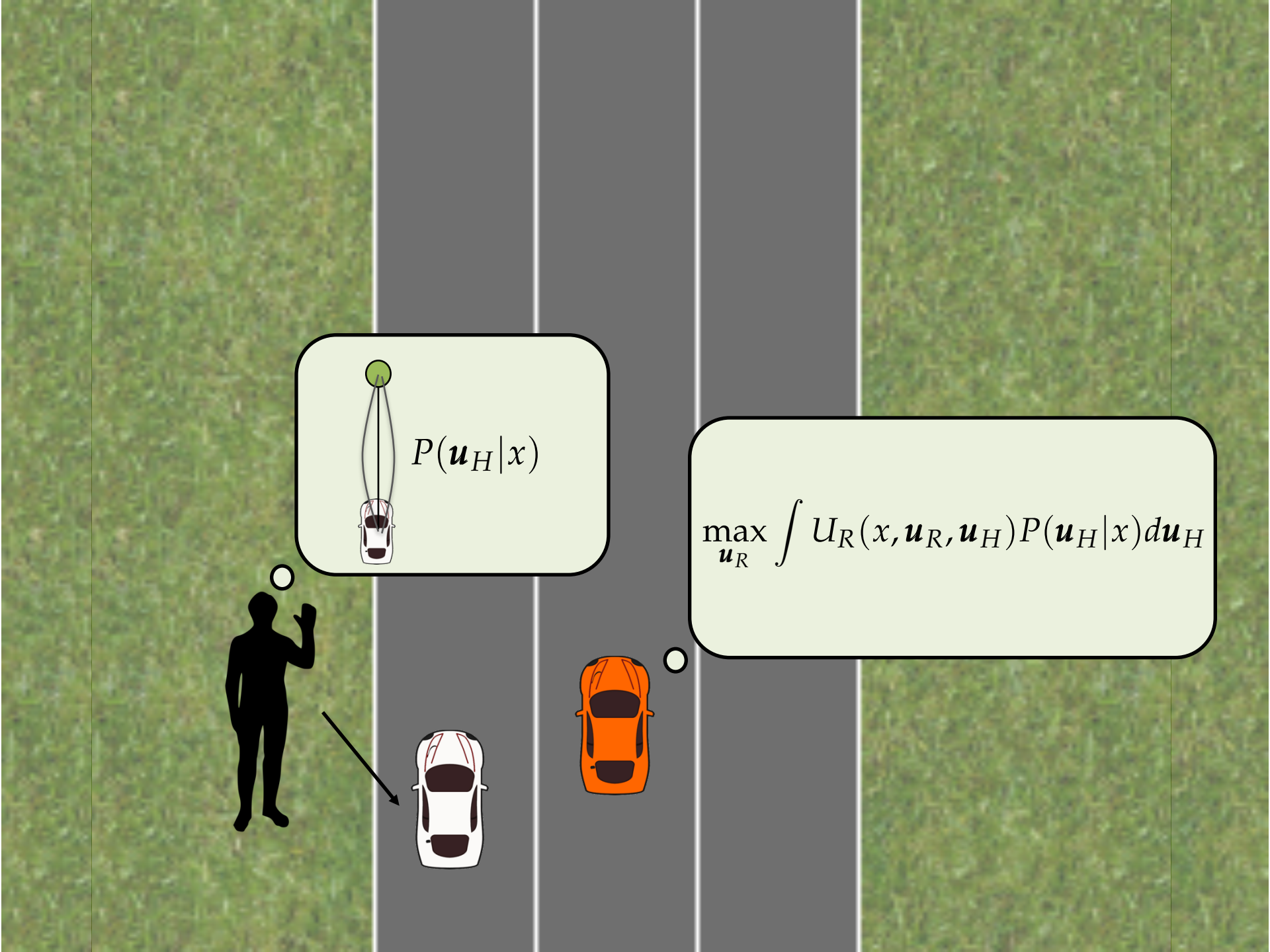

$P(u_H|x)$
$\max_{u_R} \int U_R(x, u_R, u_H) P(u_H|x) du_H$
[Simmons'06]
[Ziebart'09]
[Dragan'12]
[Koppula'13]
[Mainprice'15]
[Perez-D'Arpino'15]
[Vaibhav'16]

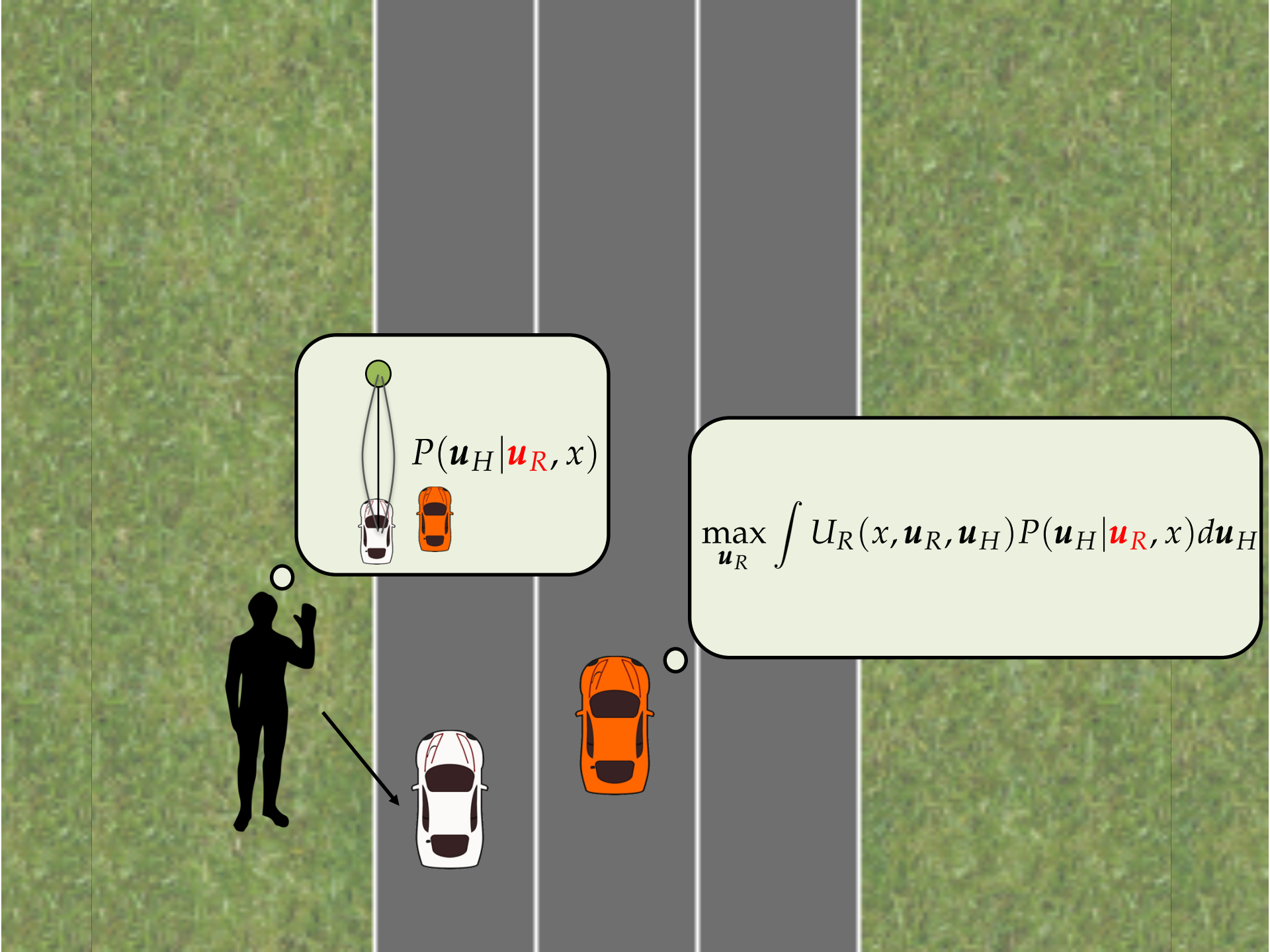
civic

STOP
4-WAY

(Nominally,) The robot's actions affect those of the human's.

Accounting for this effect improves efficiency and interaction fluency.

