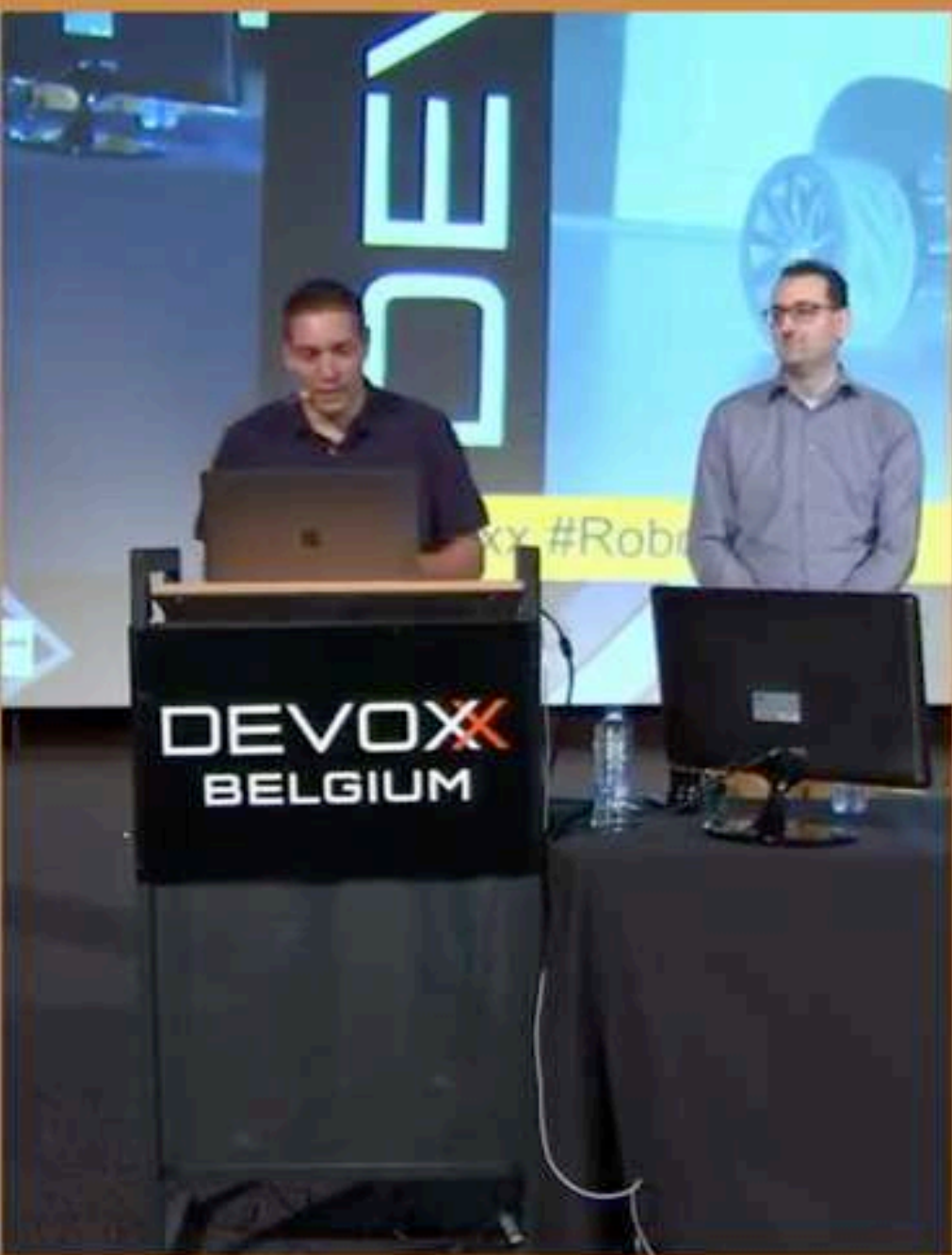




# Building a self-driving RC car

Bert Jan Schrijver  
bertjan@openvalue.nl





# Building a self-driving RC car

Bert Jan Schrijver  
Tim van Eindhoven

JPoint



#Devoxx #RoboRace

@bjschrijver @TimvEindhoven

# Let's meet



Bert Jan Schrijver

OPENVALUE

.nl.  
jug



# Let's meet



Tim van Eijndhoven

Jpoint

POLITIE

# How it all started...



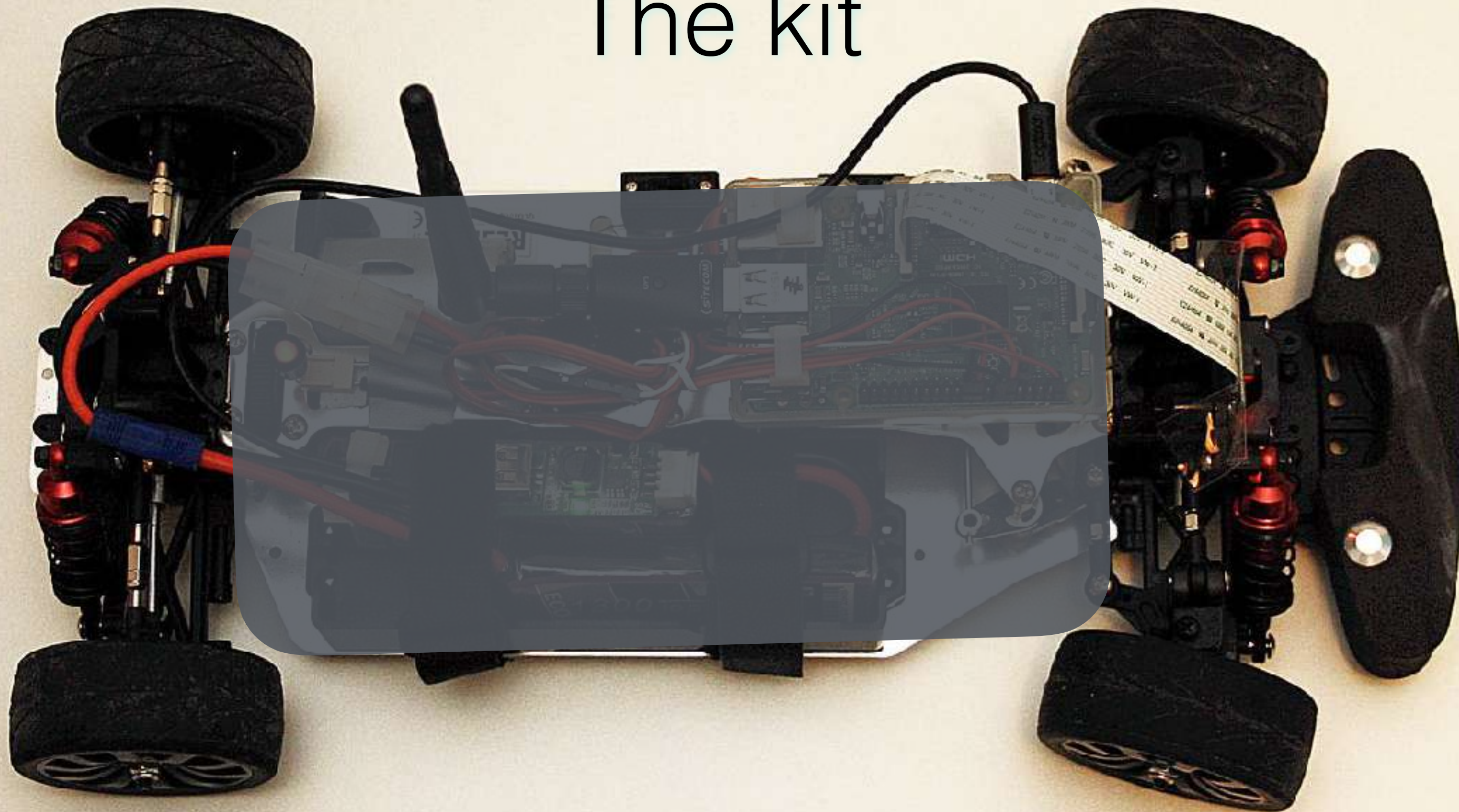
# RoboRace challenge



# The rules

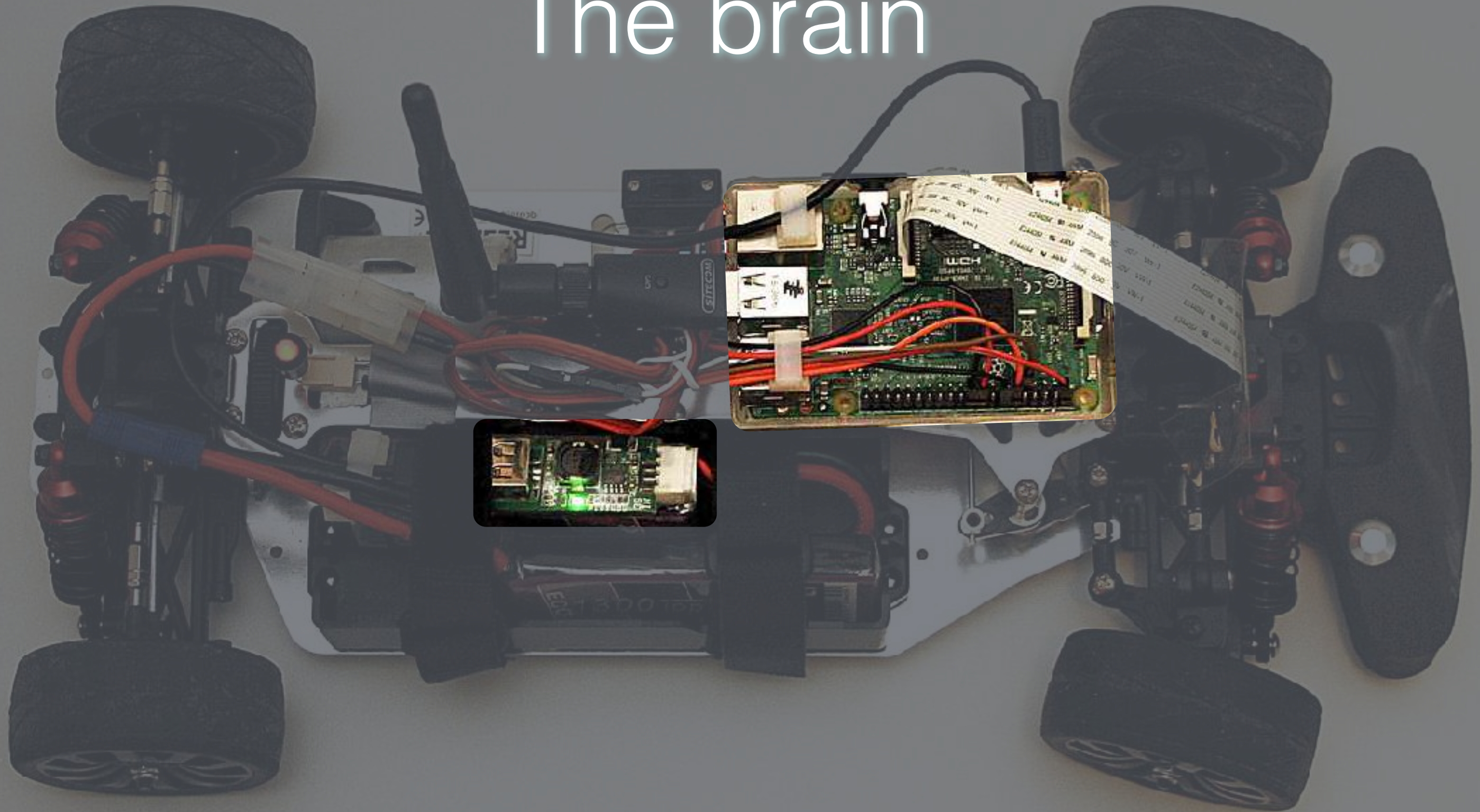
- 4 teams
- Each team gets:
