Certified Perception for Autonomous Cars

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first pedestrian fatality (uber, tempe AZ, march 2018)

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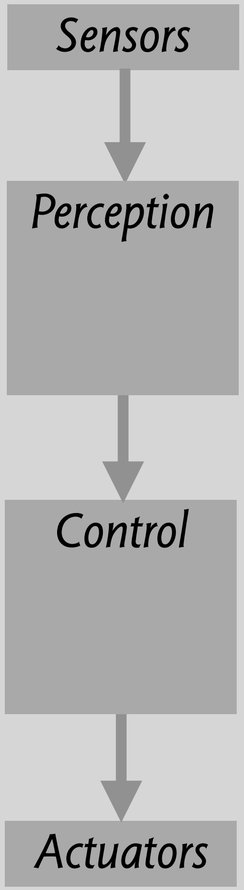
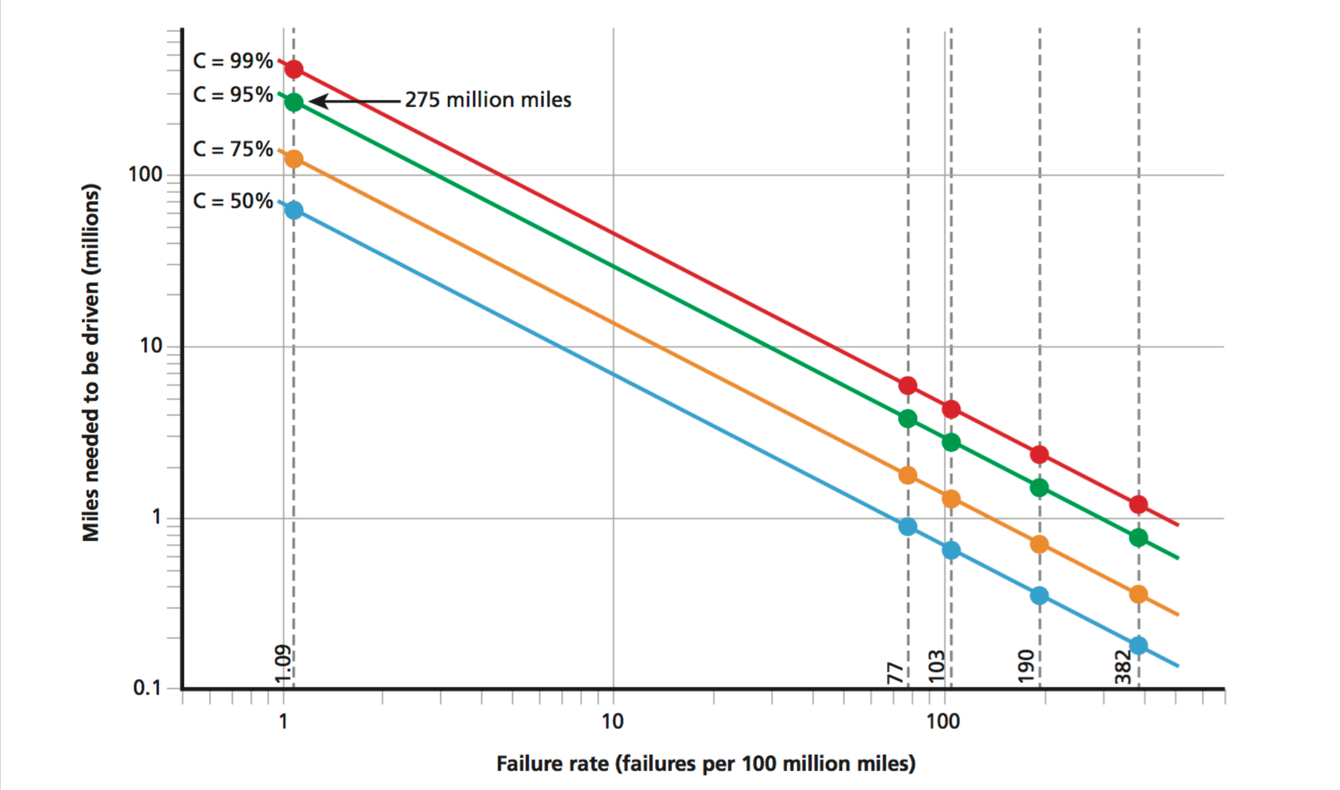
perception errors propagate through an autonomous driving system (ADS)



what about testing?



for 95% confidence in 1 death/100M miles,
need to drive 275M miles [RAND]

Waymo: 10M miles/year

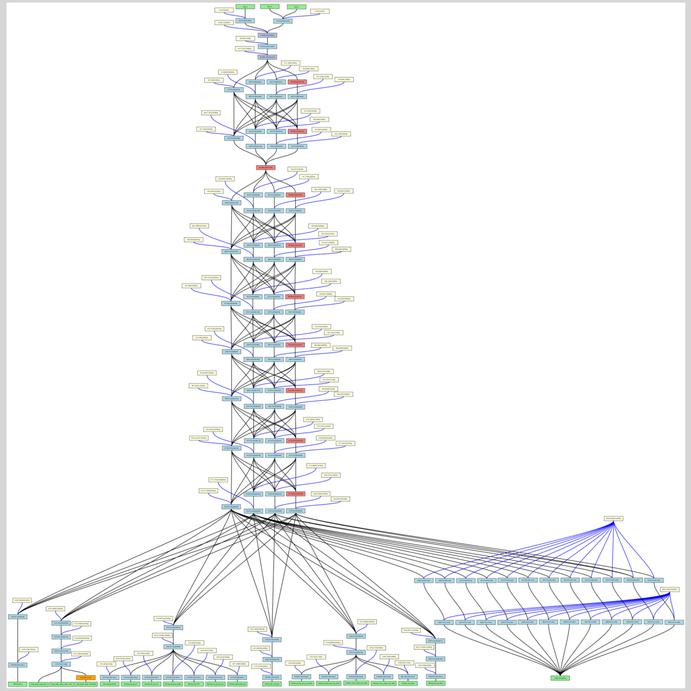
AND

must retest after every modification or upgrade

needs too much data

what about static verification?