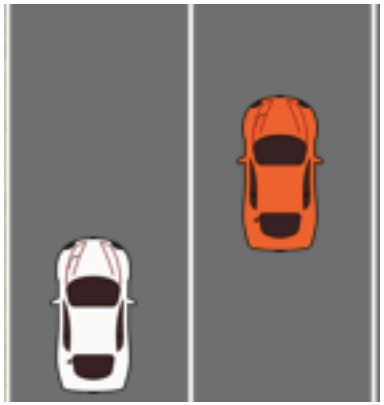

$P(\boldsymbol{u}_H|x)$
$\max_{\boldsymbol{u}_R} \int U_R(x, \boldsymbol{u}_R, \boldsymbol{u}_H) P(\boldsymbol{u}_H|x) d\boldsymbol{u}_H$


$P(\boldsymbol{u}_H|\boldsymbol{u}_R, x)$
$\max_{\boldsymbol{u}_R} \int U_R(x, \boldsymbol{u}_R, \boldsymbol{u}_H) P(\boldsymbol{u}_H|\boldsymbol{u}_R, x) d\boldsymbol{u}_H$

Interaction as a Underactuated System

$$\max_{\boldsymbol{u}_R} \int U_R(x, \boldsymbol{u}_R, \boldsymbol{u}_H) P(\boldsymbol{u}_H | \boldsymbol{u}_R, x) d\boldsymbol{u}_H$$

direct control over $\boldsymbol{u}_R$



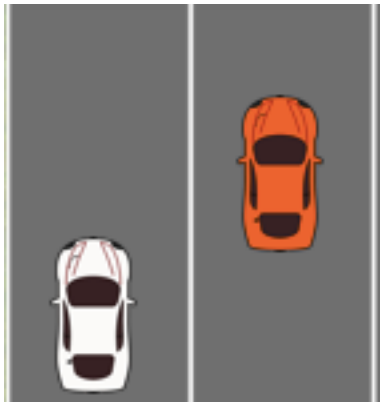
indirect control over $\boldsymbol{u}_H$

$P(\boldsymbol{u}_H | \boldsymbol{u}_R, x)$

$U_H(x, \boldsymbol{u}_R, \boldsymbol{u}_H)$

Interaction as a Underactuated System

$U_R(x, \boldsymbol{u}_R, \boldsymbol{u}_H)$

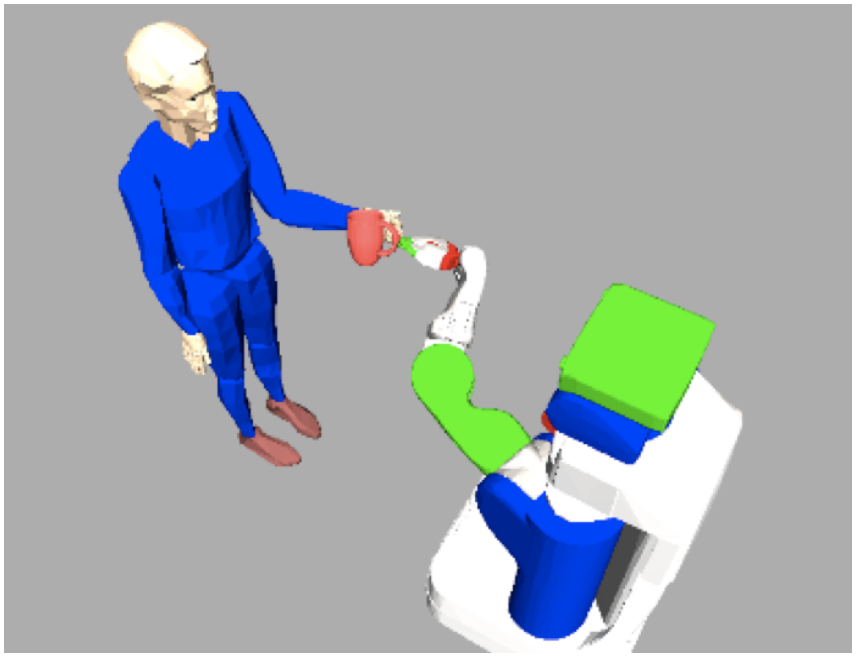


$U_H(x, \boldsymbol{u}_R, \boldsymbol{u}_H)$

Independent vs. Collaborative

$$U_R \neq U_H$$

Planning for Autonomous Cars that Leverage Effects on Human Actions, RSS'16

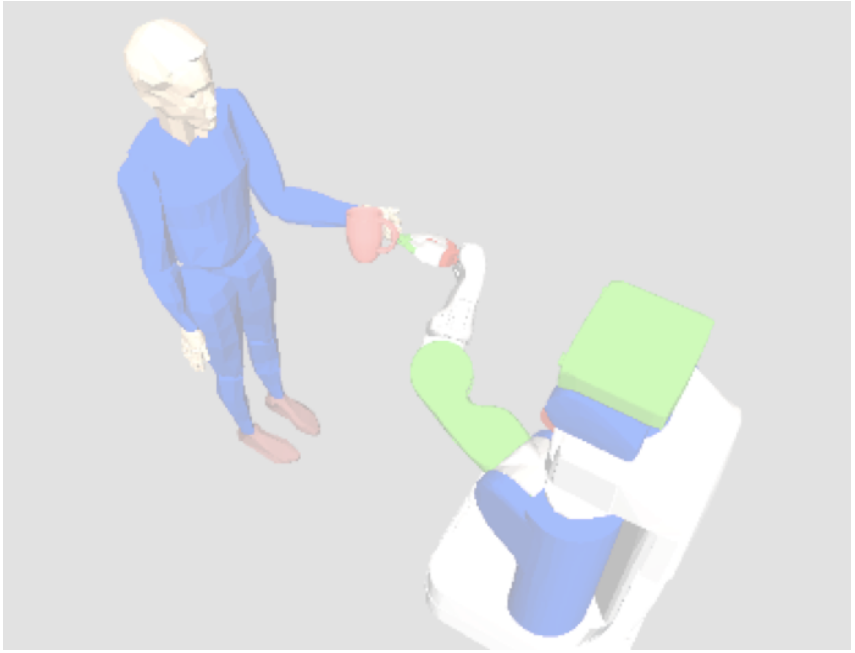


$$U_R = U_H$$

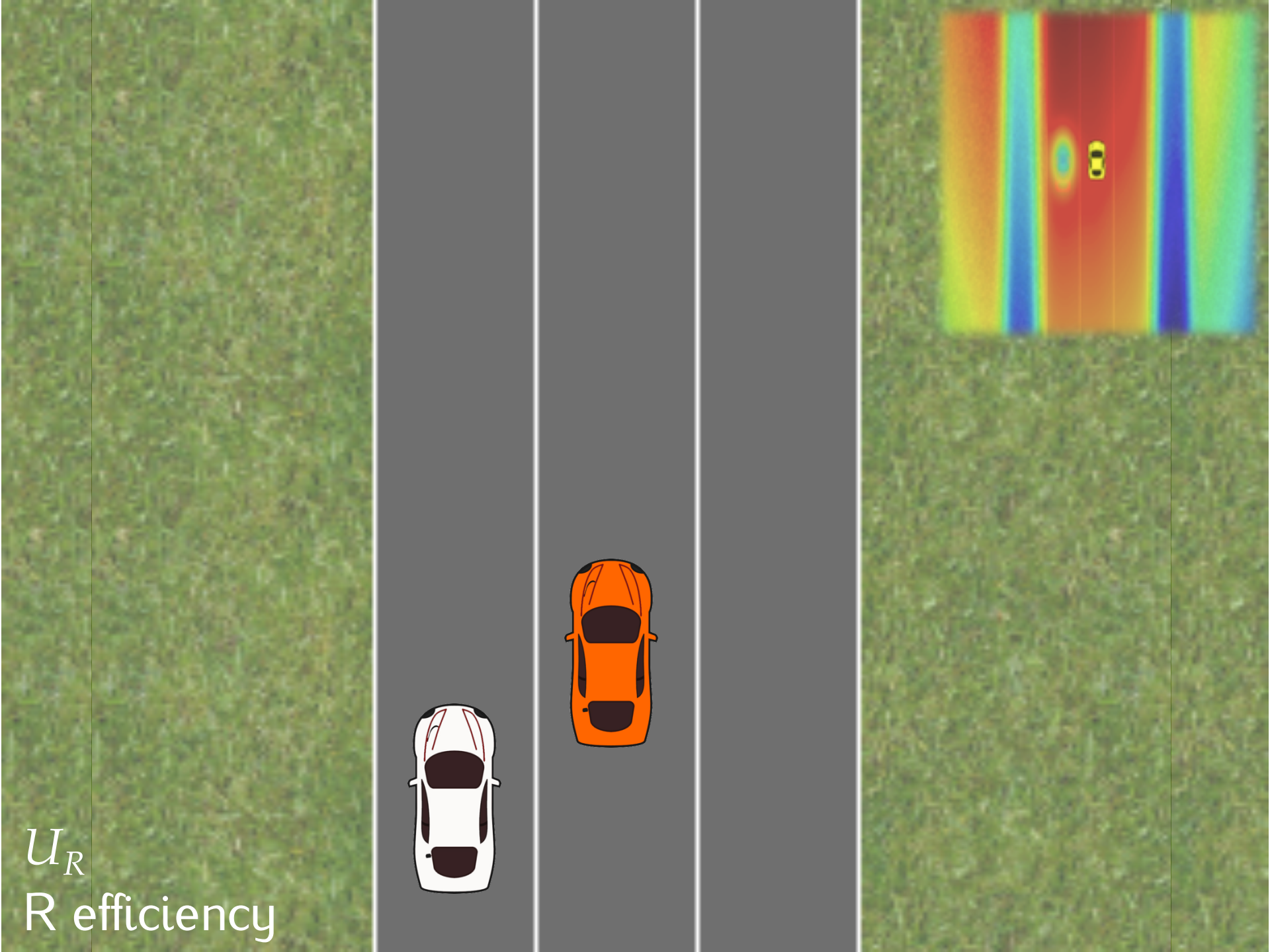
Implicitly Assisting Humans to Choose Good Grasps in Robot to Human Handovers, ISER'16