  - RC car kit
  - Fixed budget (150 euro)
- Three races:
  1. drag race (start, drive, stop)
  2. race track (race 1 + corners)
  3. destruction derby ;-)  
(race 2 with multiple cars on same track)

# The kit





# The brain



# The platform



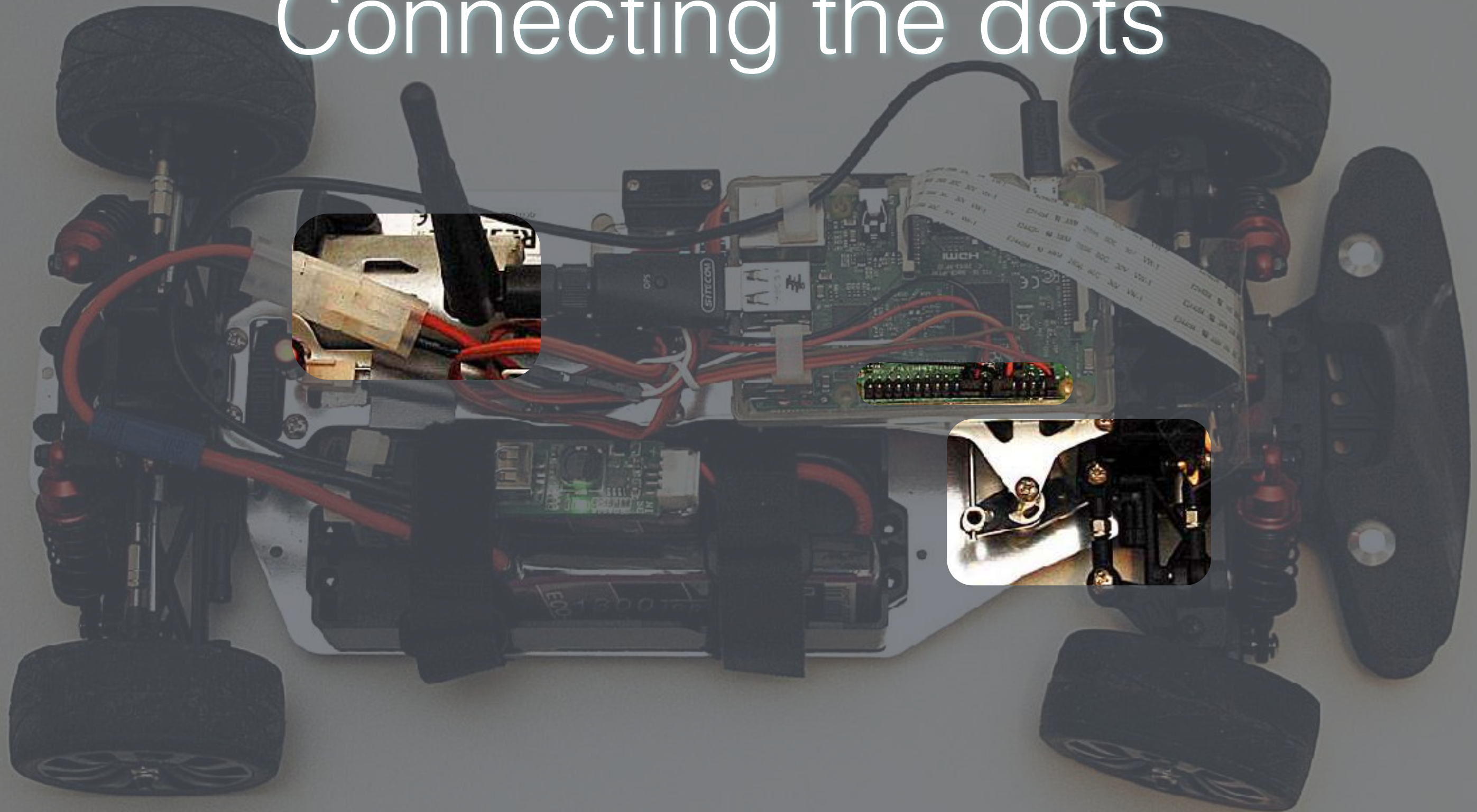
# Vert.x

- Toolkit for building reactive applications on the JVM
- Event-driven, non-blocking
- General purpose application framework
- Why Vert.x for our project?
  - Lightweight, fast
  - Polyglot
  - Distributed eventbus (browser included!)



