

Pathfinding and Routing

NAIL137

Intersections and autonomous cars

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Application on cars

- In the present
 - Assisting systems
 - Independent self-driving cars
- In the future
 - Intersection management

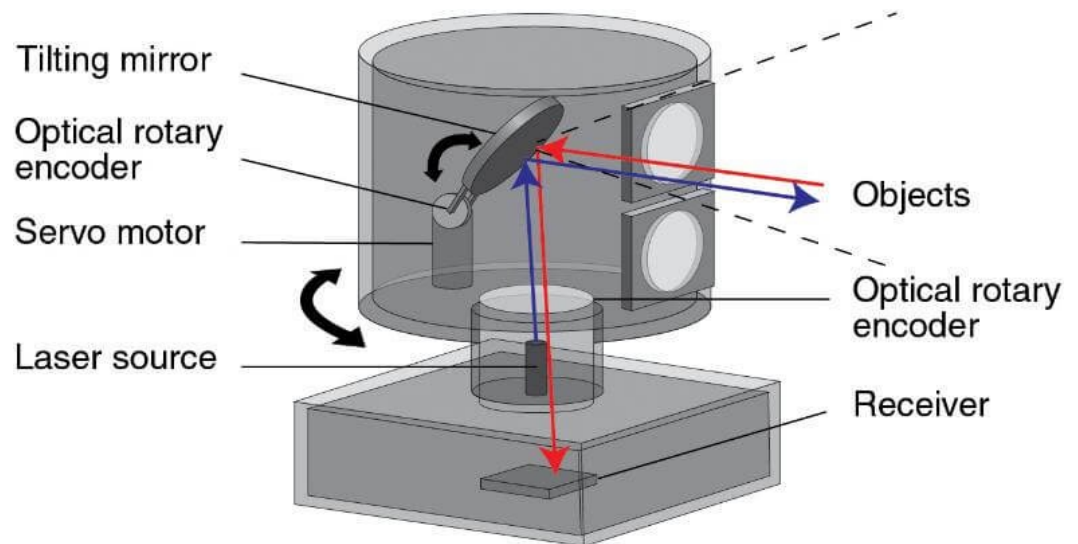
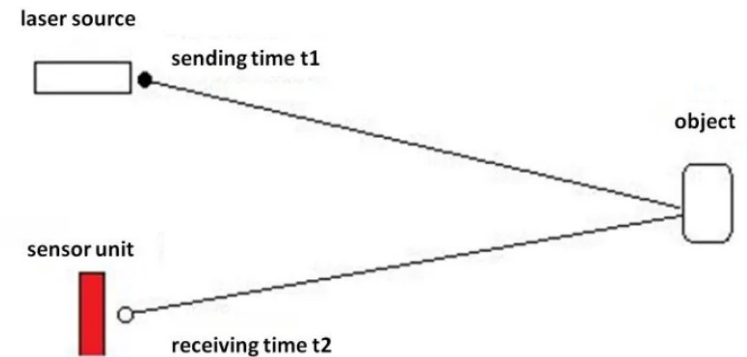
Overview

- Sensors
- Driving assist
- Not fully autonomous yet

- Intelligent cars
- Autonomous cars
- Self-driving cars

Sensors - LIDAR

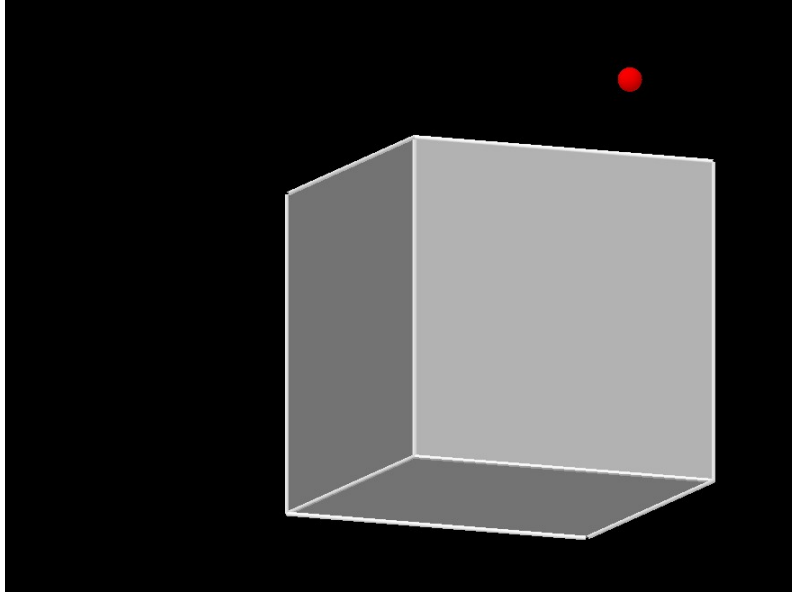
- Light Detection and Ranging
 - Often infrared light
 - Turn on/off