SEL4 verification: $400/line
1m lines of critical code: $400M

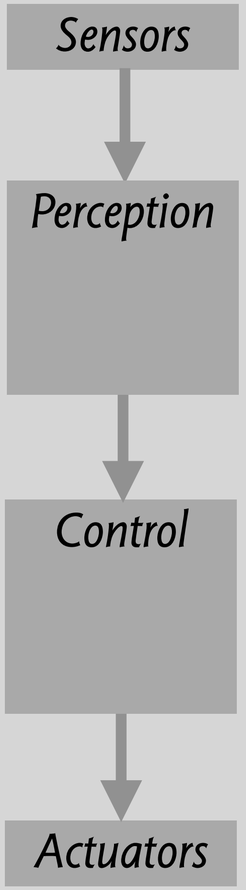


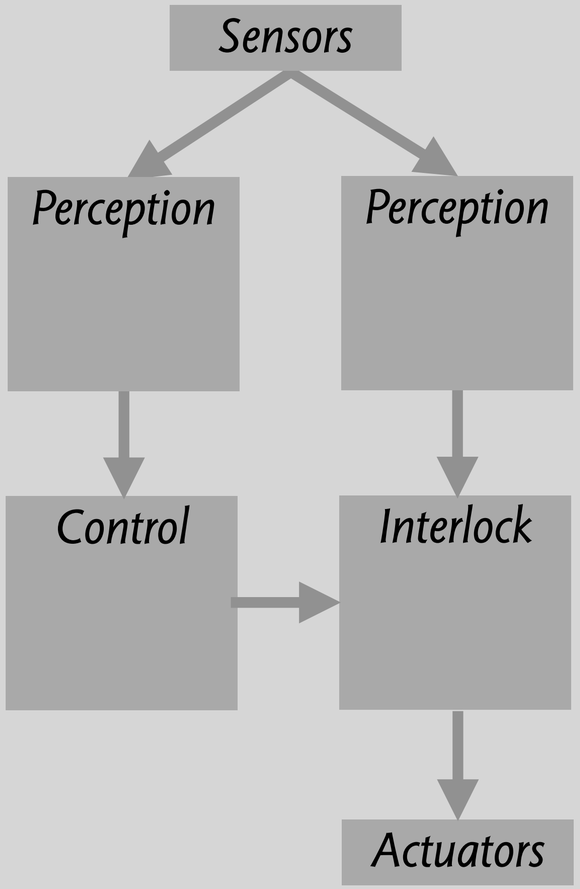
too expensive

too complex

https://teslamotorsclub.com/tmc/threads/tesla-autopilot-hw3.139550/

interlocks





no interlock

classic interlock

classic interlock leads to too many false positives

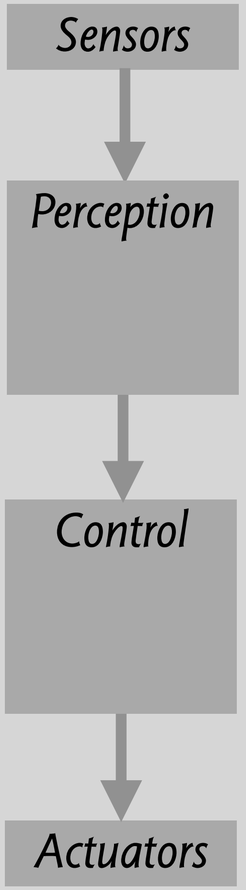
Uber Autopilot

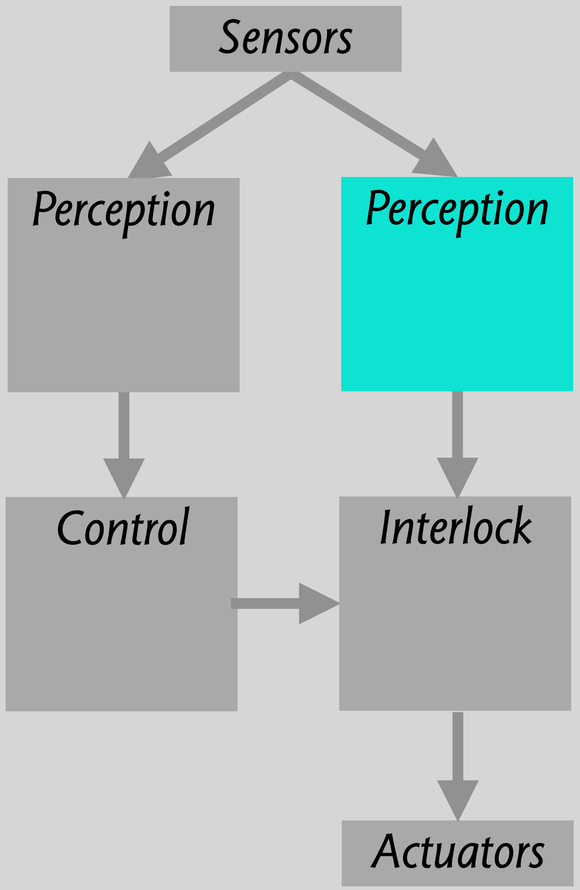
Volvo Driver-Assist

classic interlock leads to too many false positives

Uber Autopilot

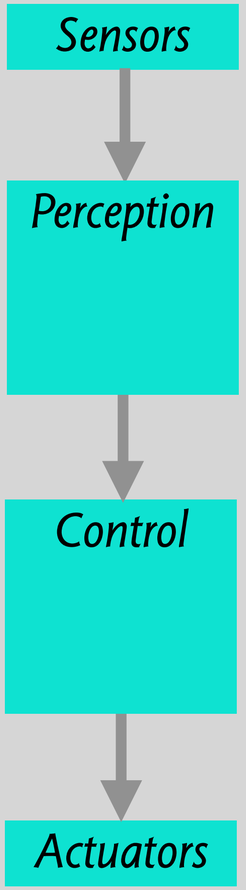
Volv… Dri… sist





no interlock

classic interlock



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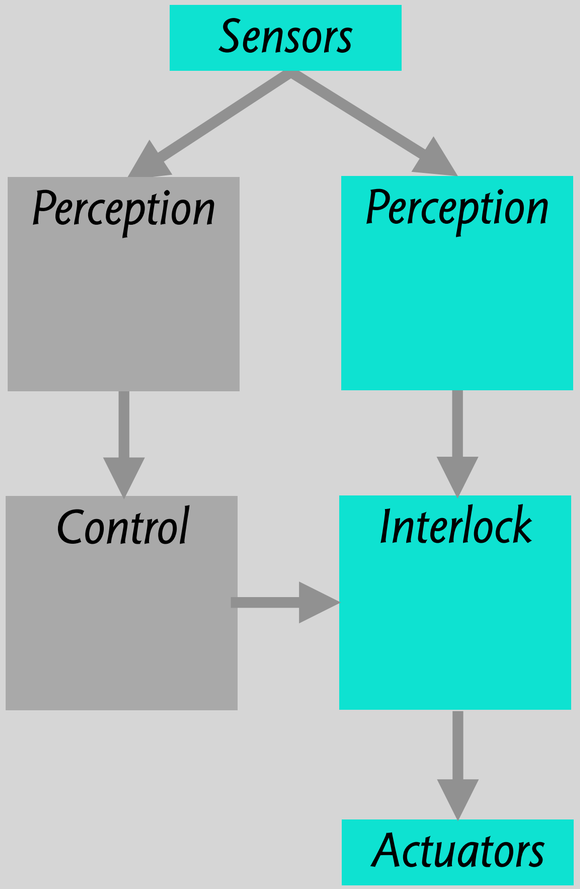

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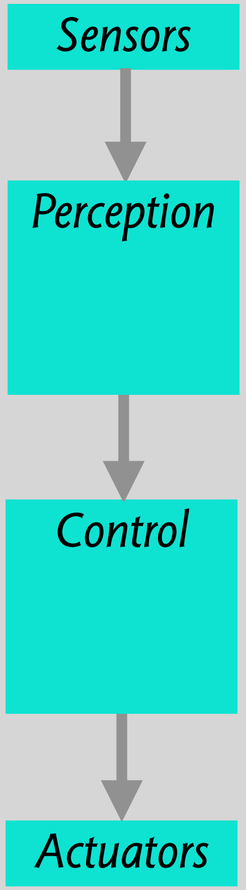