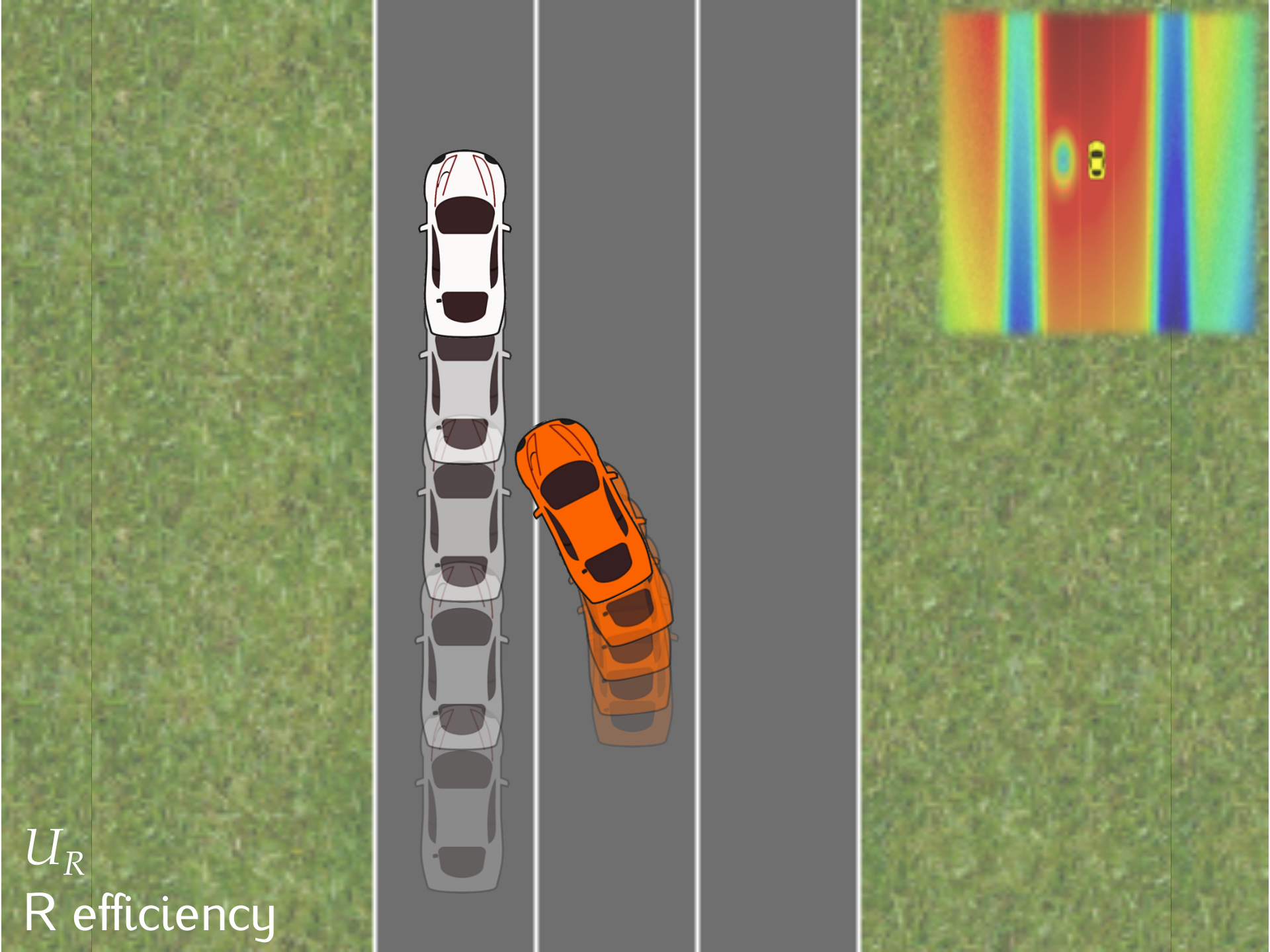
Independent vs. Collaborative

$$u_R \neq u_H$$



$$u_R = u_H$$


u_R
R efficiency

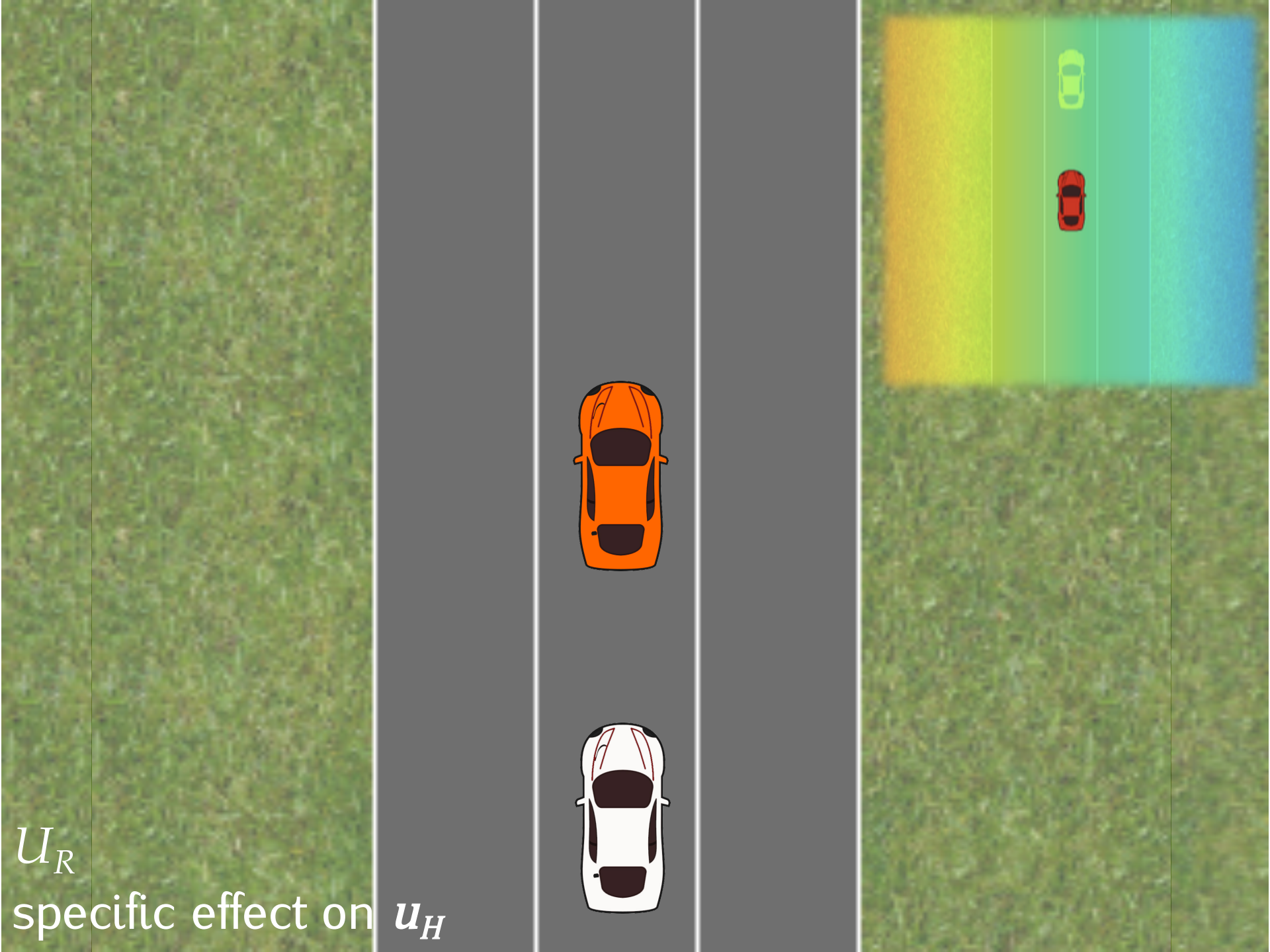