Sensors - LIDAR



Sensors - stealth



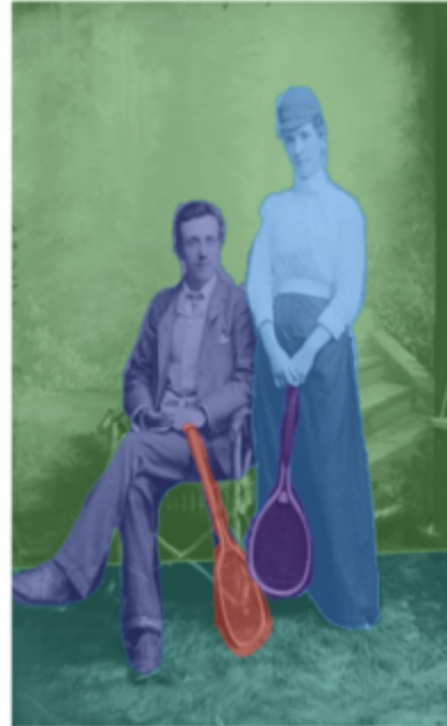
Sensors - optical recognition



Instance Segmentation



Semantic Segmentation



Panoptic Segmentation

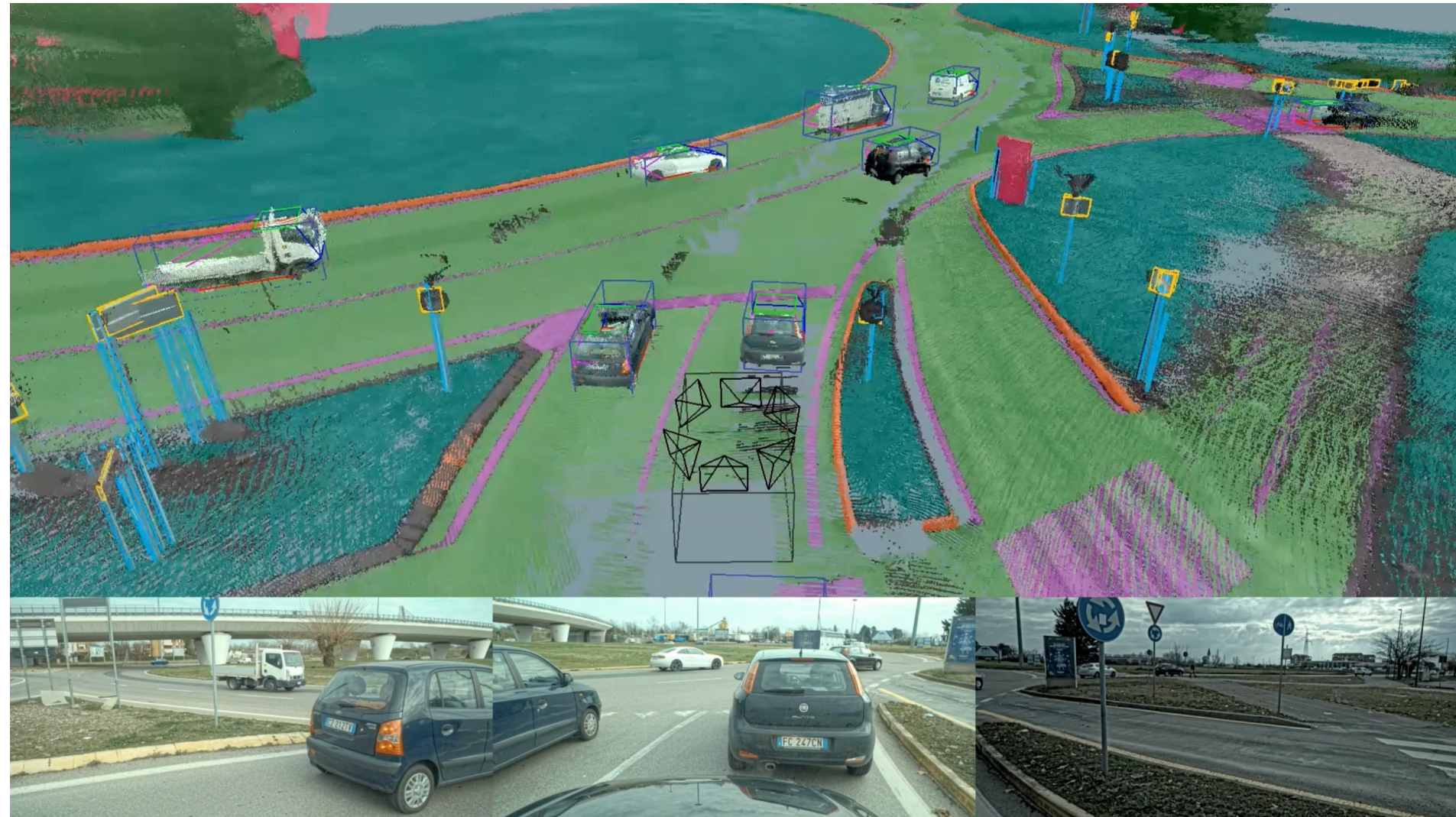


Detection
(Bounding Boxes)

Sensors - optical recognition

- Architecture
 - Deep learning (usually CNN)
 - Supervised learning (expensive labeled data)
 - Prediction is pixel-wise
 - Post-processing to increase readability

Sensors - bird eye view (BEV)



Intelligent cars – assisting systems

- Cruise control
- Parking camera
- Blind spot warning
- Line departure warning
- Forward collision warning
- Adaptive cruise control
- Blind spot intervention
- Line keeping intervention
- Emergency braking
- ...



Levels of autonomy by Society of Automobile Engineers



SAE J3016™ LEVELS OF DRIVING AUTOMATION™

Learn more here: [sae.org/standards/content/j3016_202104](https://www.sae.org/standards/content/j3016_202104)

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	SAE LEVEL 0™	SAE LEVEL 1™	SAE LEVEL 2™	SAE LEVEL 3™	SAE LEVEL 4™	SAE LEVEL 5™
What does the human in the driver's seat have to do?	You are driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You are not driving when these automated driving features are engaged – even if you are seated in “the driver’s seat”		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	

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	These are driver support features			These are automated driving features		