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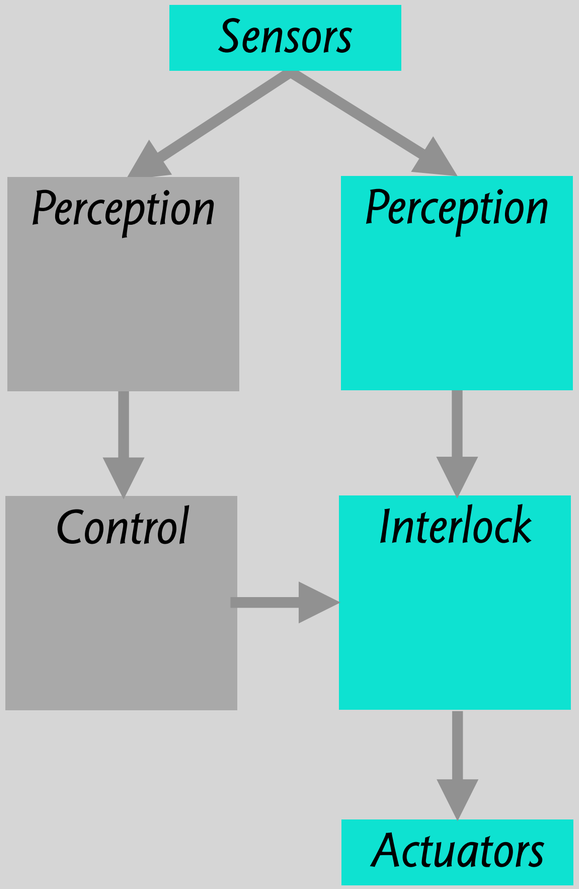

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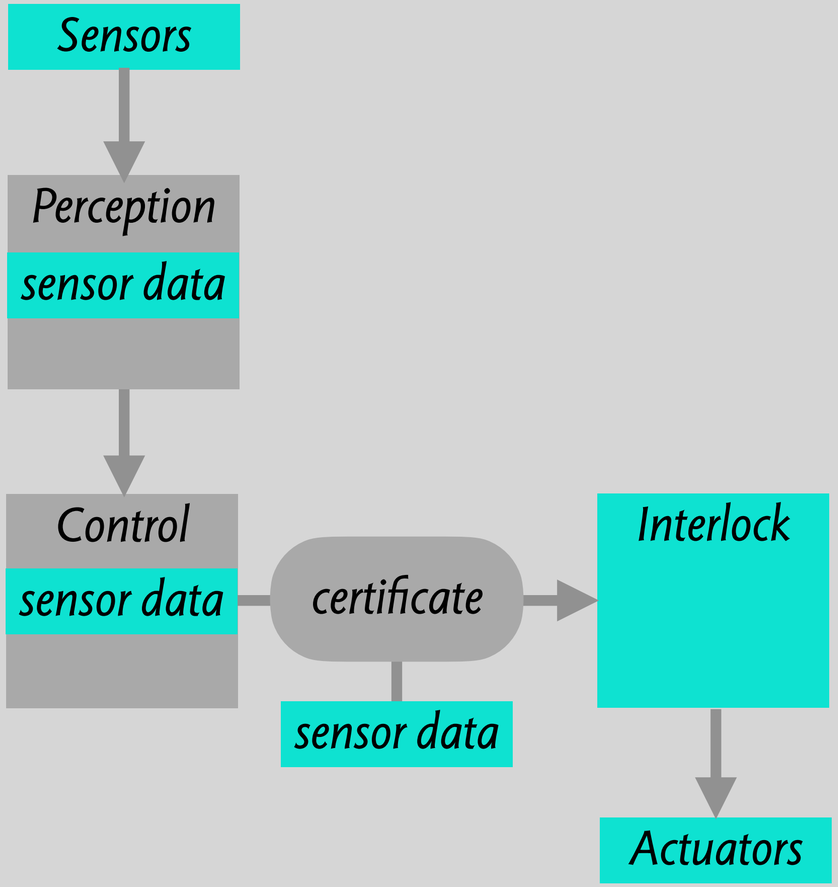
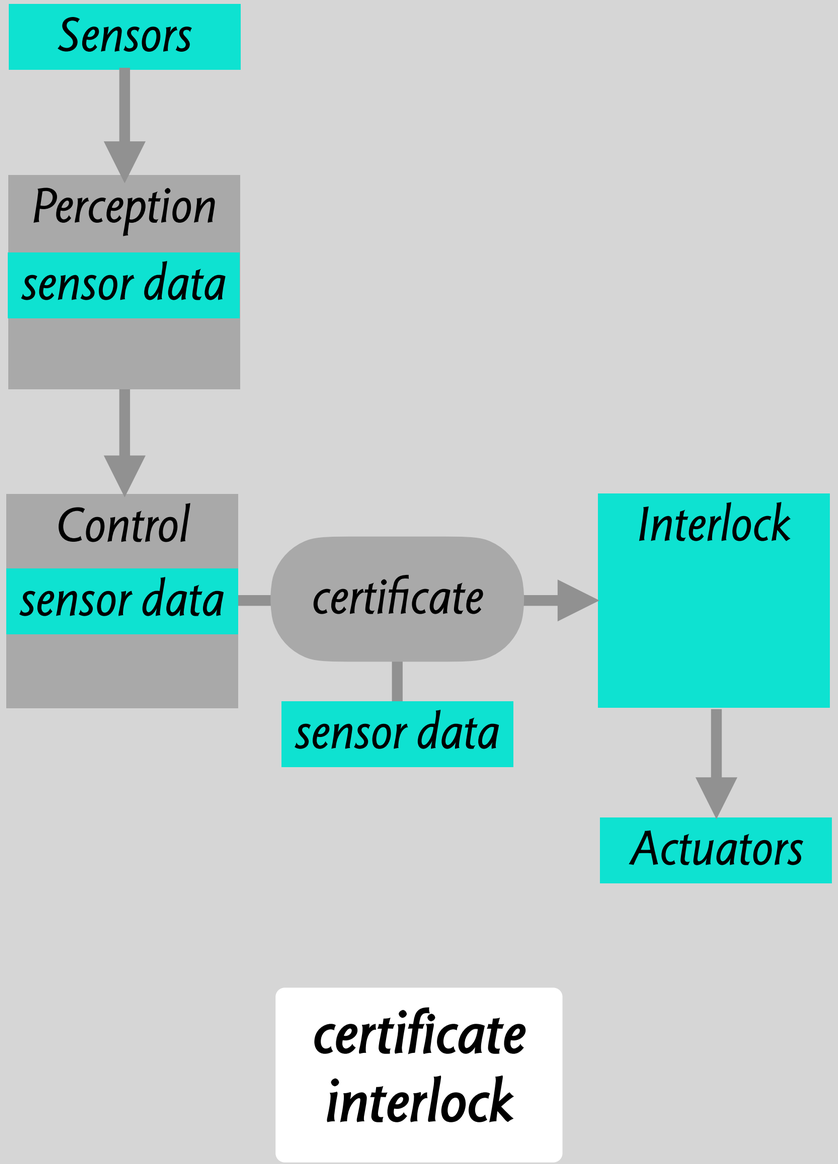