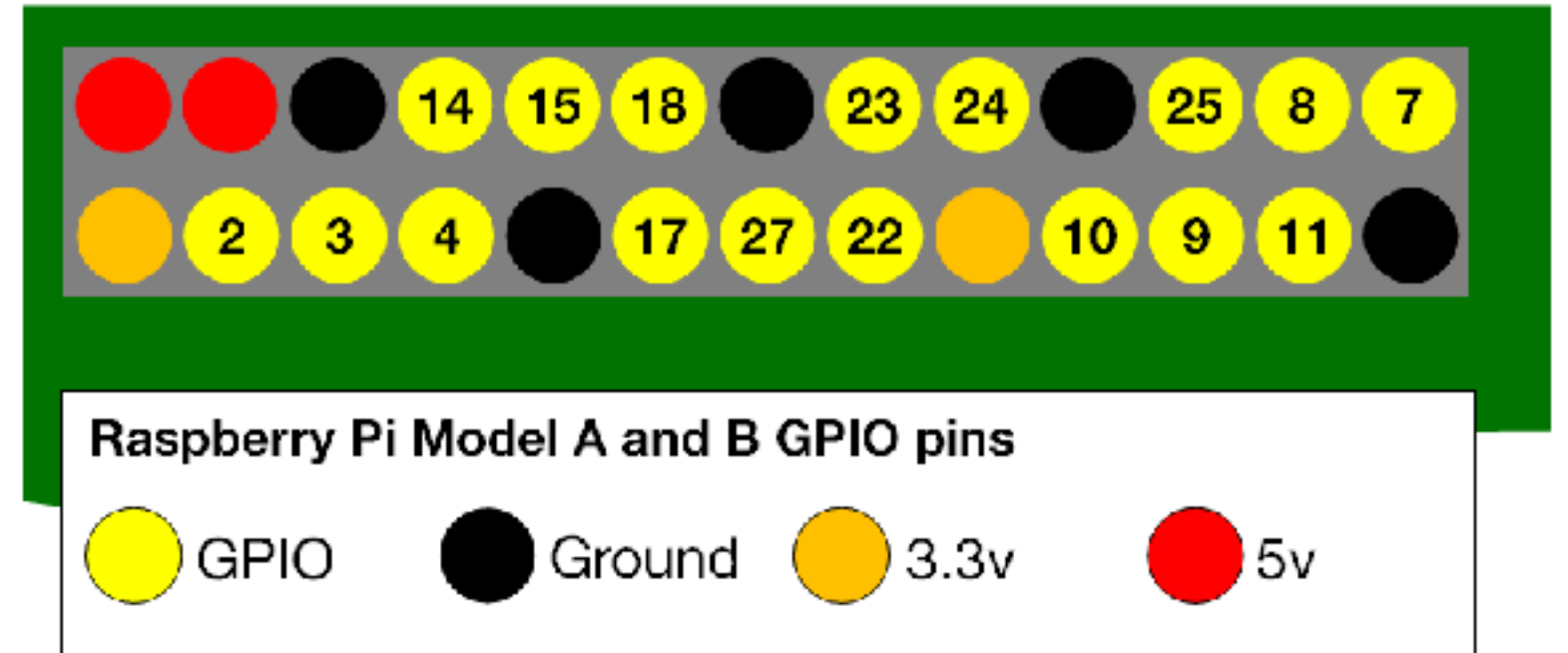
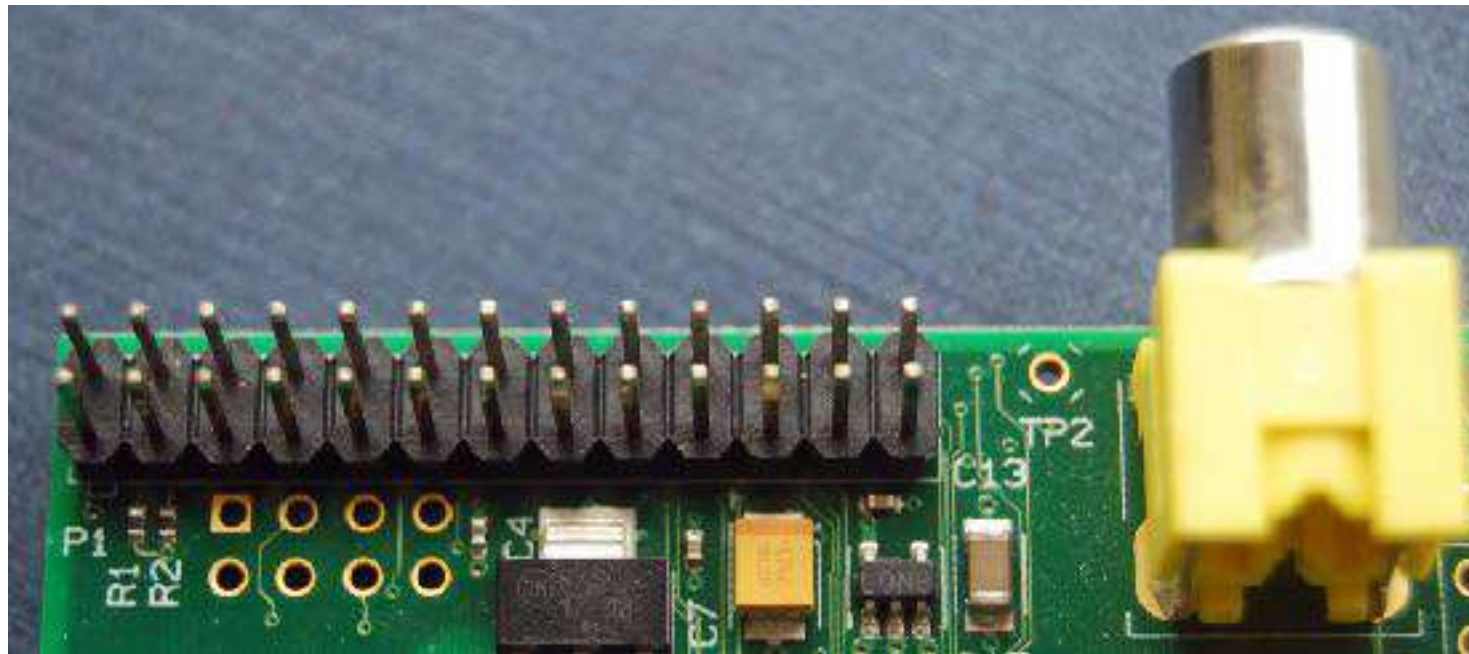
 Building microservices with Vert.x: <https://youtu.be/yLg-LPSRjho>