What do these features do?	These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/acceleration support to the driver	These features provide steering AND brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met	This feature can drive the vehicle under all conditions	
Example Features	<ul style="list-style-type: none"> • automatic emergency braking • blind spot warning • lane departure warning 	<ul style="list-style-type: none"> • lane centering OR • adaptive cruise control 	<ul style="list-style-type: none"> • lane centering AND • adaptive cruise control at the same time 	<ul style="list-style-type: none"> • traffic jam chauffeur 	<ul style="list-style-type: none"> • local driverless taxi • pedals/steering wheel may or may not be installed 	<ul style="list-style-type: none"> • same as level 4, but feature can drive everywhere in all conditions

Level 0

- Driver is in charge
- Mostly warning systems only
 - Blind spot
 - Line departure
 - Automatic emergency braking

Level 1

- Driver is in charge
- Warning systems as in L0
- Lane centering OR adaptive cruise control

Level 2

- Driver is in charge
- Warning systems as in L0
- Lane centering AND adaptive cruise control
- Able to drive in simple situations
 - Highway driving assist

Level 3

- The car is in charge but may ask the driver to take over
- Capabilities of L2
- Car manufacturer is responsible

Level 4

- The car is in charge, can not require driver intervention
- Capable to drive in almost all situations
- Conditions must be met
 - Weather
 - Visibility
 - Geofencing
- Car manufacturer is responsible

Level 5

- The car is in charge, no driver
- Capable to drive in all situations
- Car manufacturer is responsible
- *There are currently no L5 cars*