u_R
R efficiency

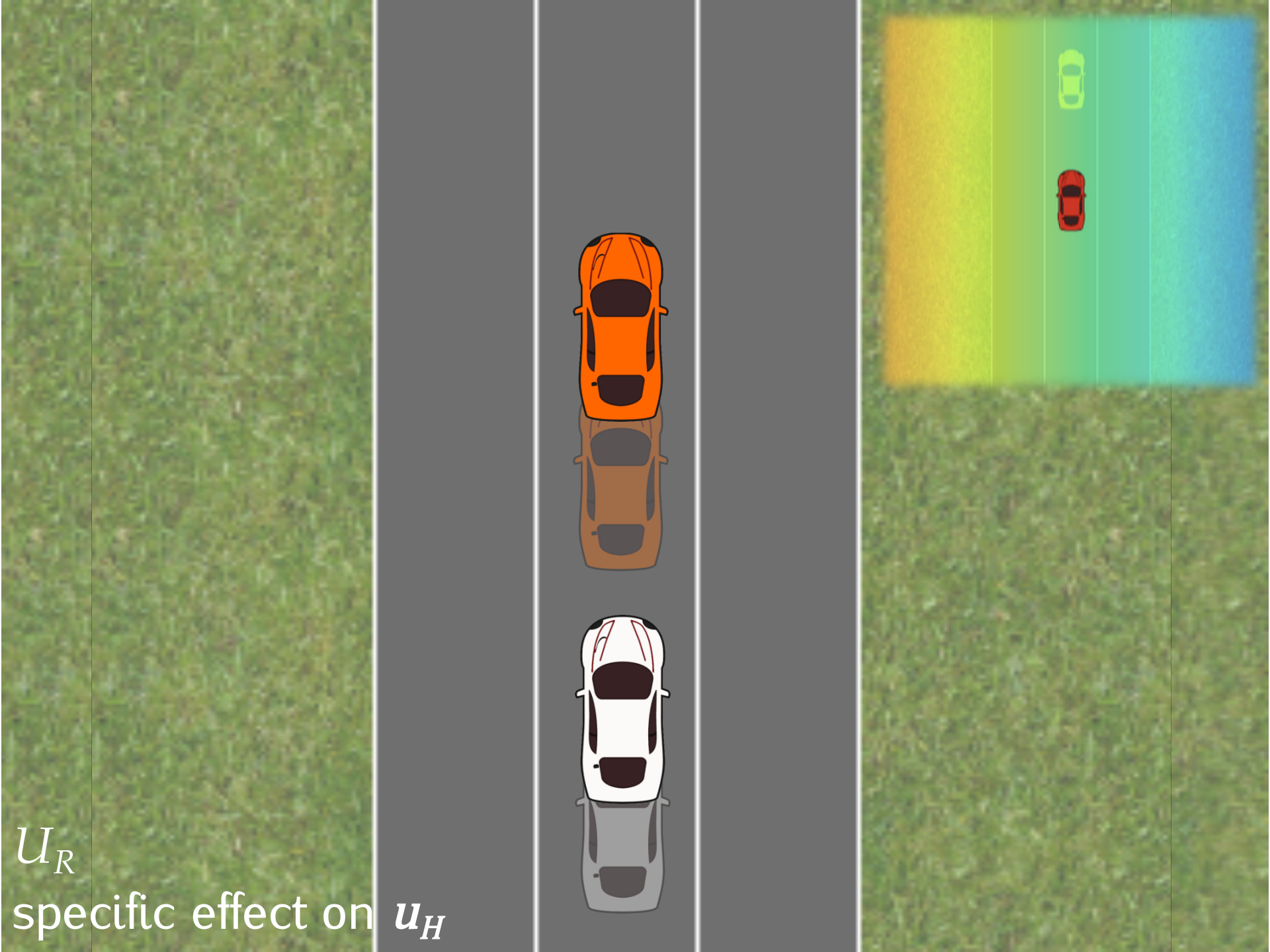
u_R
R efficiency

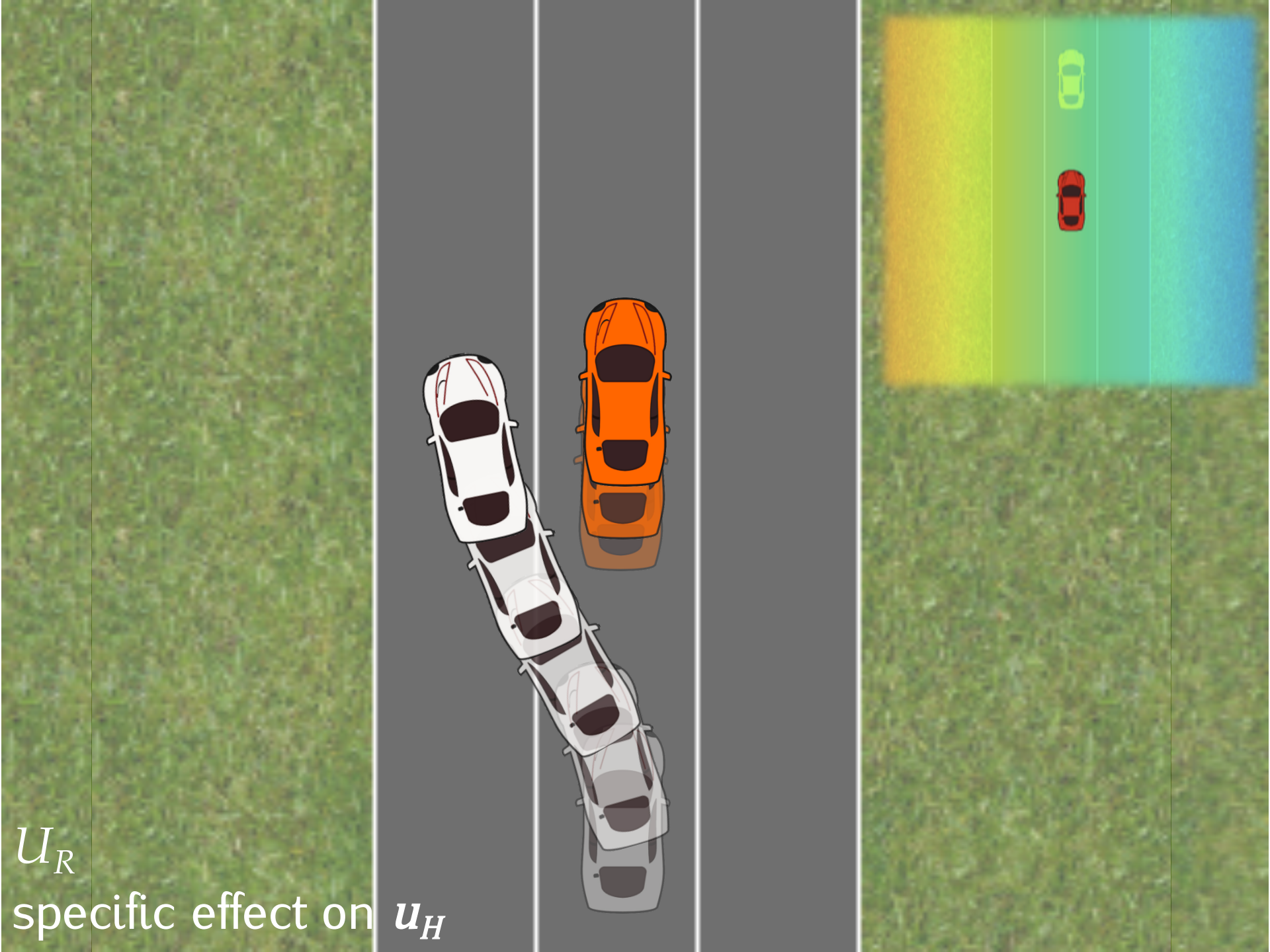
The robot can be more efficient.