# Connecting the dots

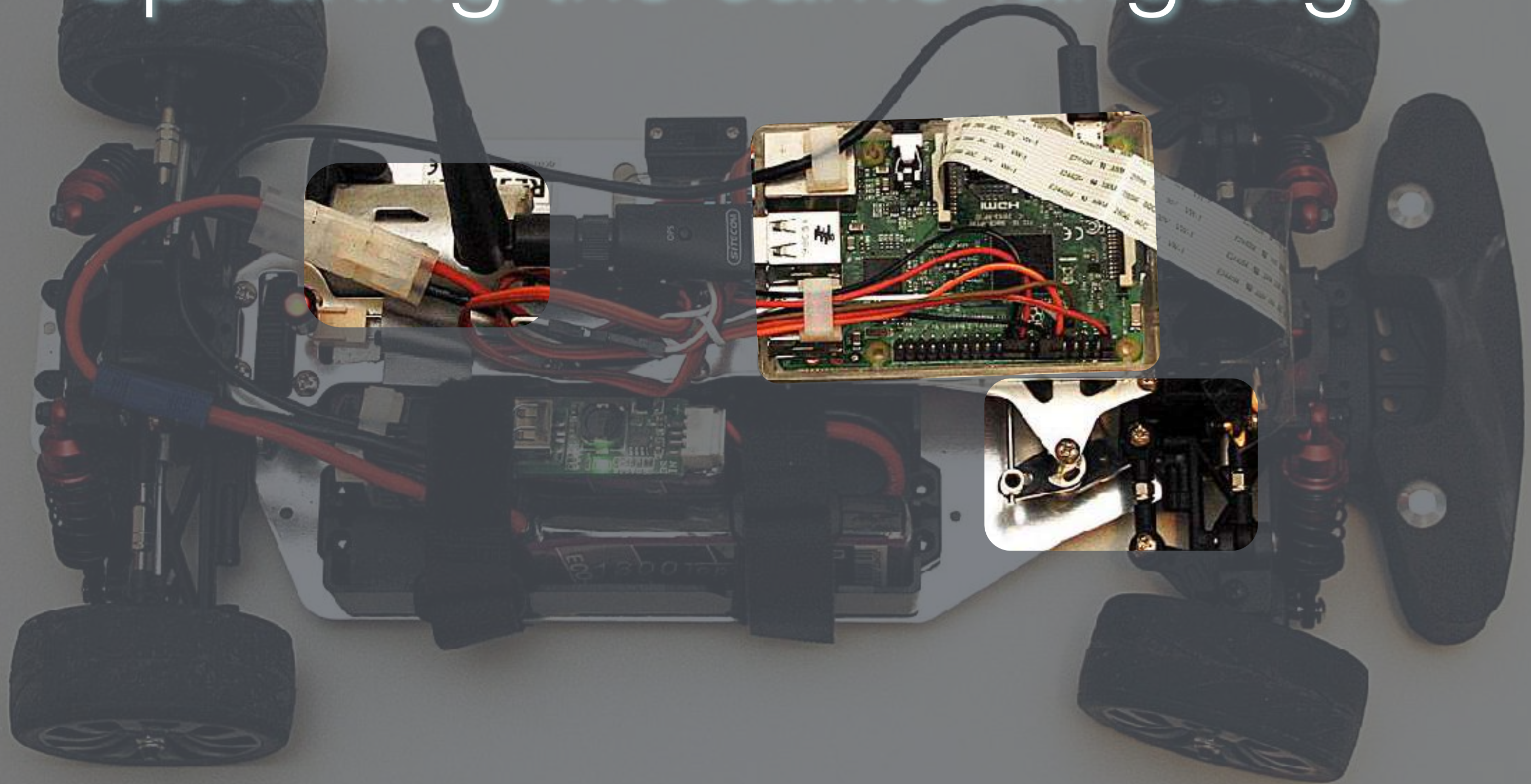


# GPIO

- General purpose input/output

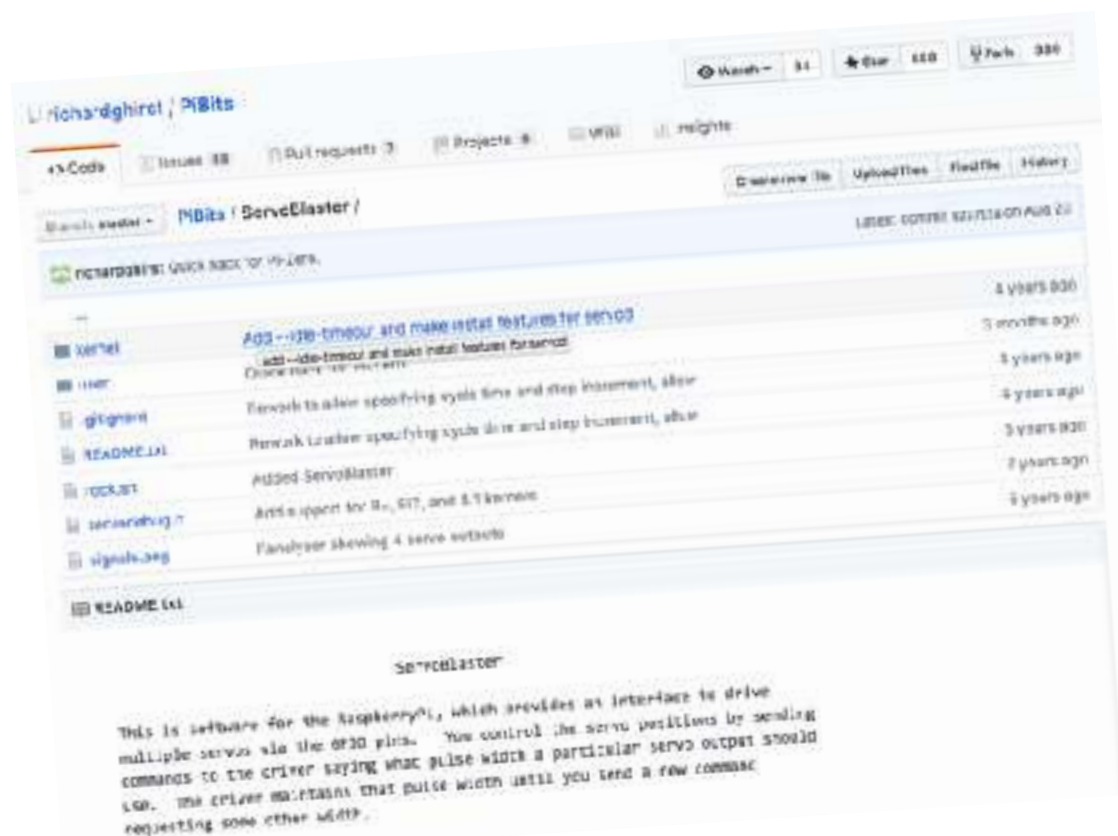


# Speaking the same language



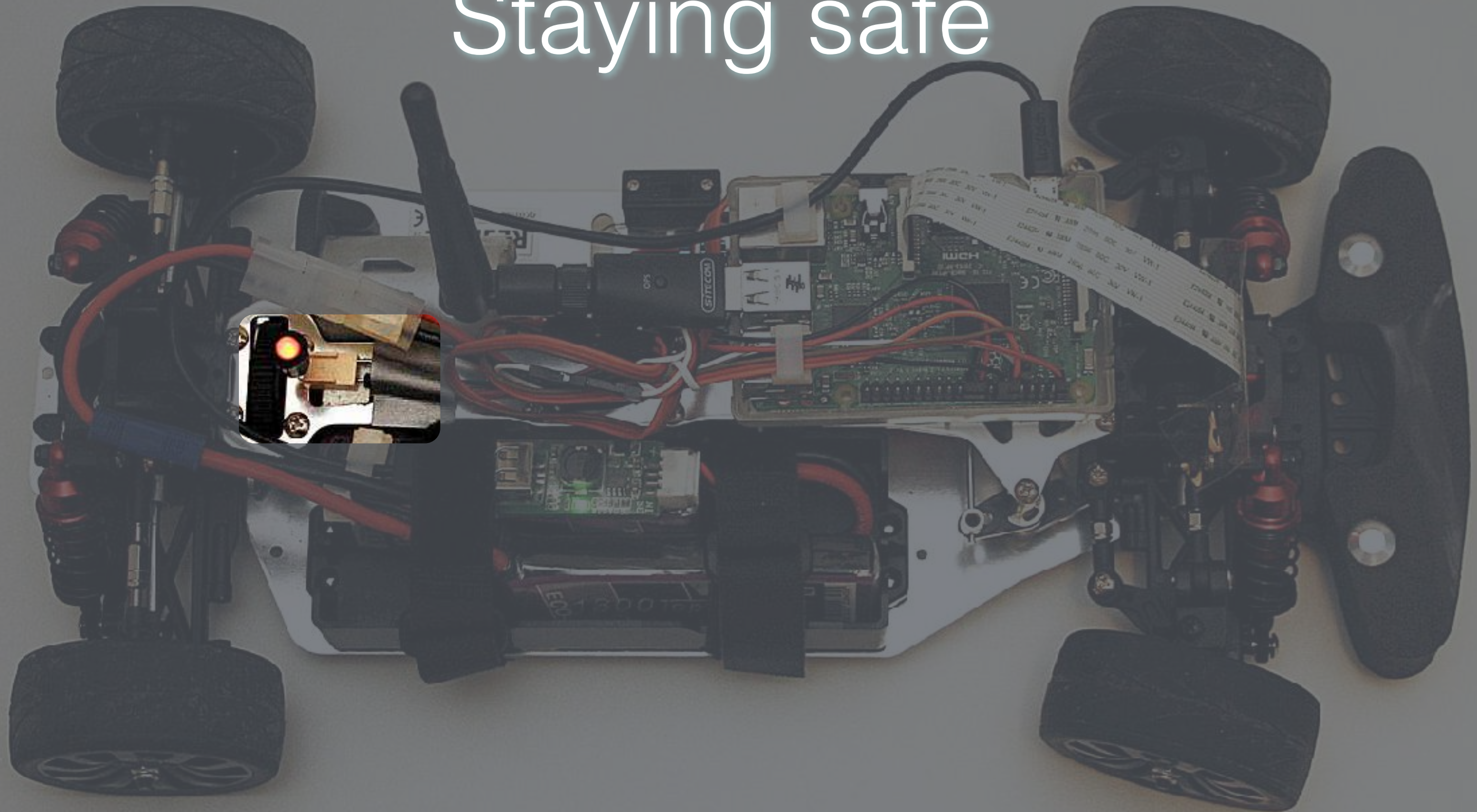
# PWM

- Pulse-width modulation, repeating pulses of variable width
- ServoBlaster: <https://github.com/richardghirst/PiBits/tree/master/ServoBlaster>



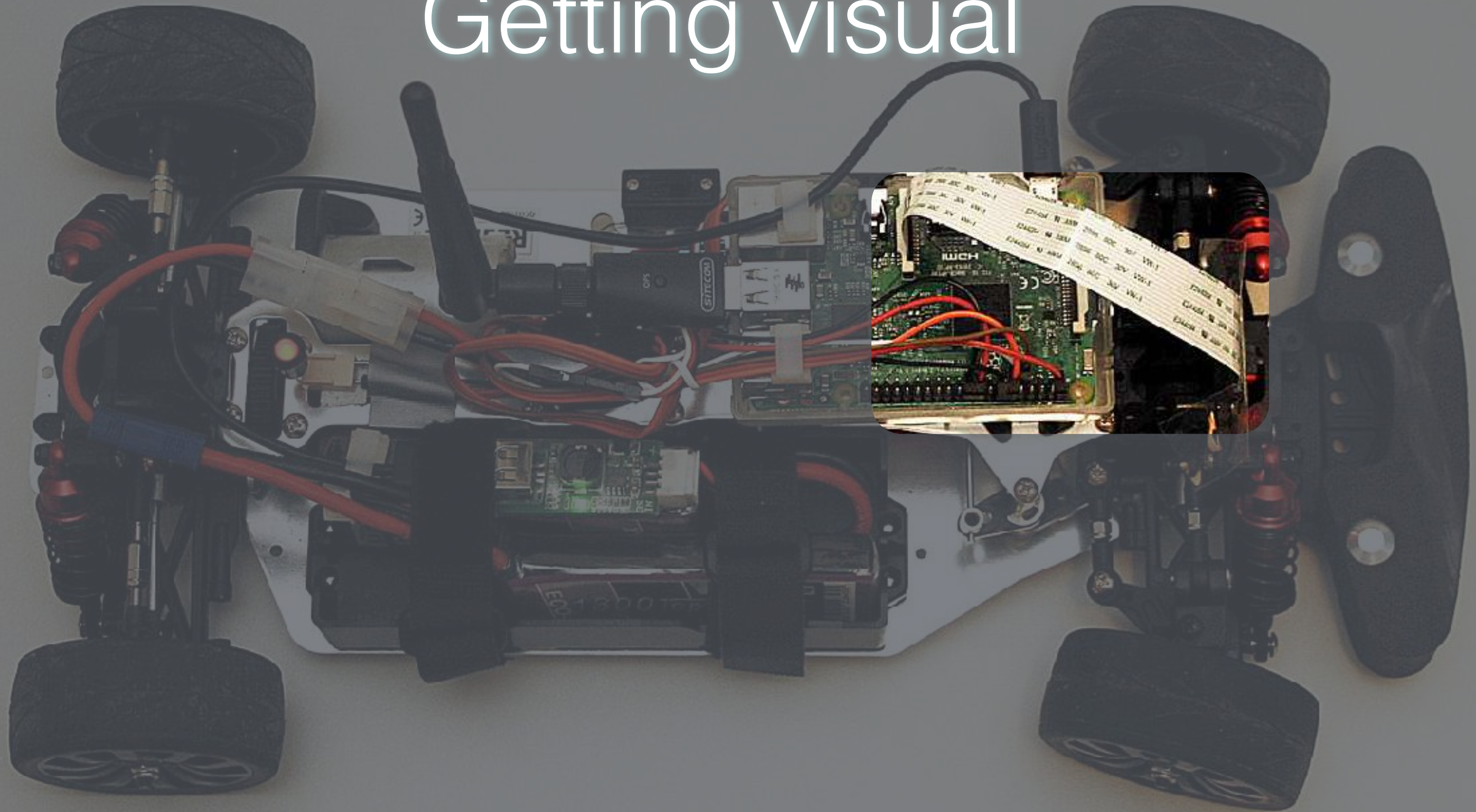
Servo number	GPIO number	Pin in P1 header
0	4	P1-7
1	17	P1-11
2	18	P1-12
3	21/27	P1-13
4	22	P1-15
5	23	P1-16
6	24	P1-18
7	25	P1-22

# Staying safe





# Getting visual



# RPi Cam Web Interface

- Web interface for the Raspberry Pi Camera module
- Video streaming
- Web interface to configure video settings