Self driving cars - current capabilities

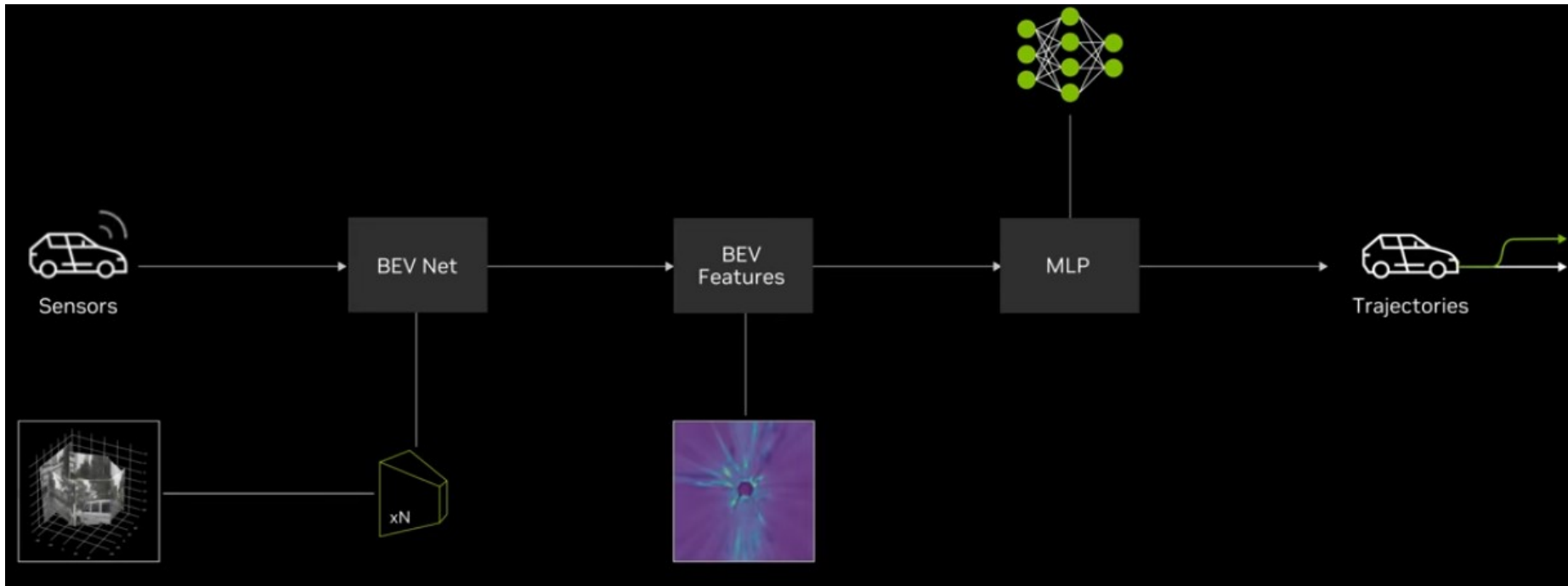
- Tesla Full-self driving (level 2 for legal reasons)
- Tesla robotaxi (level 4)
- Waymo robotaxi (level 4)