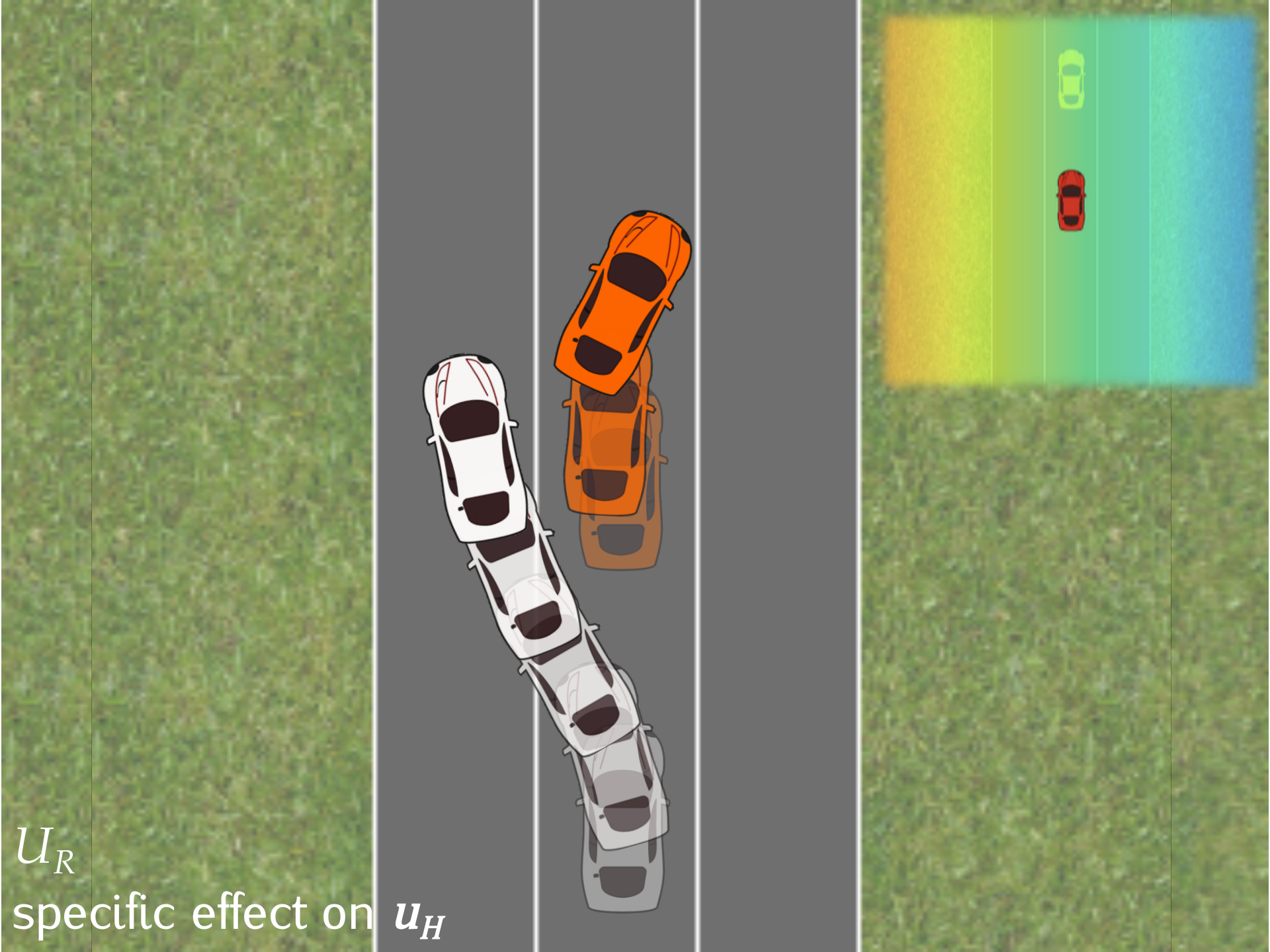
The robot can be safer.

u_R
specific effect on u_H


U_R
specific effect on u_H


U_R
specific effect on u_H

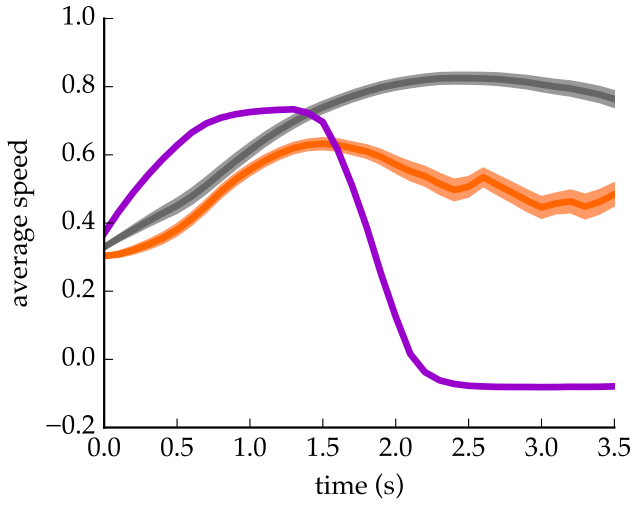

u_R
specific effect on u_H

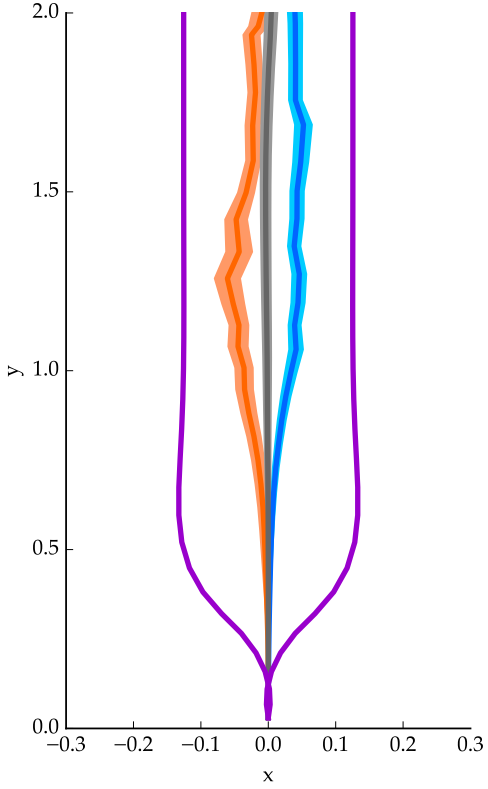

u_R
specific effect on u_H

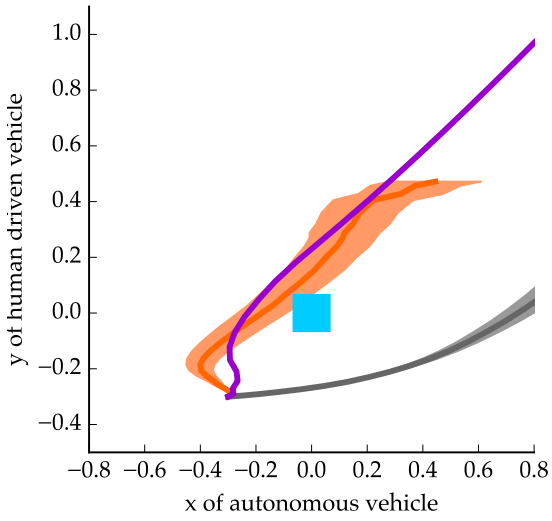
u_R
specific effect on u_H

u_R
specific effect on u_H

Working interaction strategies emerge out of the optimization.