certificate interlock



certificate interlock

- perception-control system *constructs* evidence
- system presents evidence *certificate* to interlock
- interlock *checks* certificate

trusted base

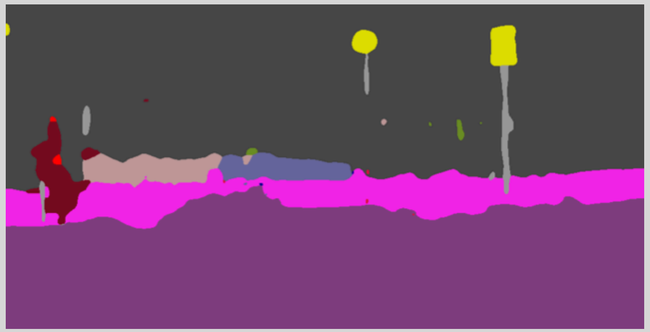
- sensors and actuators
- signed sensor data
- interlock

a segmentation certificate

adversarial segmentation example

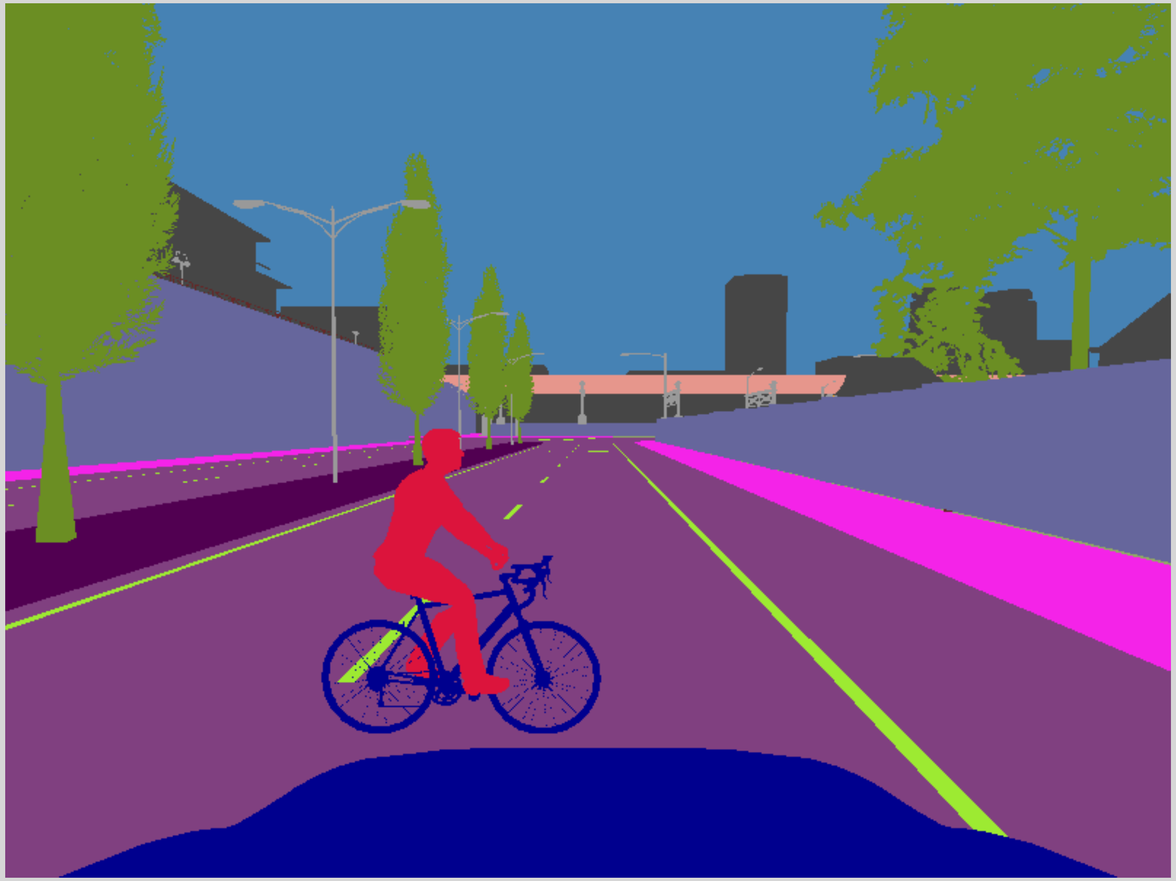
original image

adversarial image



Volker Fischer, Mummadi Chaithanya Kumar, Jan Hendrik Metzen & Thomas Brox.
Adversarial Examples For Semantic Image Segmentation (ICLR 2017)