Self driving cars - decision mechanism

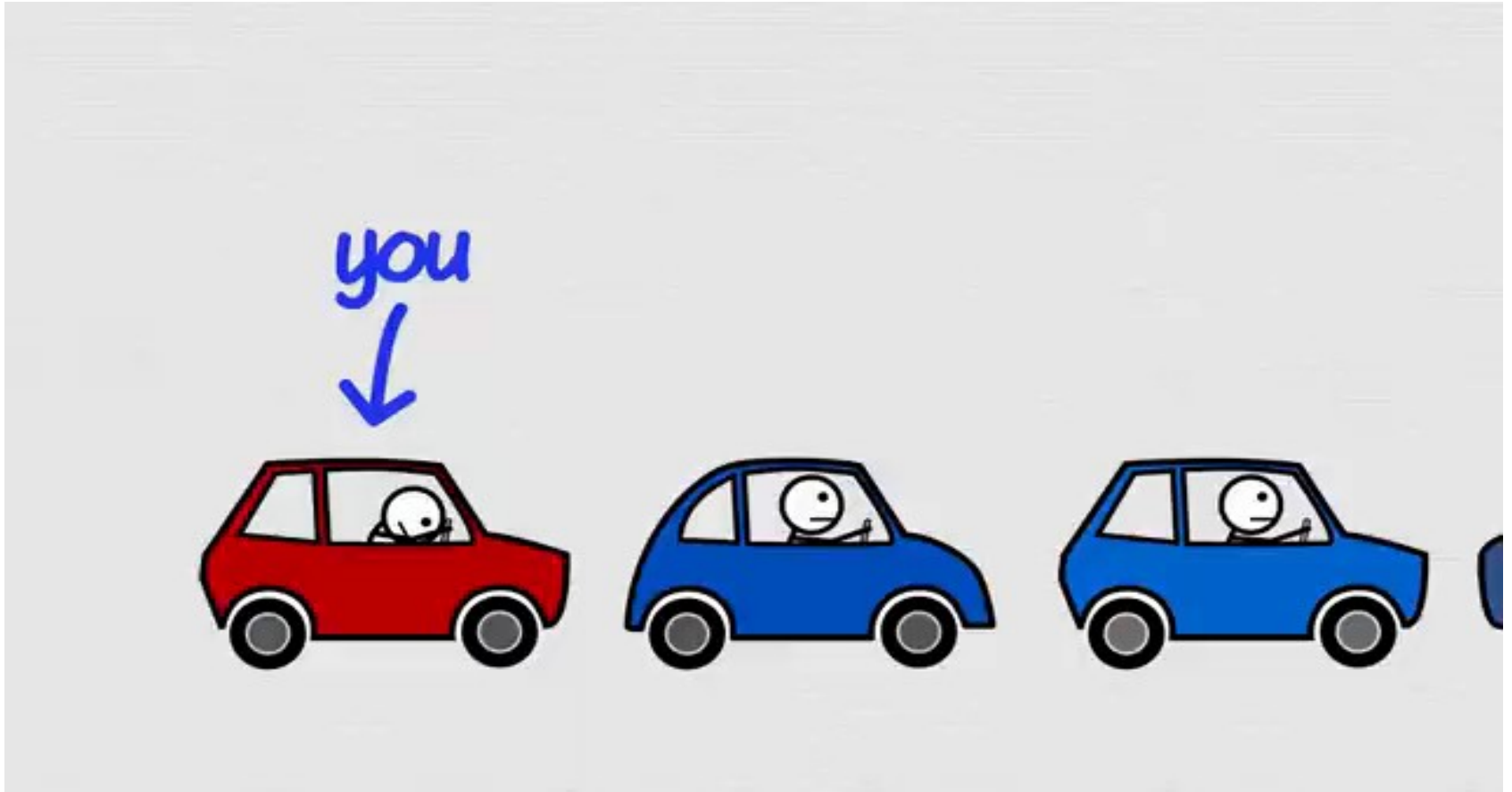
Traditional model



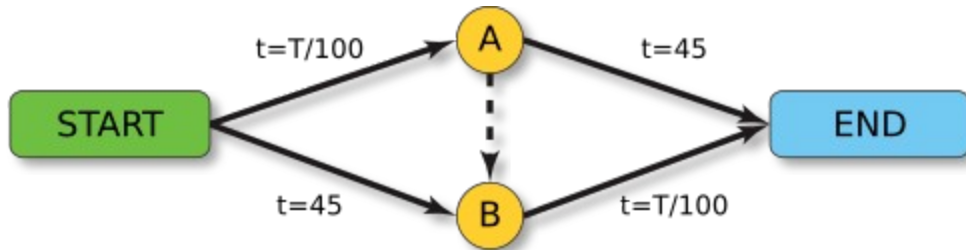
End to end model



Problems with cars



Braess's paradox



Assume 4000 drivers

S-A-E = S-B-E = 65 (split into 2000, 2000 drivers)