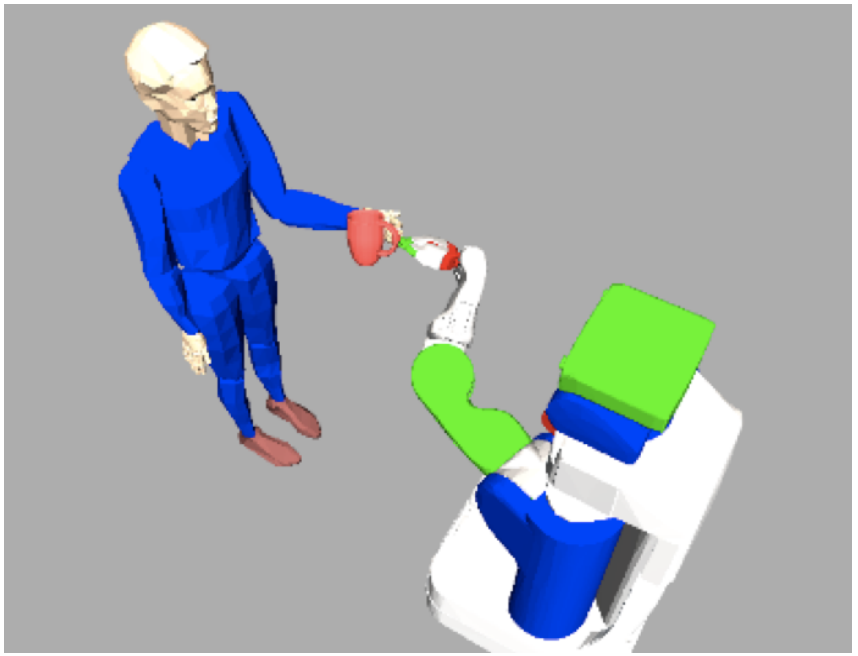




Learned Human Model Avoid Human Affect Human

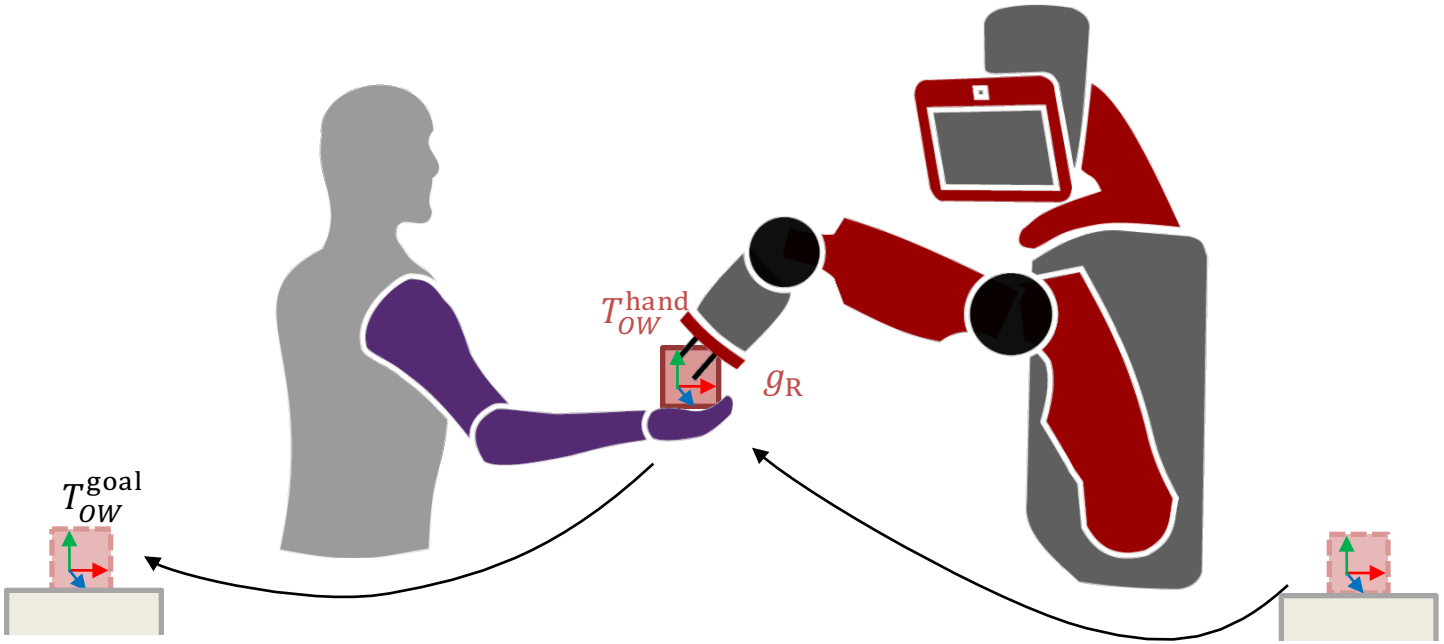
Independent vs. Collaborative

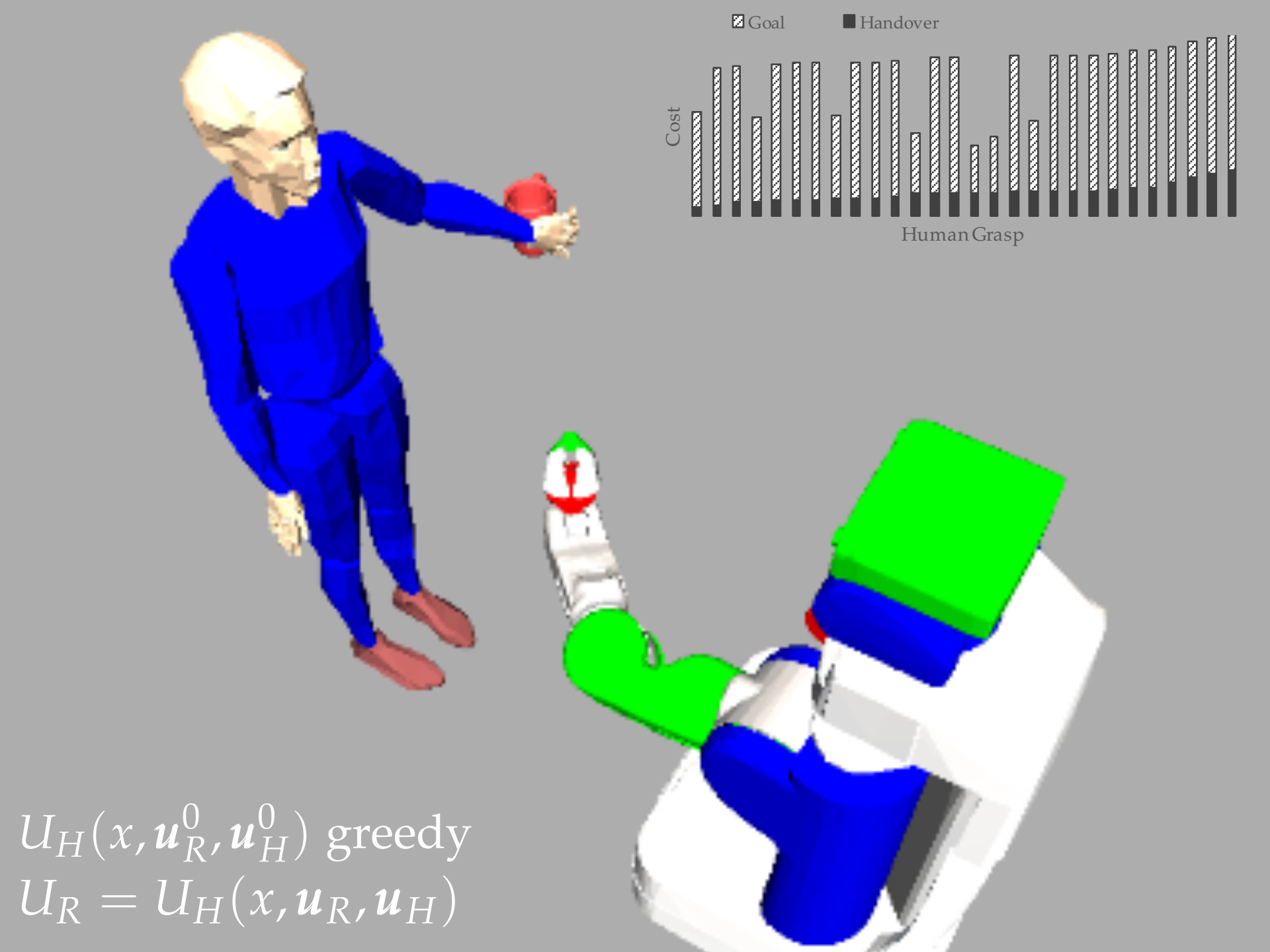
$u_R \neq u_H$

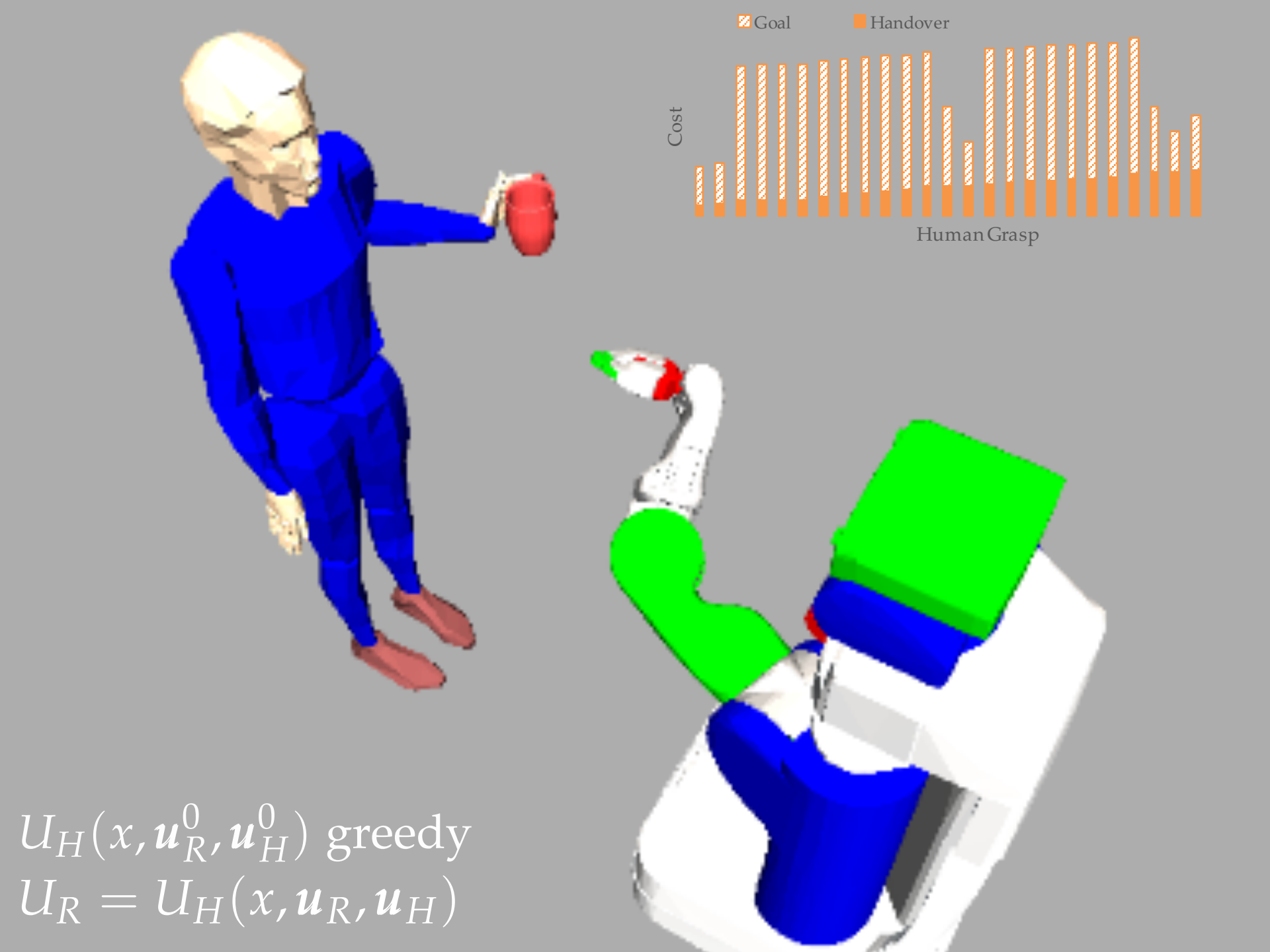


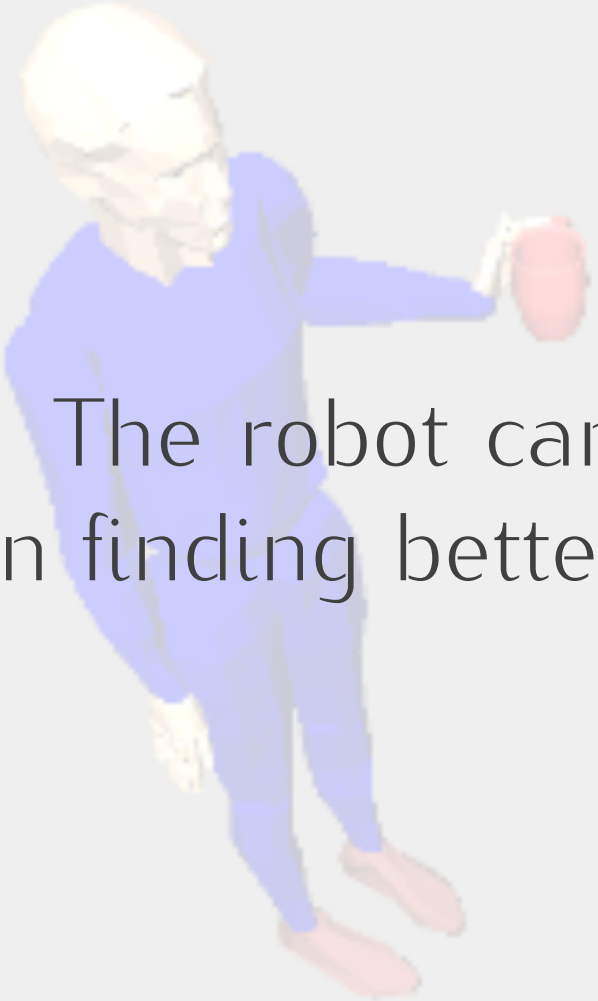
$u_R = u_H$

[Trautman'10]
[Kuderer'12]
[Nikolaidis'15]