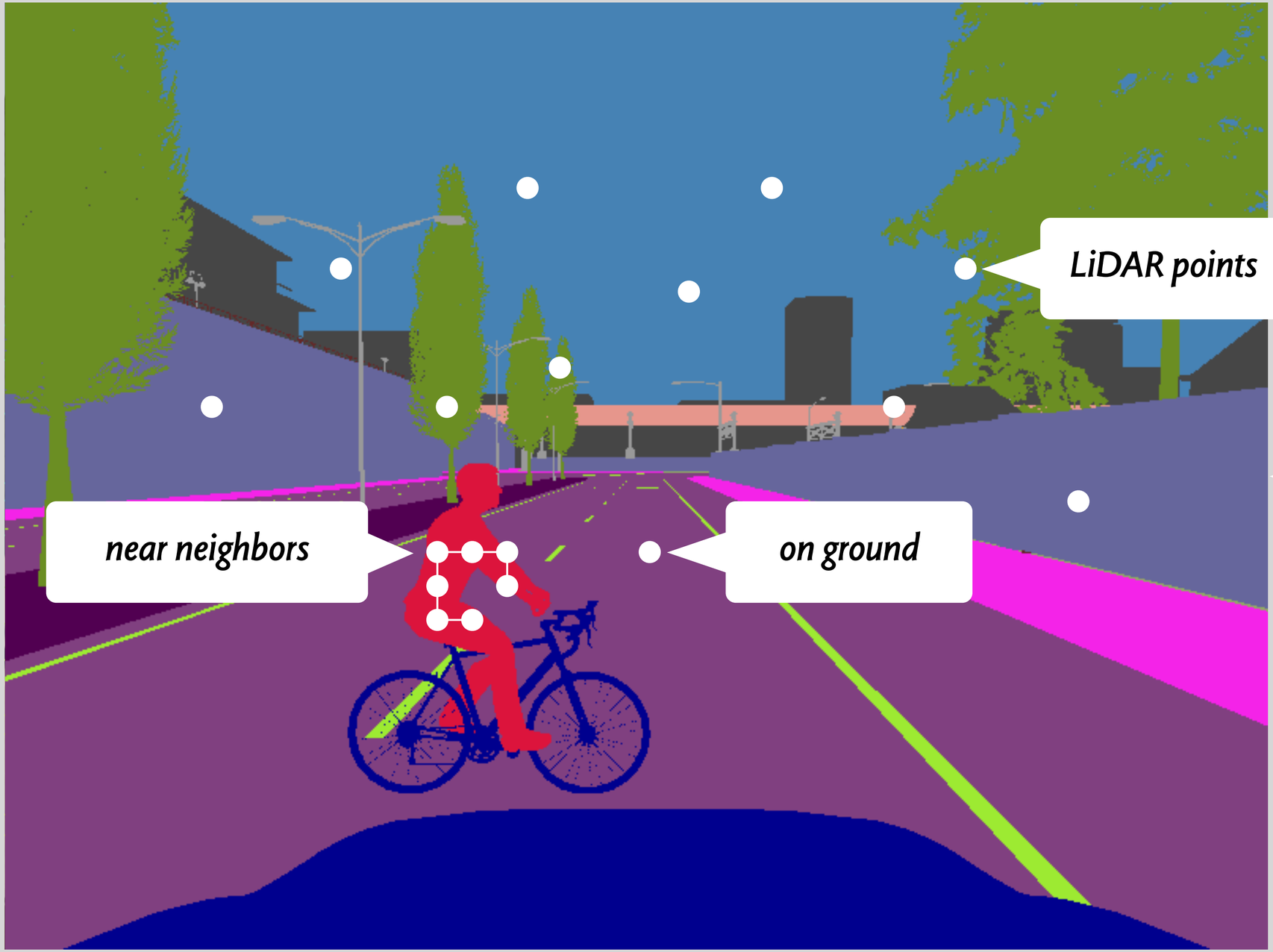
CARLA's segmentation



certificate
data

certificate data

certificate data



a segmentation certificate

certificate data

all points: a set of LiDAR points with position & velocity

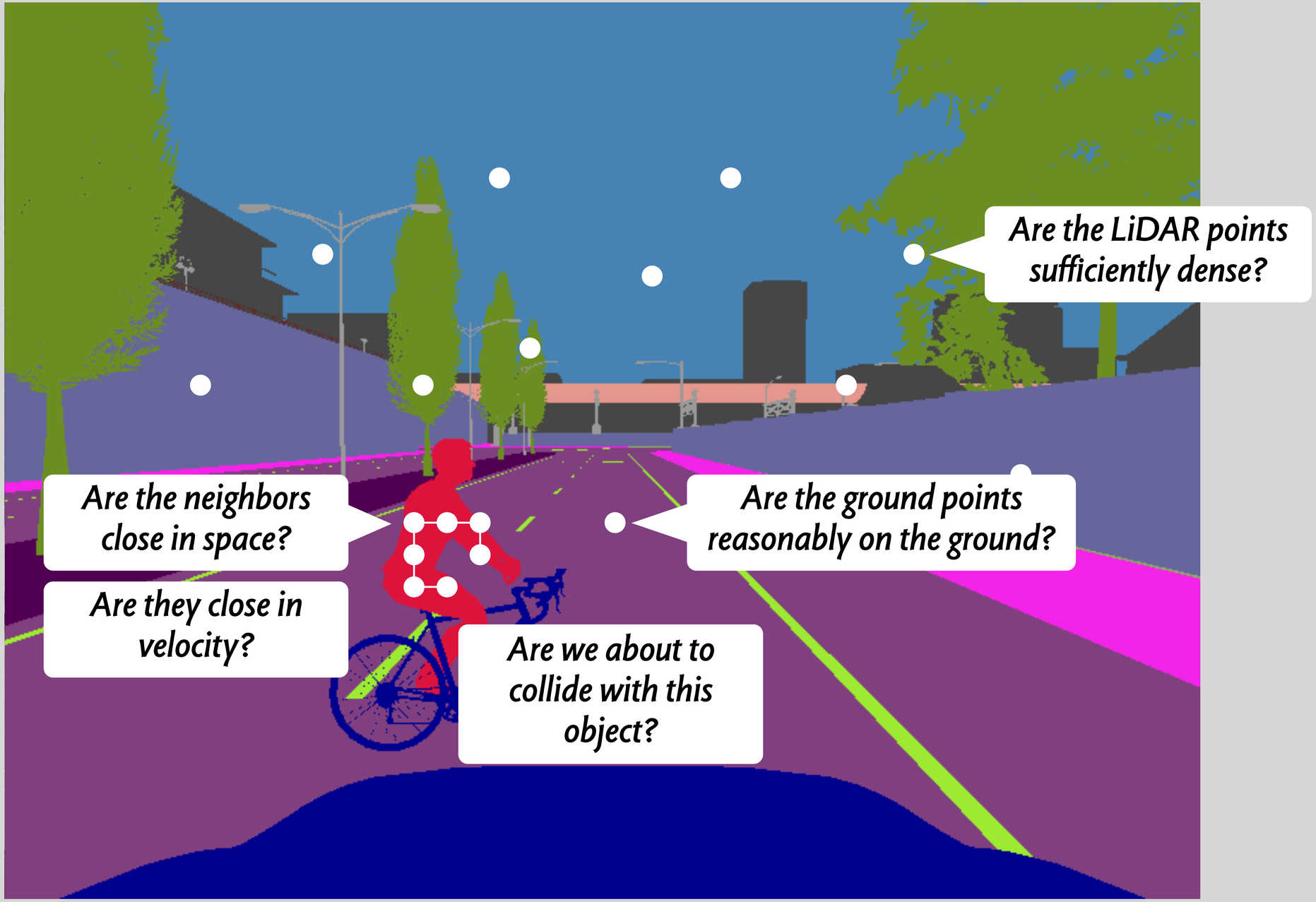
segmentation: a point -> object id map

ground ids: a list of object ids for ground plane objects

traversal: for each object id, a list of point pairs

certificate checks

certificate checks