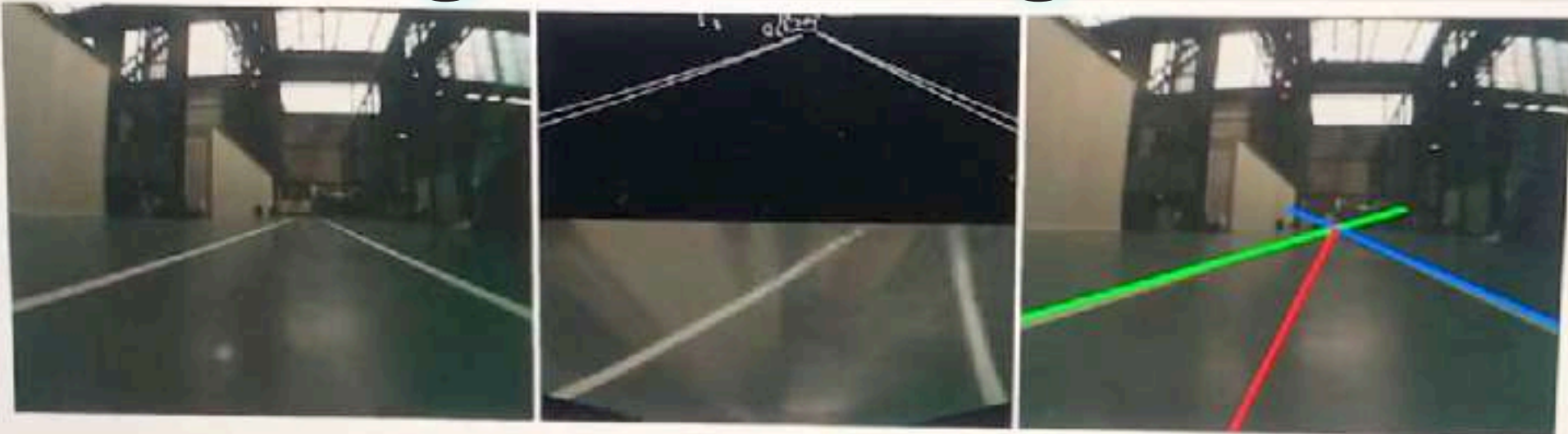
 [https://github.com/silvanmelchior/RPi\\_Cam\\_Web\\_Interface](https://github.com/silvanmelchior/RPi_Cam_Web_Interface)

# Ready for the road



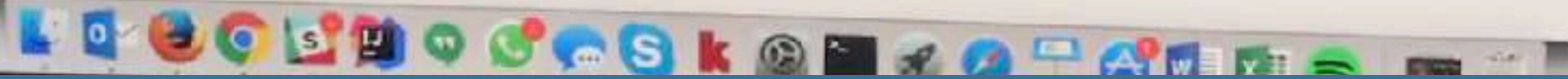
# Putting stuff together

up  
left | right  
down  
space (emergency stop, center steering)  
s:center steering)  
+ (brake)  
+ (enable autopilot)  
- (disable autopilot)  
Canny threshold 1: 60  
Canny threshold 2: 150  
www.cmtq



## Events

```
Fri Nov 03 2017 15:25:21 GMT+0100 (CET) [{"distanceRight":538.992970444948,"distanceMiddle":-8.152801358234362,"distanceLeft":505.72764531155264,"angle":13.589054789021332,"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}  
Fri Nov 03 2017 15:25:27 GMT+0100 (CET) [{"type":"servoDirect","position":0.0}  
Fri Nov 03 2017 15:25:37 GMT+0100 (CET) [{"distanceRight":538.902497391214,"distanceMiddle":-7.50277584154751,"distanceLeft":508.12988276217387,"angle":13.33135216007867,"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}  
Fri Nov 03 2017 15:25:37 GMT+0100 (CET) [{"type":"servoDirect","position":0.0}  
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Fri Nov 03 2017 15:25:37 GMT+0100 (CET) [{"type":"servoDirect","position":-18.024791413342137}  
Fri Nov 03 2017 15:25:37 GMT+0100 (CET) [{"distanceRight":675.3724080813097,"distanceMiddle":-50.8883626363628,"distanceLeft":451.39931923101786,"angle":24.764882212977216,"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}  
Fri Nov 03 2017 15:25:38 GMT+0100 (CET) [{"distanceRight":687.4806858465392,"distanceMiddle":-23.85404393604397,"distanceLeft":460.89280242008074,"angle":25.381618211948028,"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}  
Fri Nov 03 2017 15:25:38 GMT+0100 (CET) [{"type":"servoDirect","position":0.0}  
Fri Nov 03 2017 15:25:38 GMT+0100 (CET) [{"distanceRight":848.8093209119953,"distanceMiddle":-20.191506810256446,"distanceLeft":456.05599938082316,"angle":24.632821638755815,"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}  
Fri Nov 03 2017 15:25:38 GMT+0100 (CET) [{"type":"servoDirect","position":18.554431453231112}  
Fri Nov 03 2017 15:25:38 GMT+0100 (CET) [{"distanceRight":558.1879691088502,"distanceMiddle":19.429292929295013,"distanceLeft":476.4187887639826,"angle":17.123261040417923,"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}  
Fri Nov 03 2017 15:25:38 GMT+0100 (CET) [{"distanceRight":548.6386602234483,"distanceMiddle":-10.35246653932185,"distanceLeft":505.2059755881982,"angle":14.2691939707627,"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}  
Fri Nov 03 2017 15:25:38 GMT+0100 (CET) [{"type":"servoDirect","position":0.0}
```