A-B is constructed and takes 0

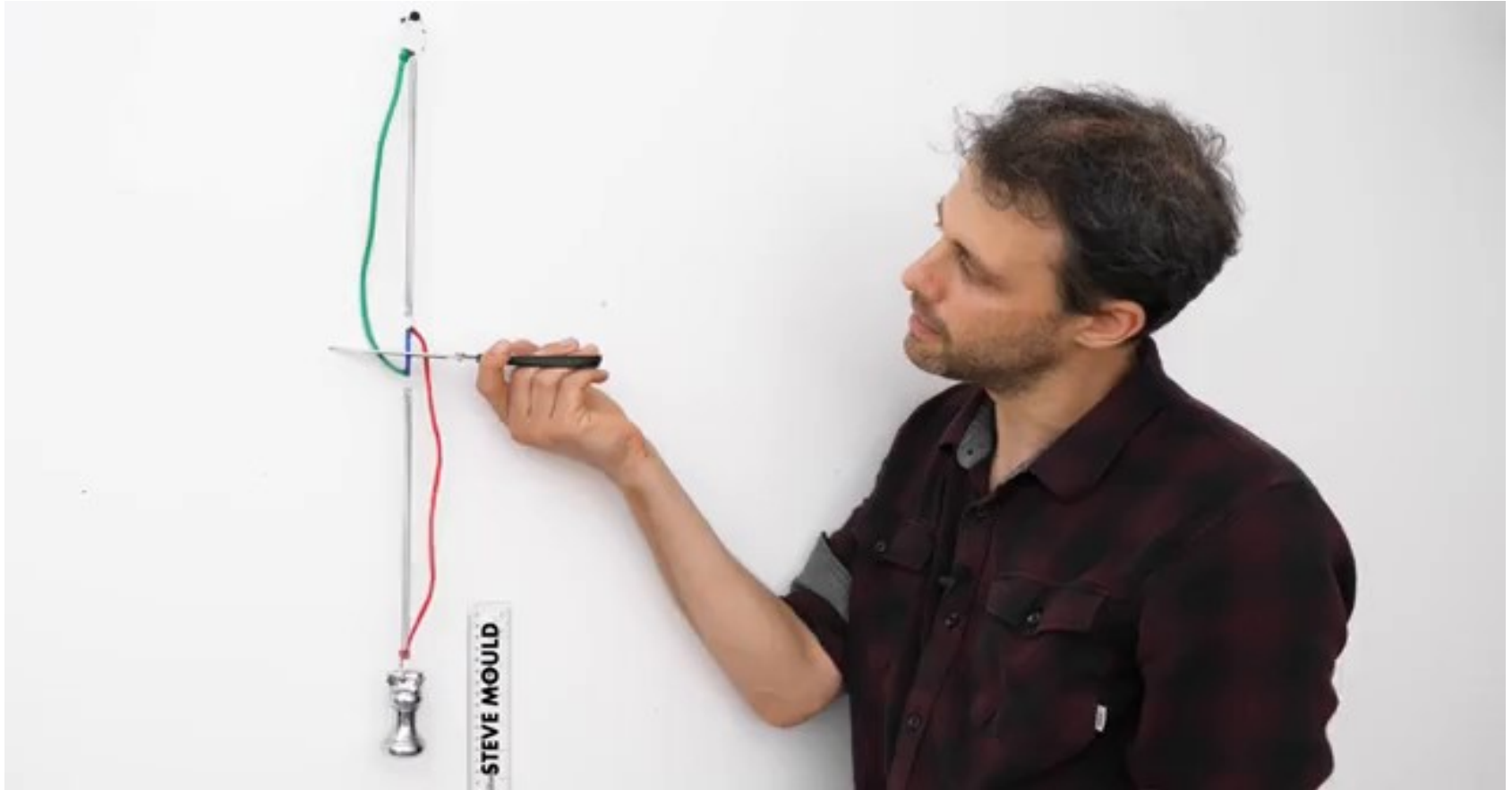
S-A-B-E takes $1/100 + 0 + 1/100$ for the first driver