T_{OW}^{hand}
g_{R}
T_{OW}^{goal}


Goal
Handover
Cost
Human Grasp
$U_H(x, \boldsymbol{u}_R^0, \boldsymbol{u}_H^0)$ greedy
$U_R = U_H(x, \boldsymbol{u}_R, \boldsymbol{u}_H)$

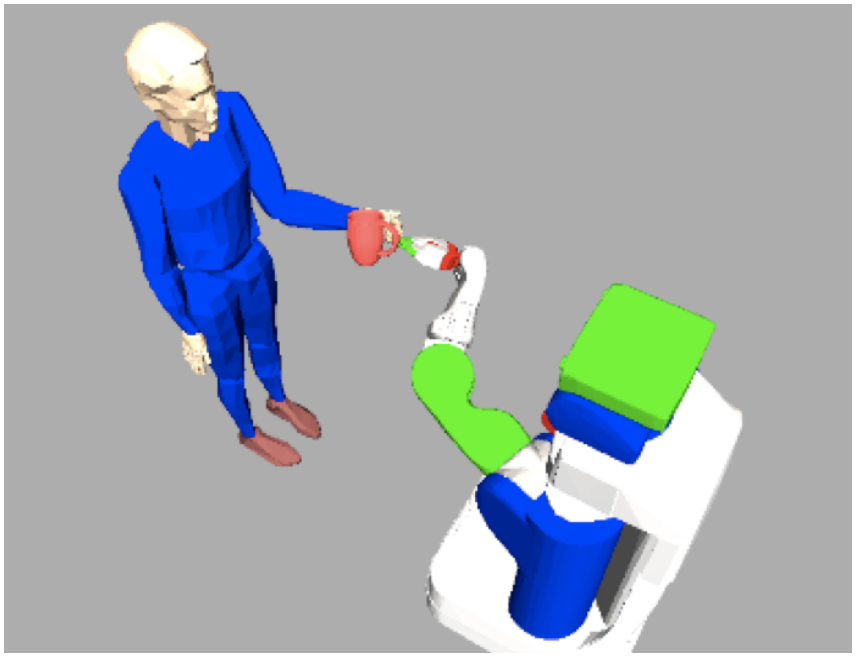

Goal
Handover
Cost
Human Grasp
$U_H(x, \boldsymbol{u}_R^0, \boldsymbol{u}_H^0)$ greedy
$U_R = U_H(x, \boldsymbol{u}_R, \boldsymbol{u}_H)$