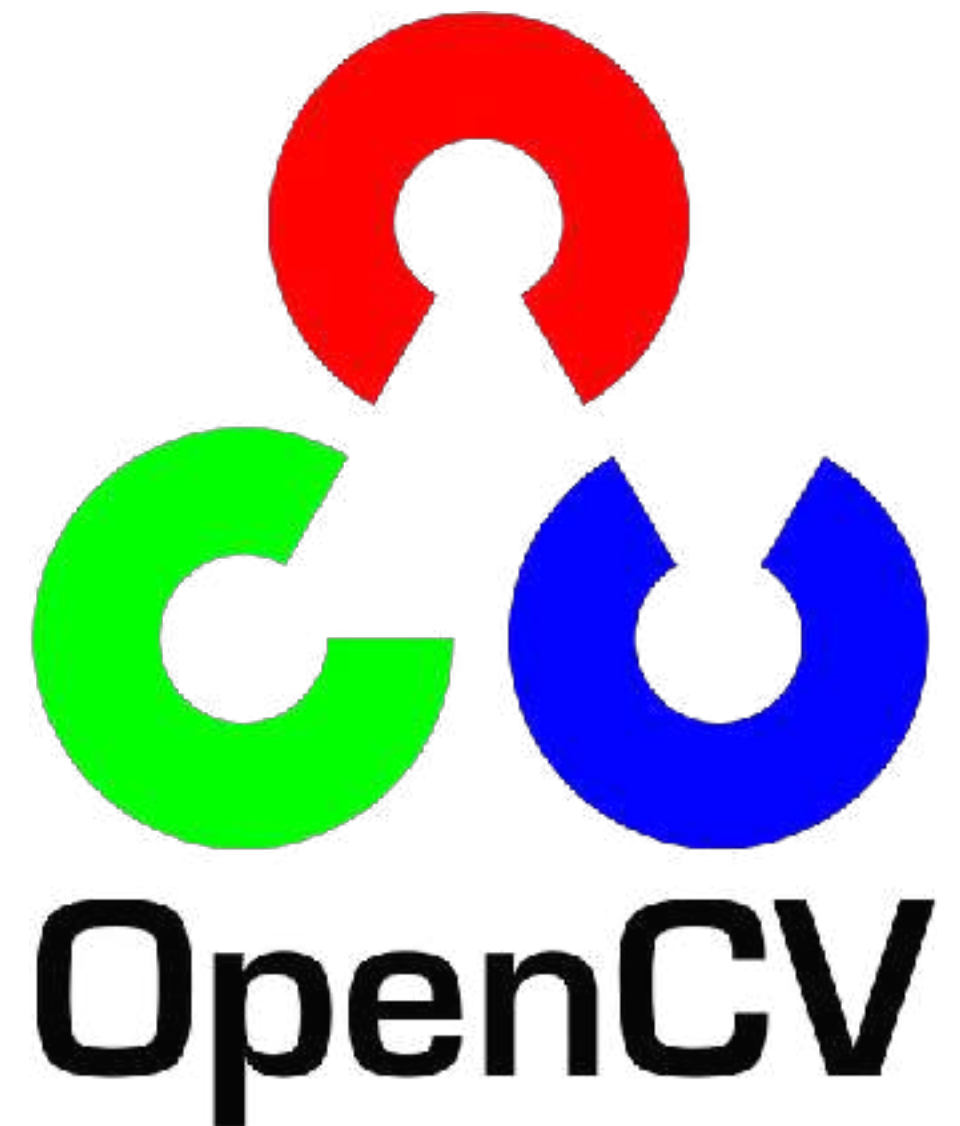


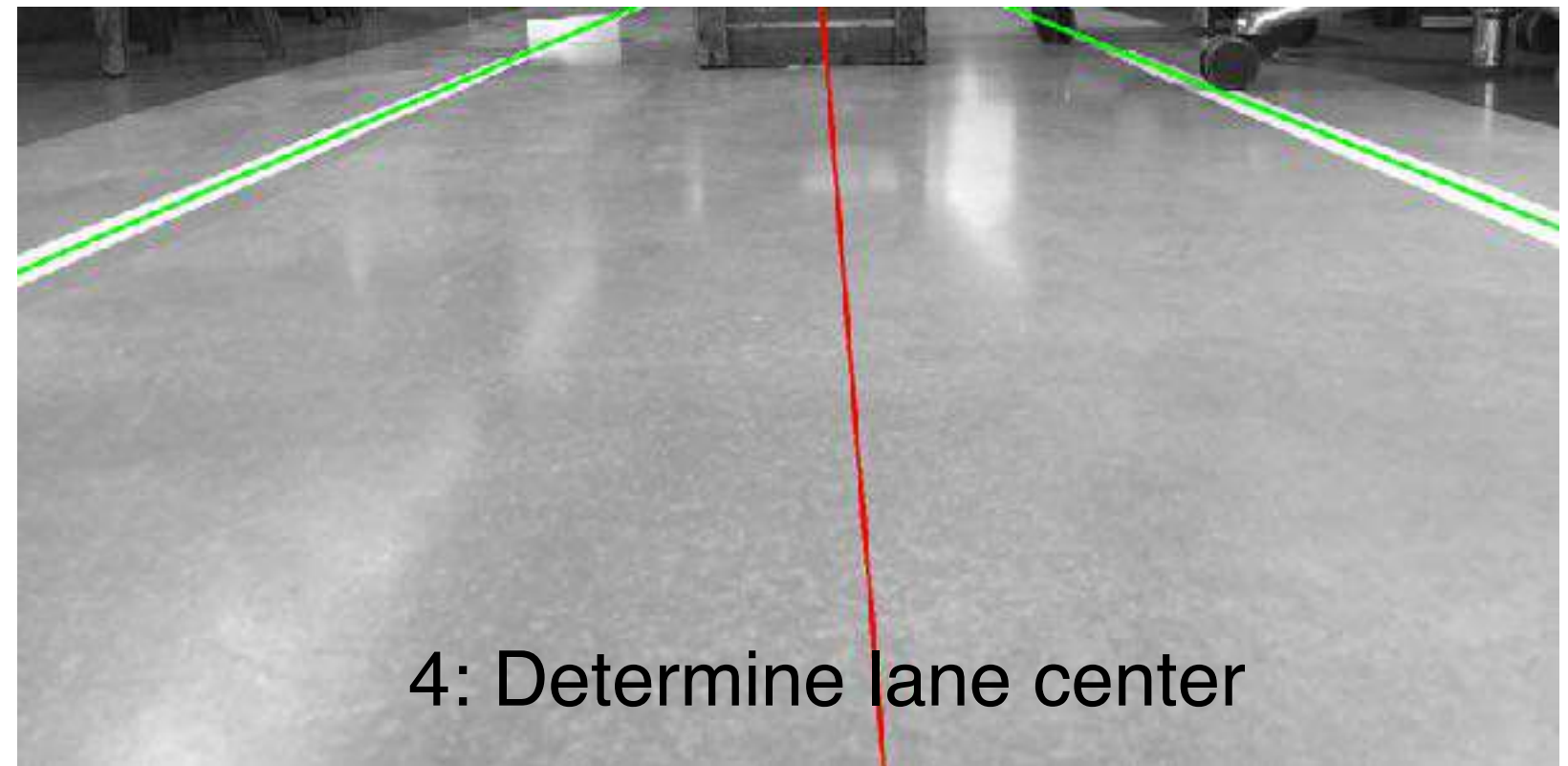
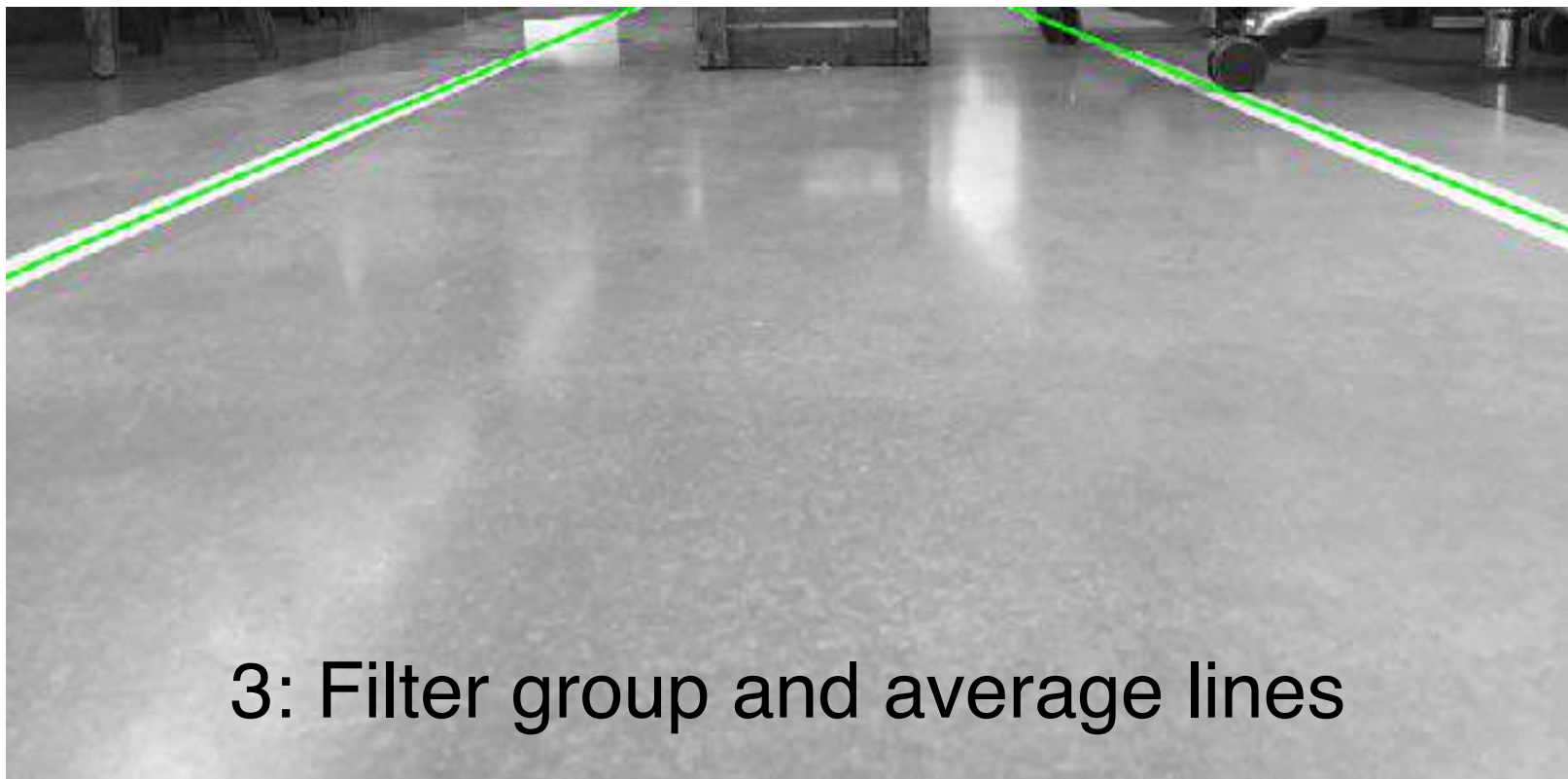
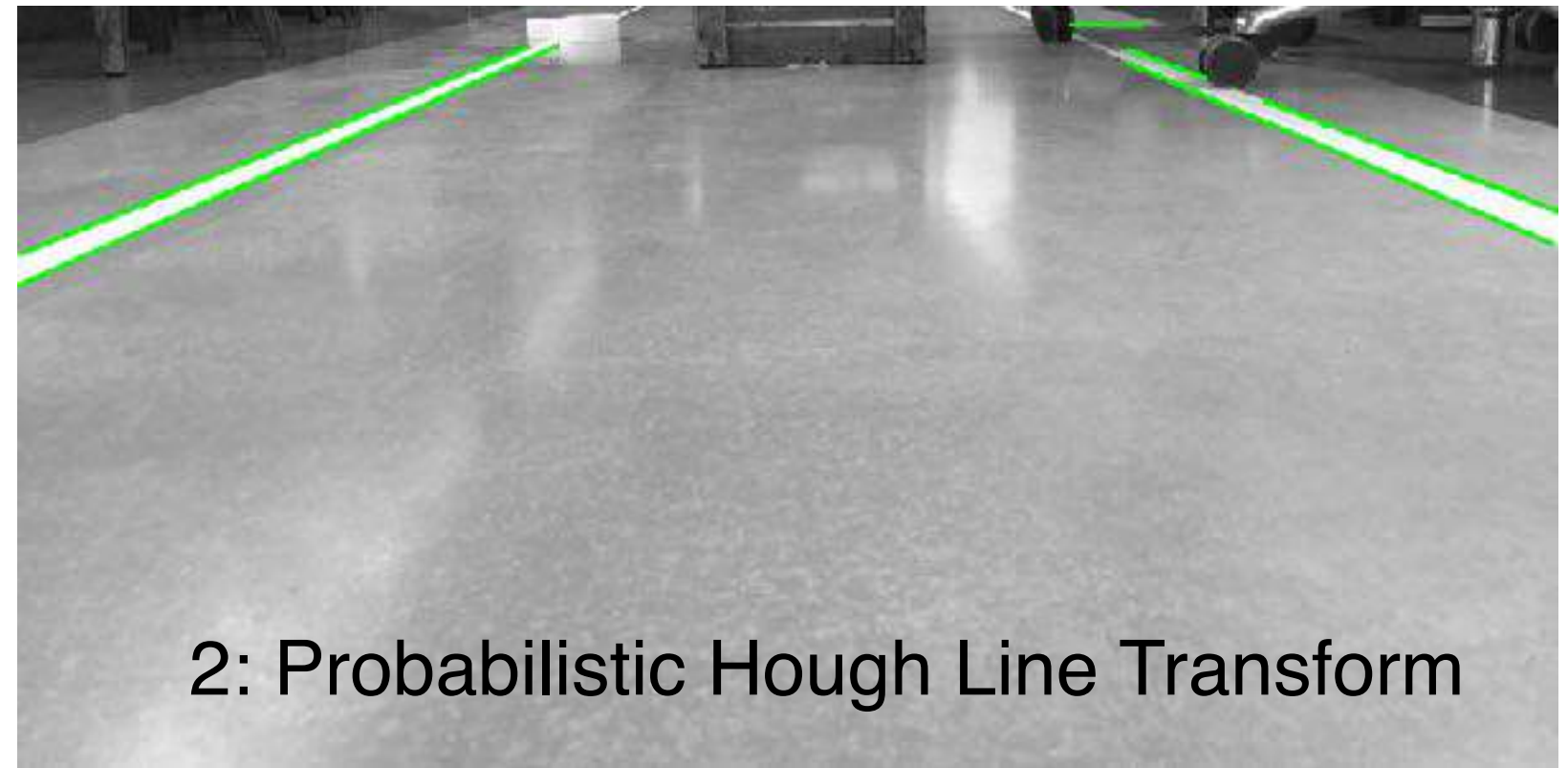
# Learning to drive...