Once 2500 joins (1500 still on S-B-E), it takes $25 + 0 + 40 = 65$

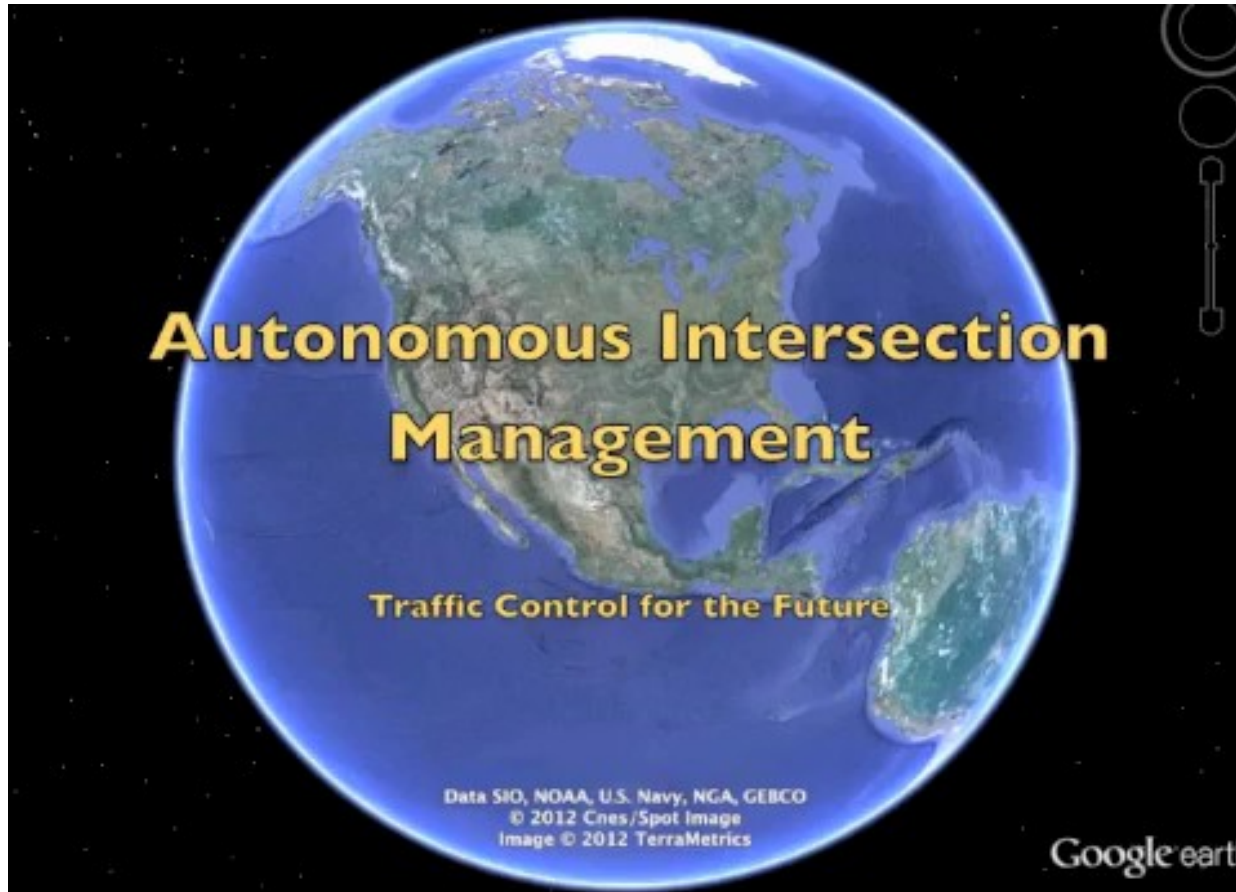
Those on S-B-E take now $45 + 40 = 85$

It is better to join S-A-B-E for everyone, $40 + 0 + 40 = 80$

Braess's paradox



AIM - Autonomous Intersection Management



IM - solution method

- MAPF approach - Online MAPF
 - Not really applicable to cars
 - The agents might not be cars
 - Replan all – replan all agent on change
 - Replan single – plan the new agent
 - OID – plan the new agent and replan affected agents
 - SubID – the new plans need not be optimal

IM - solution method

- Query-based
 - Reservation table
 - New car sends request with time and speed
 - A) Accepted – new reservation
 - B) Rejected – car slows down and sends new request later

IM - solution method

- Assignment-based
 - Reservation table
 - New car sends earliest arrival time
 - IM schedules the speed to fit into the reservation table
- Usually higher throughput than QB