a segmentation certificate

certificate checks

sufficient density: input LiDAR points are sufficiently dense

ground height: all ground points are close to the plane below the car

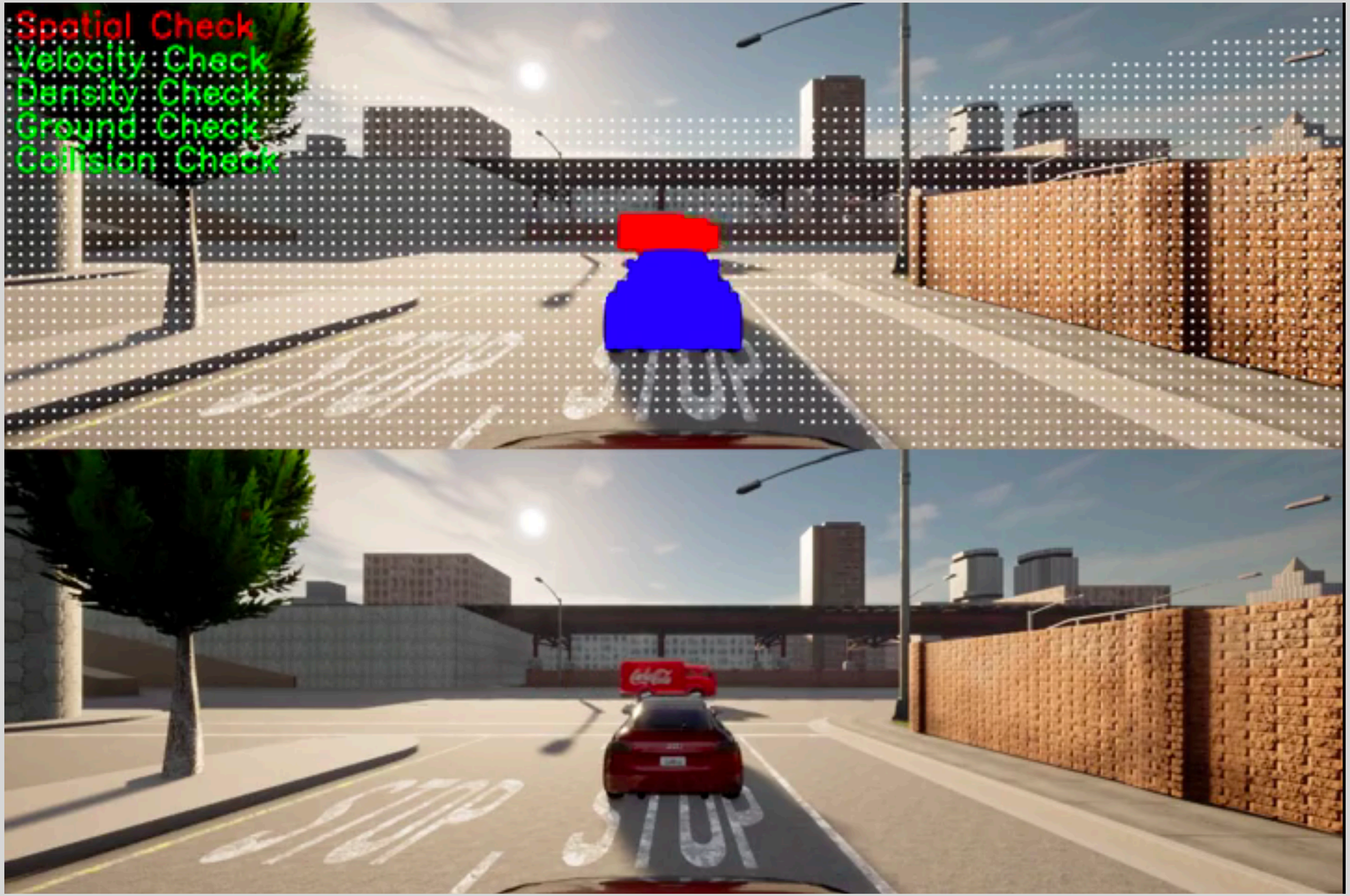
spatial contiguity: in each traversal, in each pair, the two points are close

consistent velocity: in each traversal, in each pair, the two points have similar velocities

collision prediction: the car will not collide with non-ground objects in the near future