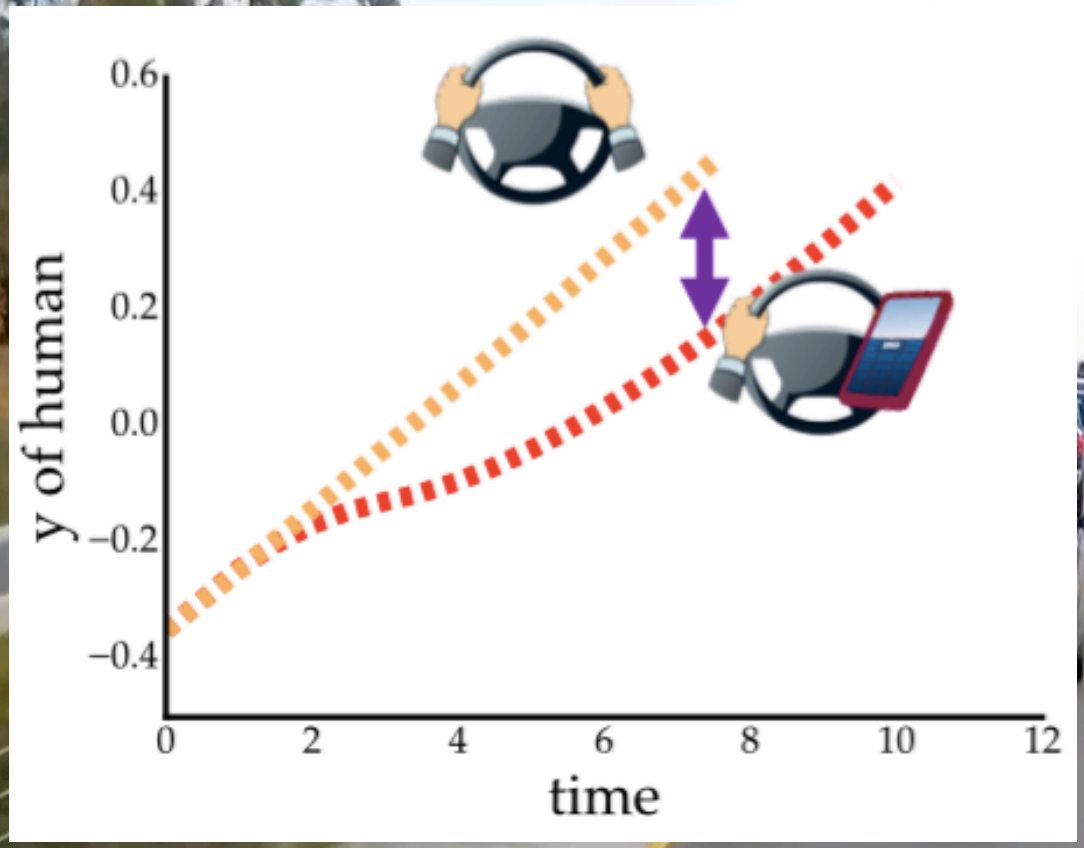
The robot can assist the human in finding better planning solutions.

Independent vs. Collaborative

$u_R \neq u_H$



$u_R = u_H$


0.6
0.4
0.2
0.0
−0.2
−0.4
y of human
0
2
4
6
8
10
12
time

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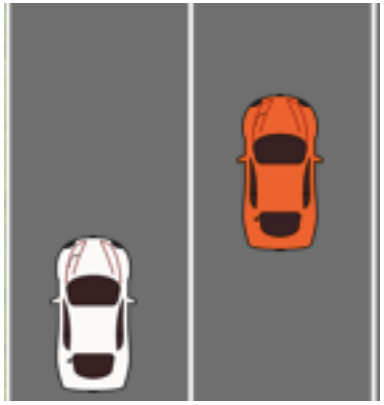
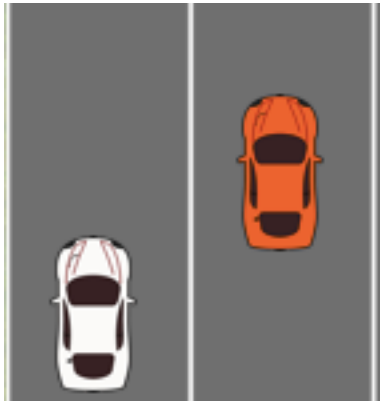
direct control over $\boldsymbol{u}_R$



indirect control over $\boldsymbol{u}_H$

Robot actions affect human actions.

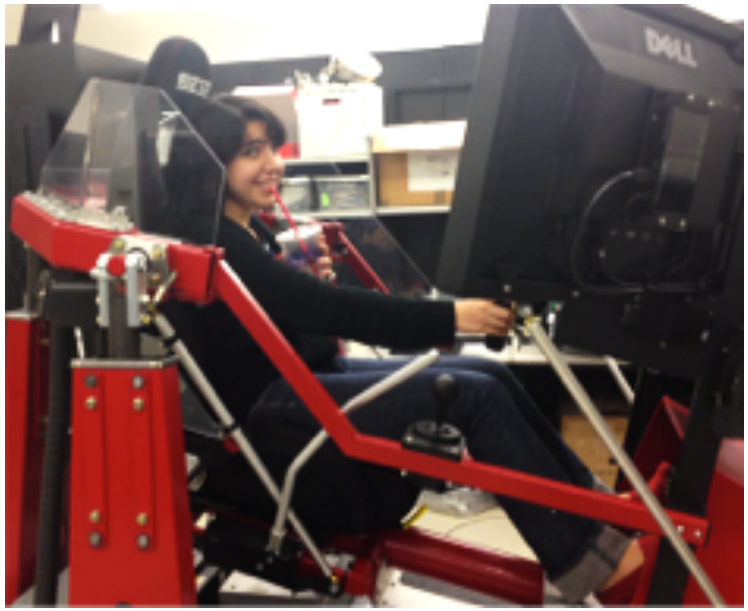
direct control over $\boldsymbol{u}_R$



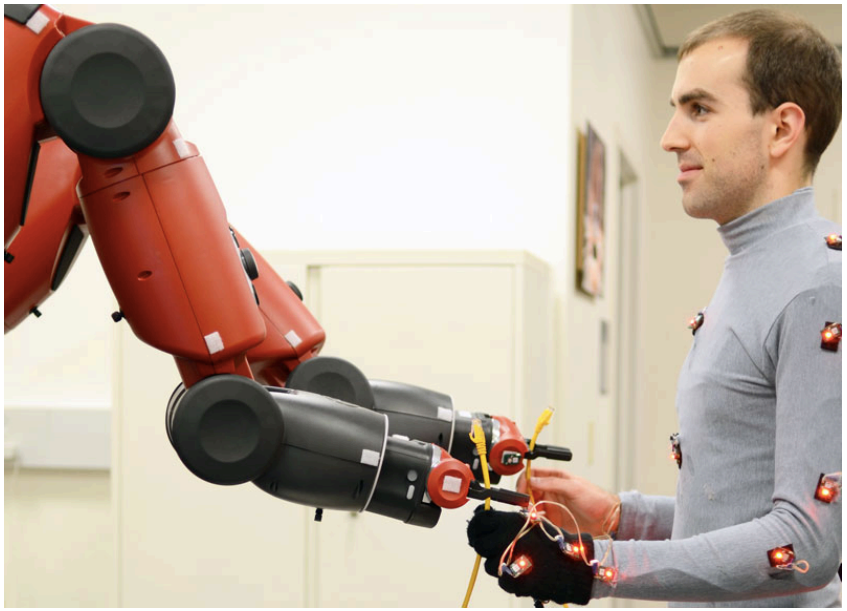
indirect control over $\boldsymbol{u}_H$

Robot actions affect human trust?

Thanks!



Dorsa Sadigh



Aaron Bestick