IM - assignment-base

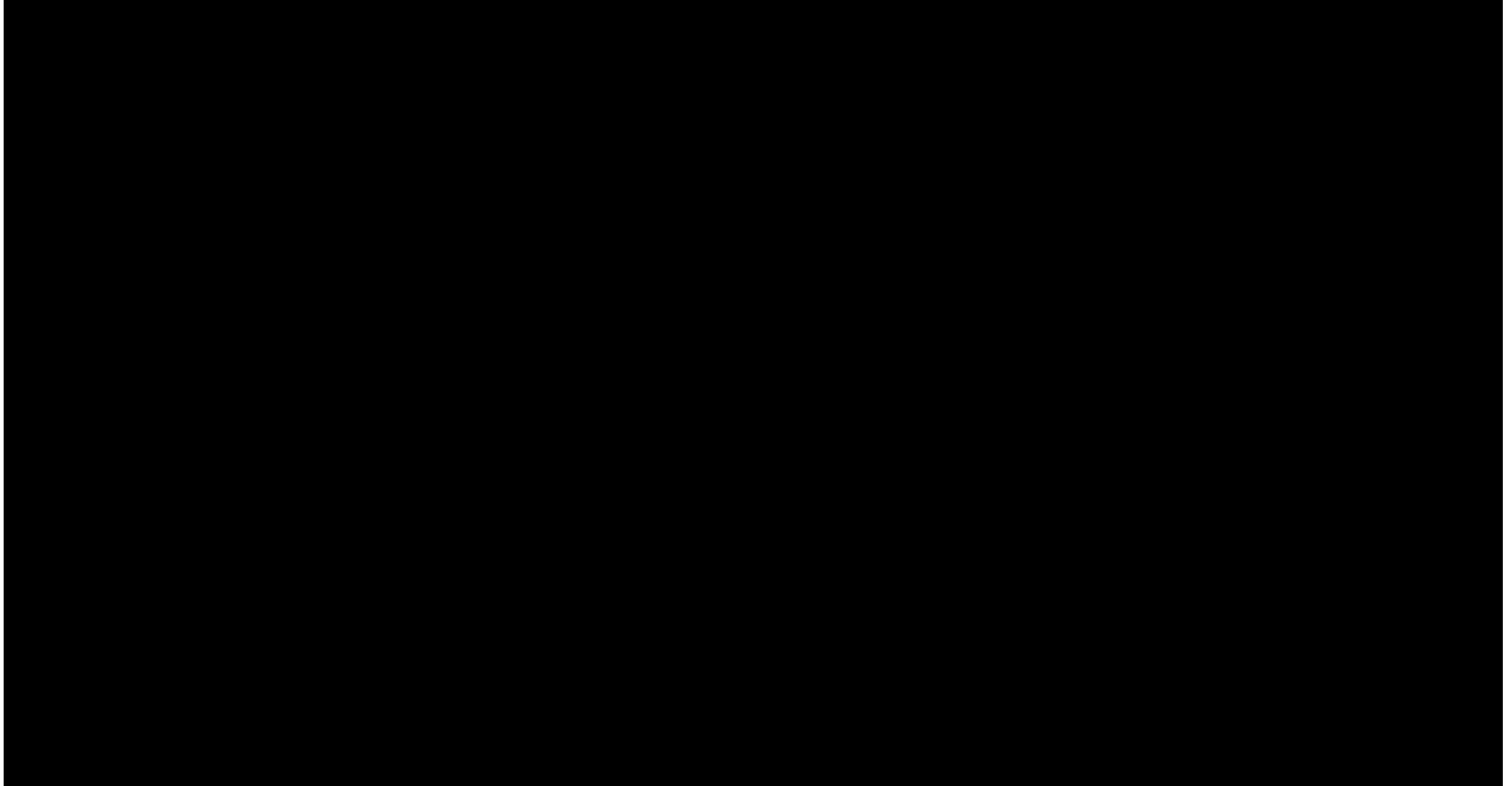
- Traversal speed should be constant
 - Simpler solution (similar to SIPP)
- Minimal traversal speed
 - Too low speeds block the intersection for too long
- Order of traversal
 - First come first served
 - Auction system
 - Priority-based

Resources



<https://sumo.dlr.de/docs/index.html>
<https://www.cs.utexas.edu/~aim/>

Intersections interact!



<https://www.youtube.com/@BiffaPlaysCitiesSkylines>

https://www.youtube.com/watch?v=kbCrqN5ODx0&list=PLR5G_Kc9r-JDza2Bzd2GIA01_jVyHhhXw&index=3

Intersections interact!