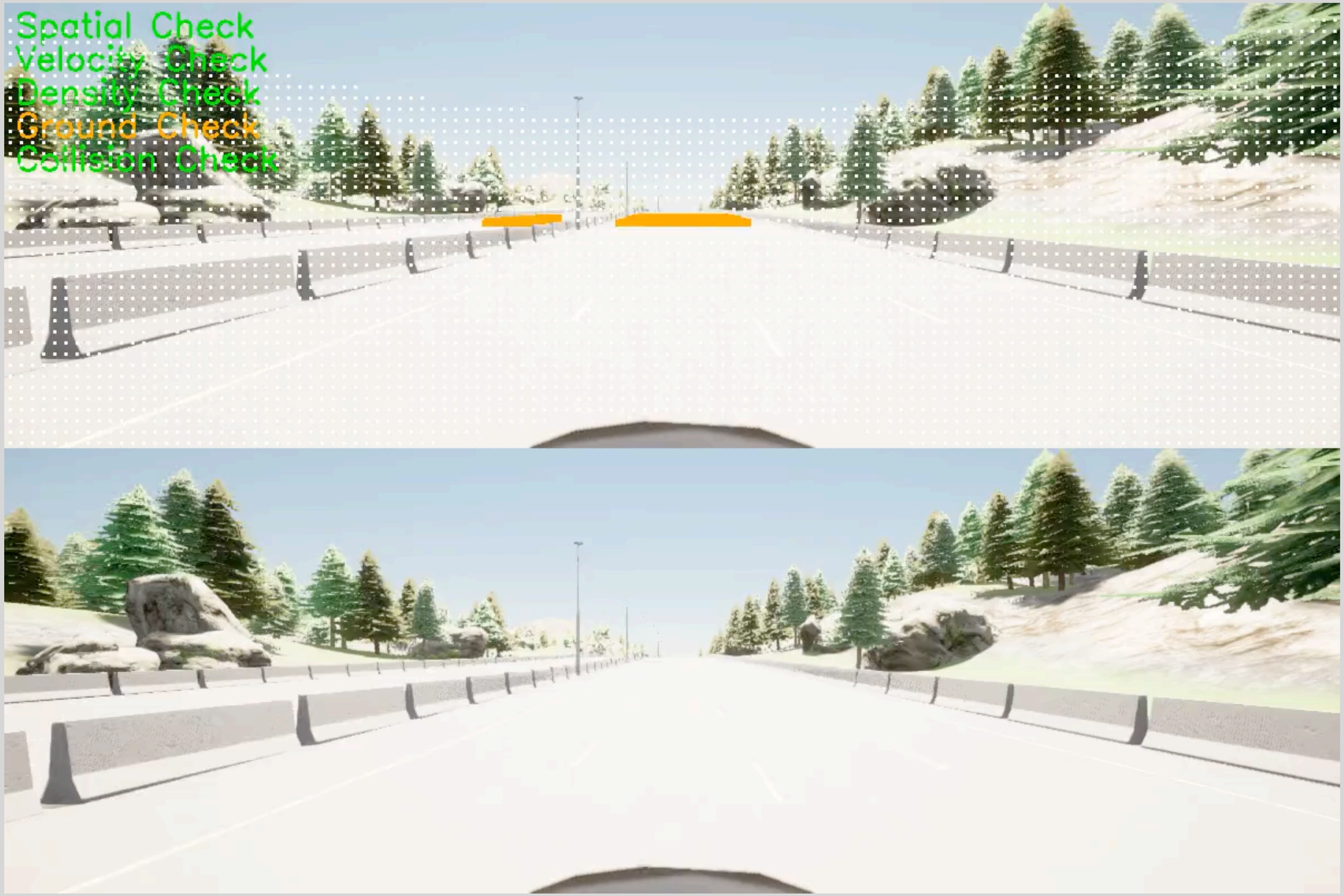
experiments

detecting a conflation of two objects

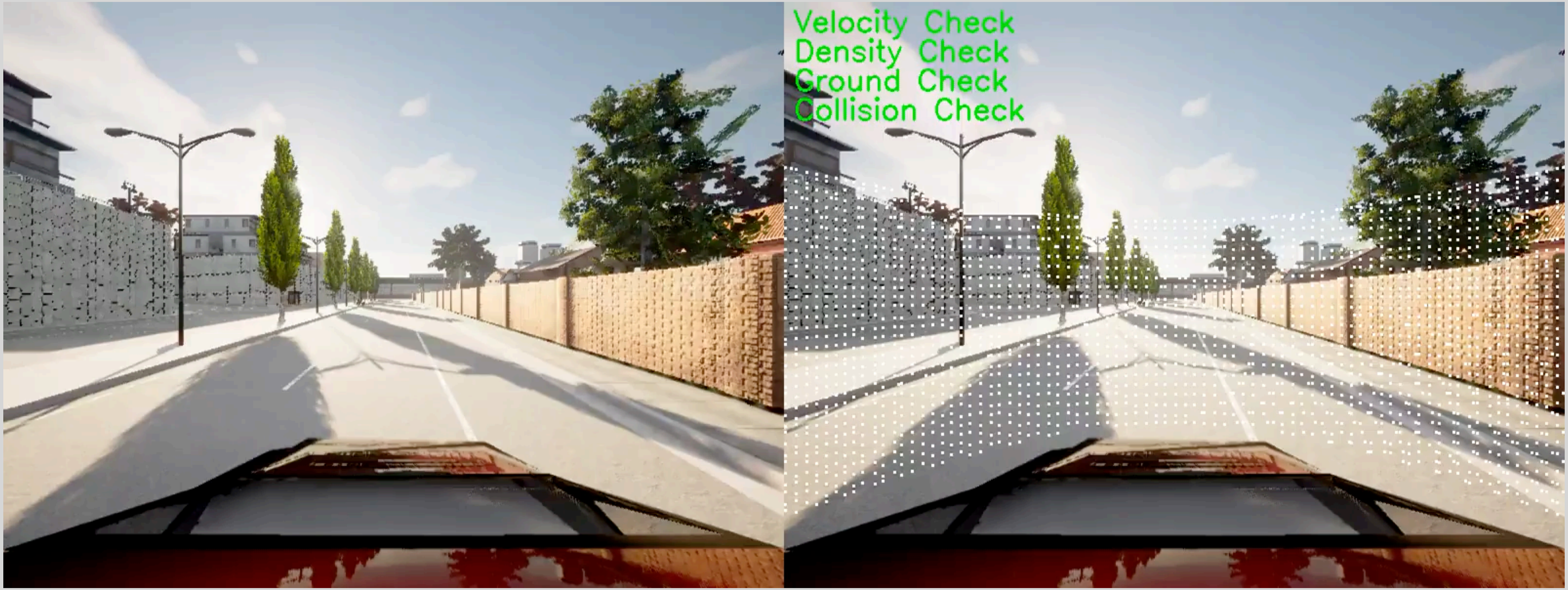


maintaining separation from car in front

interlock does not interfere when the ADS is safe



simulating uber tempe accident



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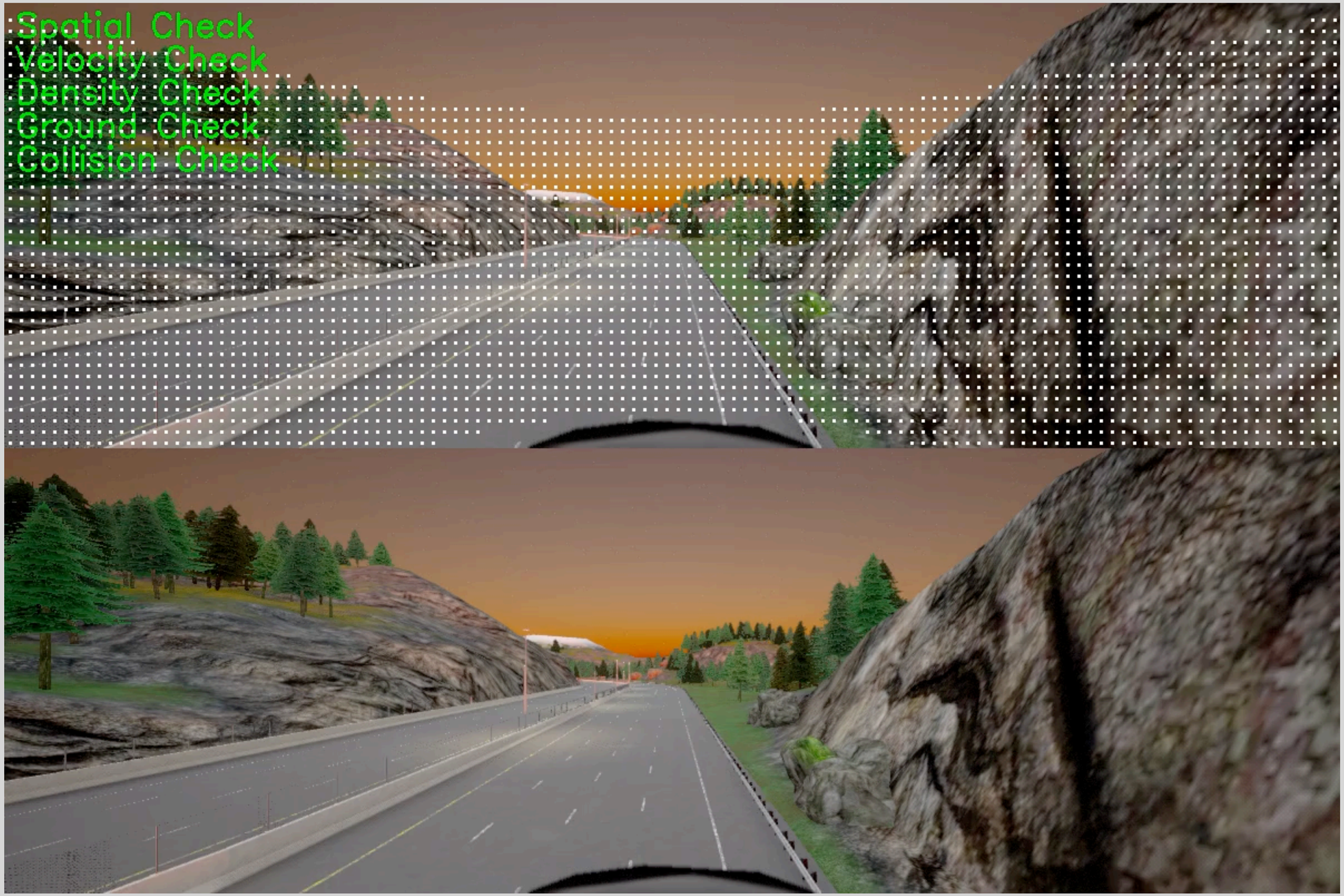