# OpenCV

- Open source computer vision and machine learning library written in C++ with Java interfaces
- Optimised algorithms for computer vision
- Most widely used computer vision library
- Many resources available

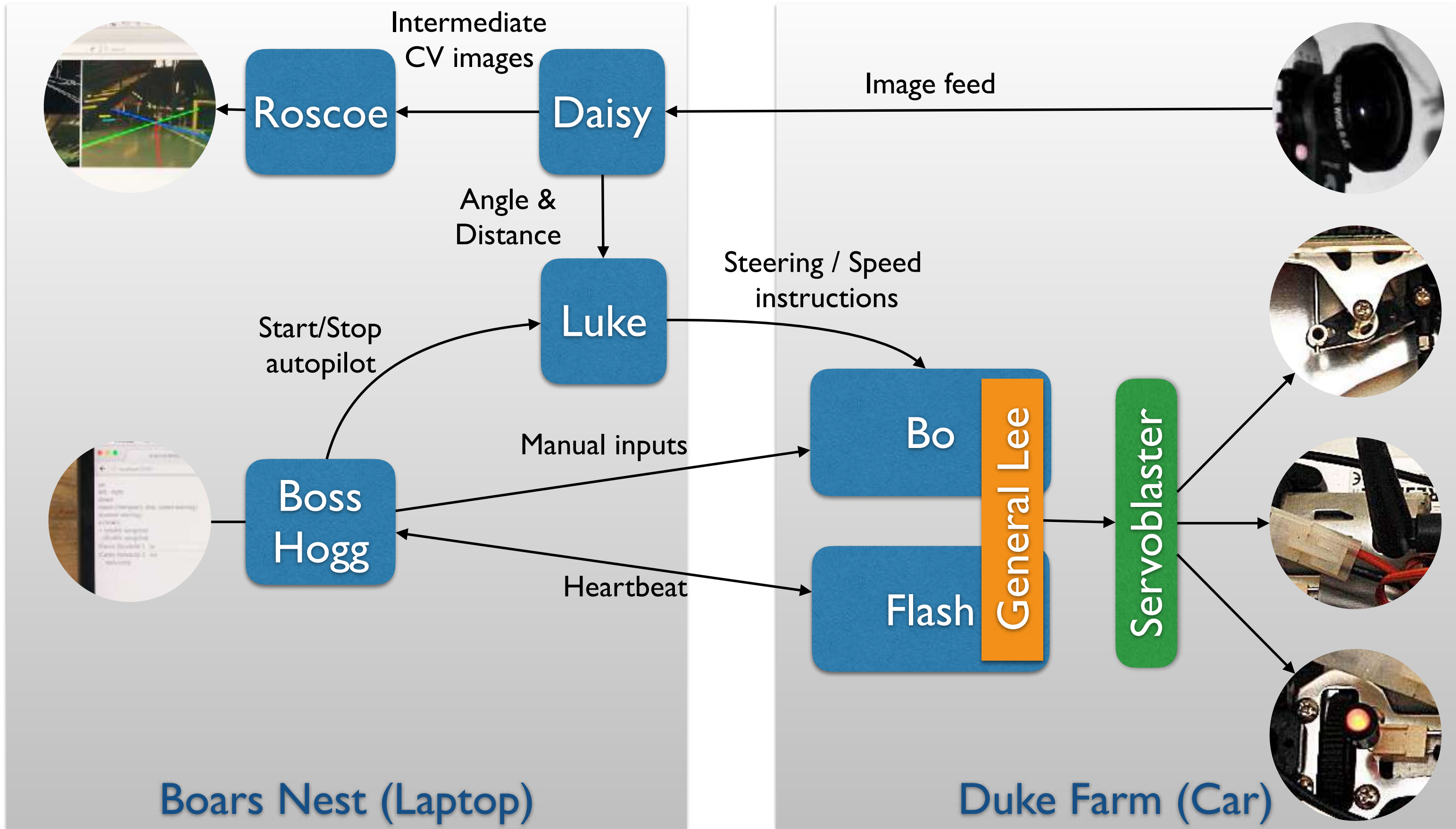




# Show me some code...





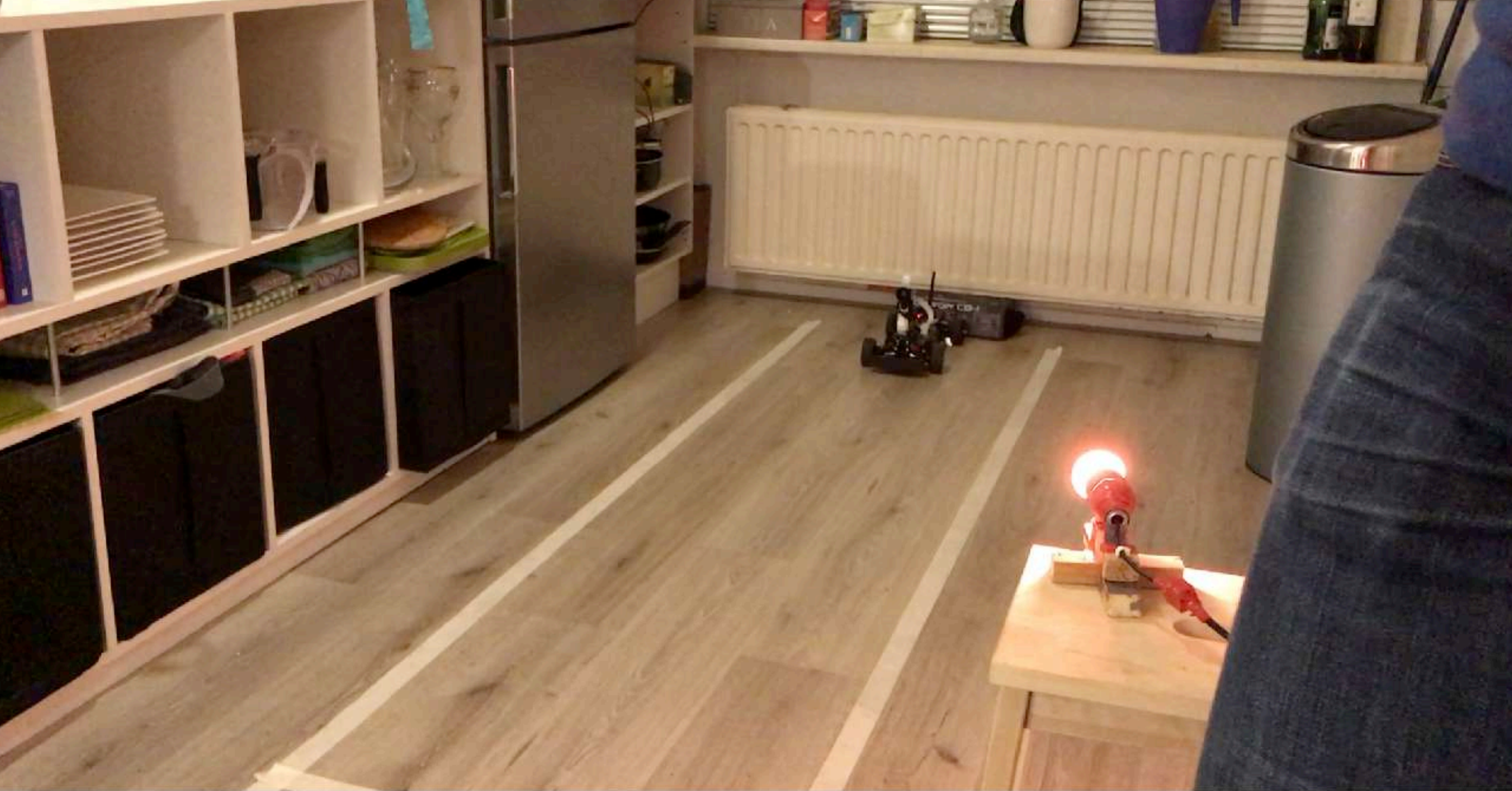


# Expectation

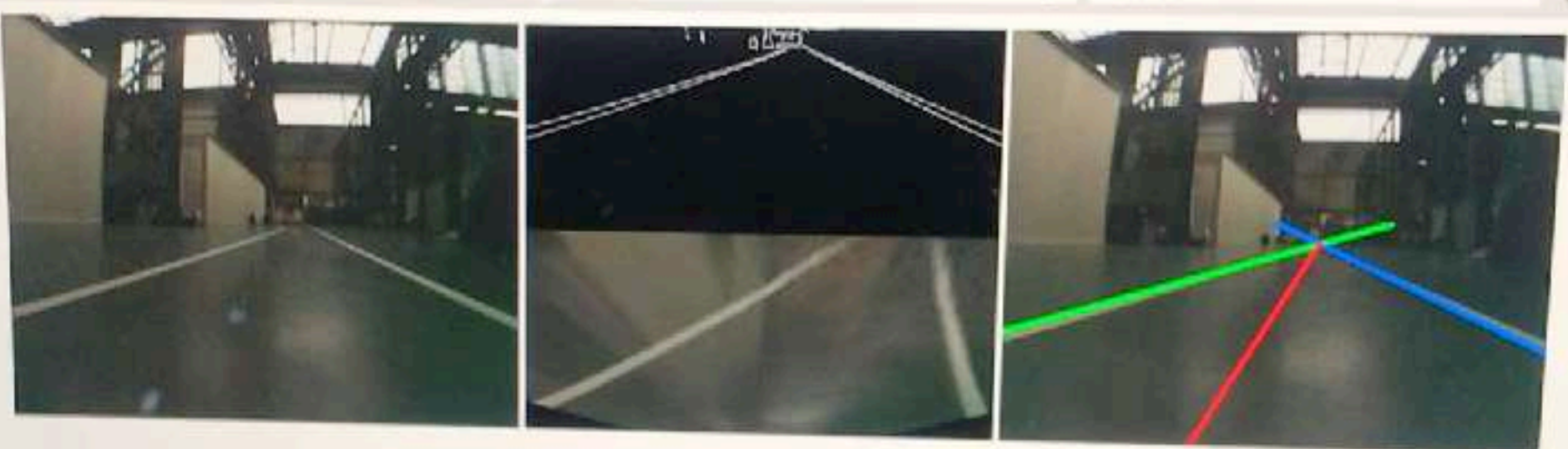


# Reality



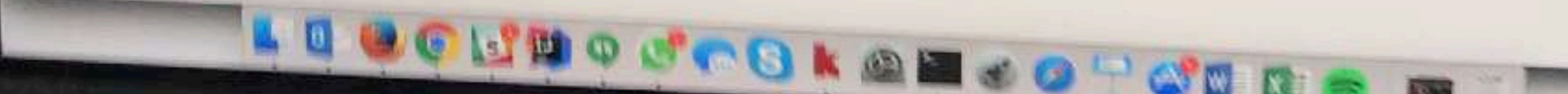


up  
left right  
down  
space (emergency stop, center steering)  
z (center steering)  
w (brake)  
+ (enable autopilot)  
- (disable autopilot)  
Camera threshold 1: 80  
Camera threshold 2: 100  
Auto center



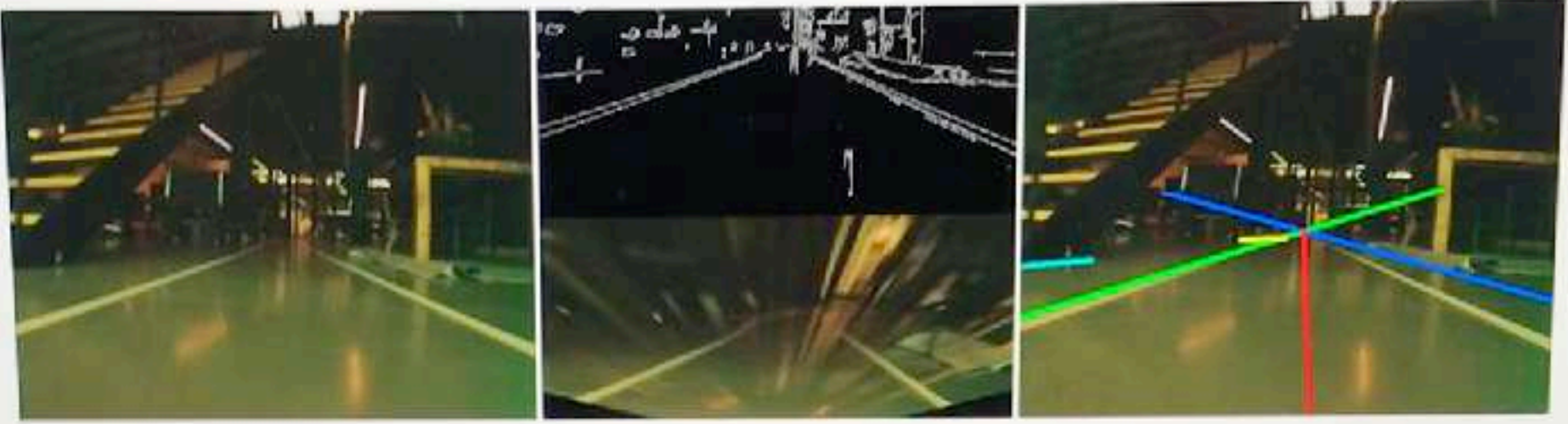
### Events

```
2017-11-03 15:25:36 GMT+0100 (CET) [{"distanceRight":546.1100510700982,"distanceMidline":-9.801961199222048,"distanceLeft":505.81448104995896,"angle":14.06342822263987,  
"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}  
2017-11-03 15:25:36 GMT+0100 (CET) [{"type":"servobias","position":0.0}]  
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"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}  
2017-11-03 15:25:36 GMT+0100 (CET) [{"distanceRight":596.1640149634765,"distanceMidline":-73.90106951071455,"distanceLeft":394.37830054465446,"angle":29.691233078993425,  
"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}  
2017-11-03 15:25:36 GMT+0100 (CET) [{"distanceRight":621.2801078998122,"distanceMidline":-37.19911945811948,"distanceLeft":394.37830054465446,"angle":29.691233078993425,  
"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}  
2017-11-03 15:25:36 GMT+0100 (CET) [{"type":"servobias","position":-16.414344812504977}]  
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"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}  
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"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}  
2017-11-03 15:25:36 GMT+0100 (CET) [{"type":"servobias","position":-18.774128133830217}]  
2017-11-03 15:25:36 GMT+0100 (CET) [{"distanceRight":681.5428278880496,"distanceMidline":-7.07244276815881,"distanceLeft":508.44207198802084,"angle":13.055247022196184,  
"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}  
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2017-11-03 15:25:36 GMT+0100 (CET) [{"type":"servobias","position":-18.774128133830217}]  
2017-11-03 15:25:36 GMT+0100 (CET) [{"distanceRight":681.5428278880496,"distanceMidline":-7.07244276815881,"distanceLeft":508.44207198802084,"angle":13.055247022196184,  
"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}  
2017-11-03 15:25:36 GMT+0100 (CET) [{"type":"servobias","position":-18.774128133830217}]  
2017-11-03 15:25:36 GMT+0100 (CET) [{"distanceRight":681.5428278880496,"distanceMidline":-7.07244276815881,"distanceLeft":508.44207198802084,"angle":13.055247022196184,  