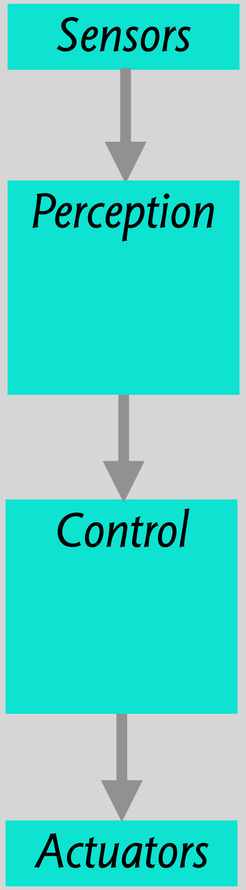

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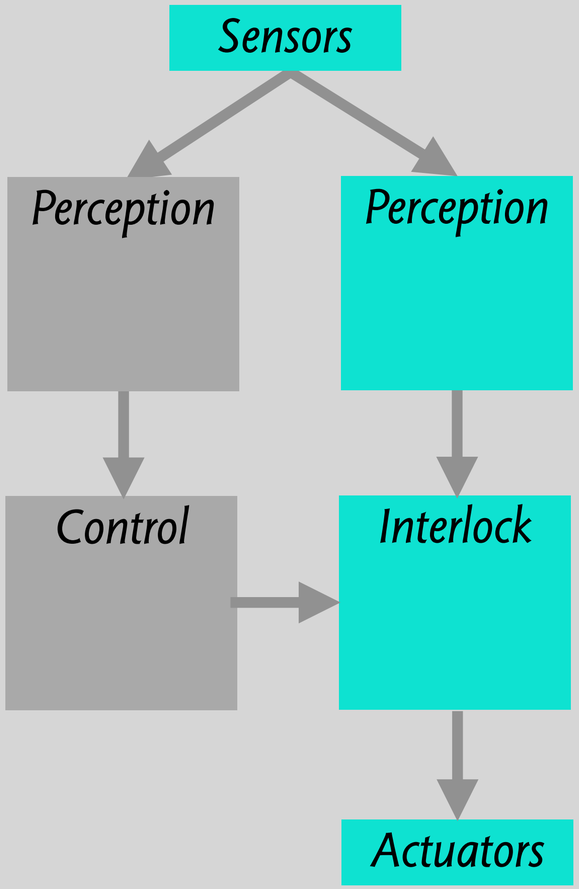
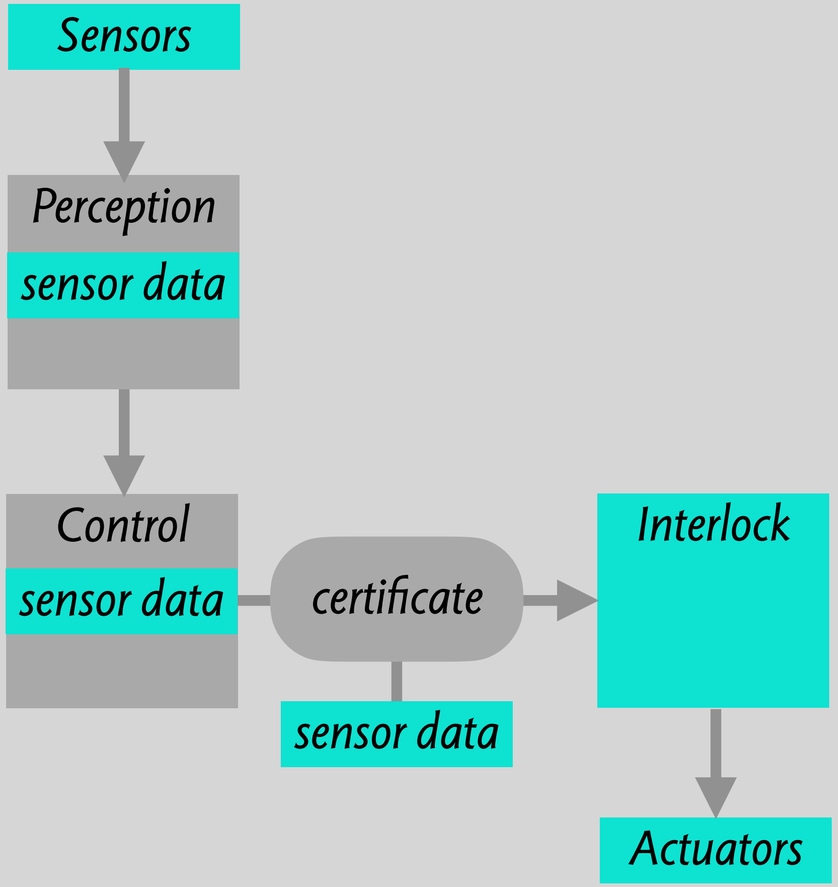
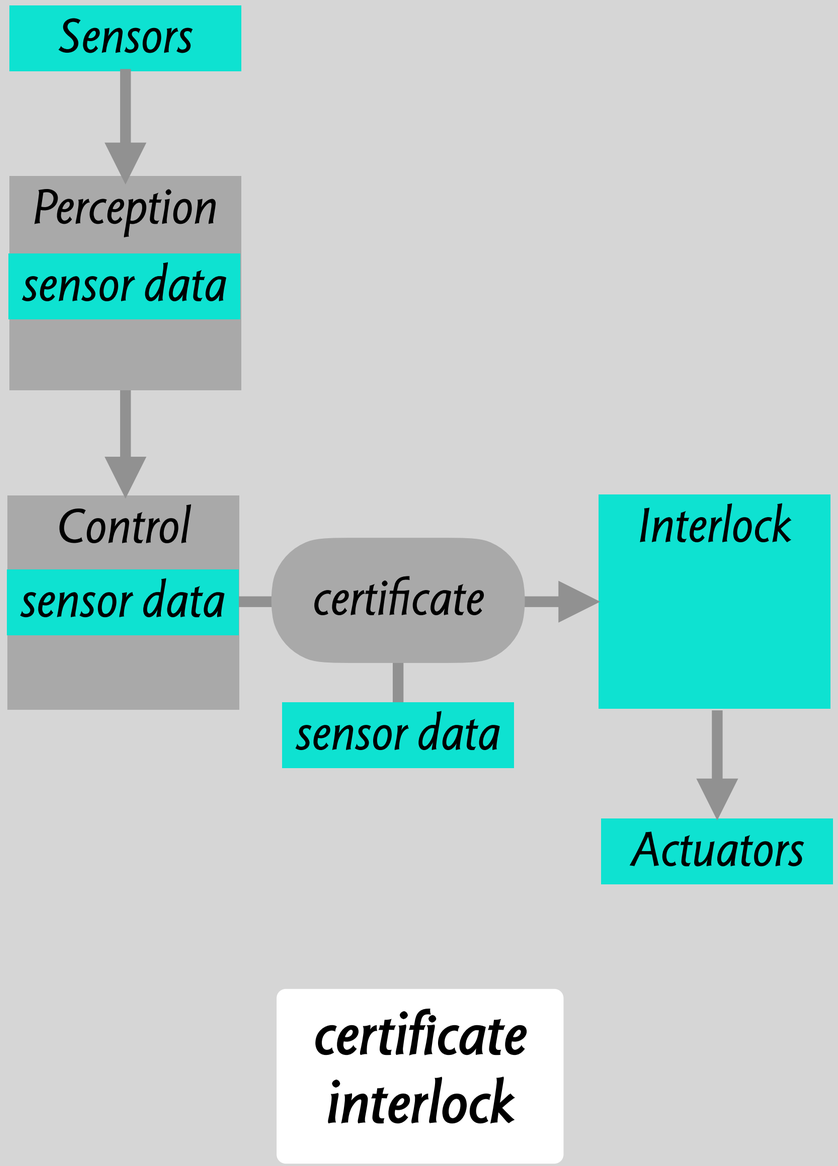


classic interlock



certificate interlock

discussion



what are the risks to certified perception?
machine learning gets so good, we don't need checks
certificate checks are too strong & binary

what are the key challenges?
can't mitigate super-rare events (eg, avalanche)
better at mitigating egregious errors than subtle flaws

what do you think?
will we tolerate "good enough?"
will adversarial attacks matter?