"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}
```





up  
 left / right  
 down  
 space (emergency stop, center steering)  
 x (center steering)  
 s (brake)  
 + (enable autopilot)  
 - (disable autopilot)  
 Canny threshold 1: 50  
 Canny threshold 2: 150  
 Apply settings

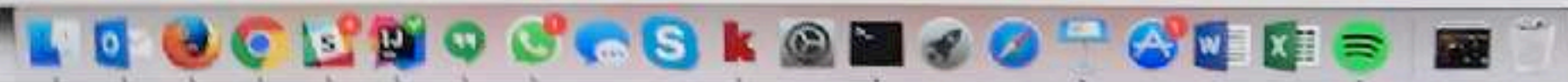


### Events

```

Fri Nov 03 2017 13:48:45 GMT+0100 (CET) [{"distanceToStoppingZone":170.74150657928836,"distanceMiddle":-62.642837142857224,"distanceLeft":
-452.9110530941131,"angle":-15.94539950922879,"distanceToStoppingZoneEnd":166.66883023733982,"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present
":true}}}
Fri Nov 03 2017 13:48:45 GMT+0100 (CET) [{"distanceToStoppingZone":173.9919920393468,"distanceMiddle":-65.60181819181818,"distanceLeft":
-451.33064150734807,"angle":24.44395475041652,"distanceToStoppingZoneEnd":187.76352135398454,"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}
Fri Nov 03 2017 13:48:45 GMT+0100 (CET) [{"type":"accv0Driver","position":18.33296085313397}
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-450.1135101732142,"angle":26.22396467392253,"distanceToStoppingZoneEnd":181.0175804591265,"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}
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"angle":-16.026243461806496,"distanceToStoppingZoneEnd":181.0615073718888,"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}
Fri Nov 03 2017 13:48:45 GMT+0100 (CET) [{"type":"accv0Driver","position":13.688357281222025}
Fri Nov 03 2017 13:48:45 GMT+0100 (CET) [{"distanceToStoppingZone":177.238254811309,"distanceMiddle":-101.71290769230766,"distanceLeft":
-452.1053888147845,"angle":132.08503310229834,"distanceToStoppingZoneEnd":179.89394297881149,"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present
":true}}}
Fri Nov 03 2017 13:48:45 GMT+0100 (CET) [{"distanceToStoppingZone":178.1670177645006,"distanceMiddle":-18.5,"distanceLeft":398.7975015625,"angle":
-10.0,"distanceToStoppingZoneEnd":184.73767481638518,"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}
Fri Nov 03 2017 13:48:45 GMT+0100 (CET) [{"type":"accv0Driver","position":70.07}
Fri Nov 03 2017 13:48:45 GMT+0100 (CET) [{"distanceToStoppingZone":167.98166049229819,"distanceMiddle":-47.1101058813202,"distanceLeft":
-449.794474818015,"angle":-10.28833511788882,"distanceToStoppingZoneEnd":188.76788818335285,"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present
":true}}}
Fri Nov 03 2017 13:48:45 GMT+0100 (CET) [{"distanceToStoppingZone":116.45761044444441,"distanceMiddle":-58.1480523809522,"distanceLeft":
-450.08044410437,"angle":122.248850116301889,"distanceToStoppingZoneEnd":122.83836383838383,"lane":{"leftBoundary":{"present":true},"rightBoundary":{"present":true}}}
Fri Nov 03 2017 13:48:45 GMT+0100 (CET) [{"type":"accv0Driver","position":16.48517811720035}

```

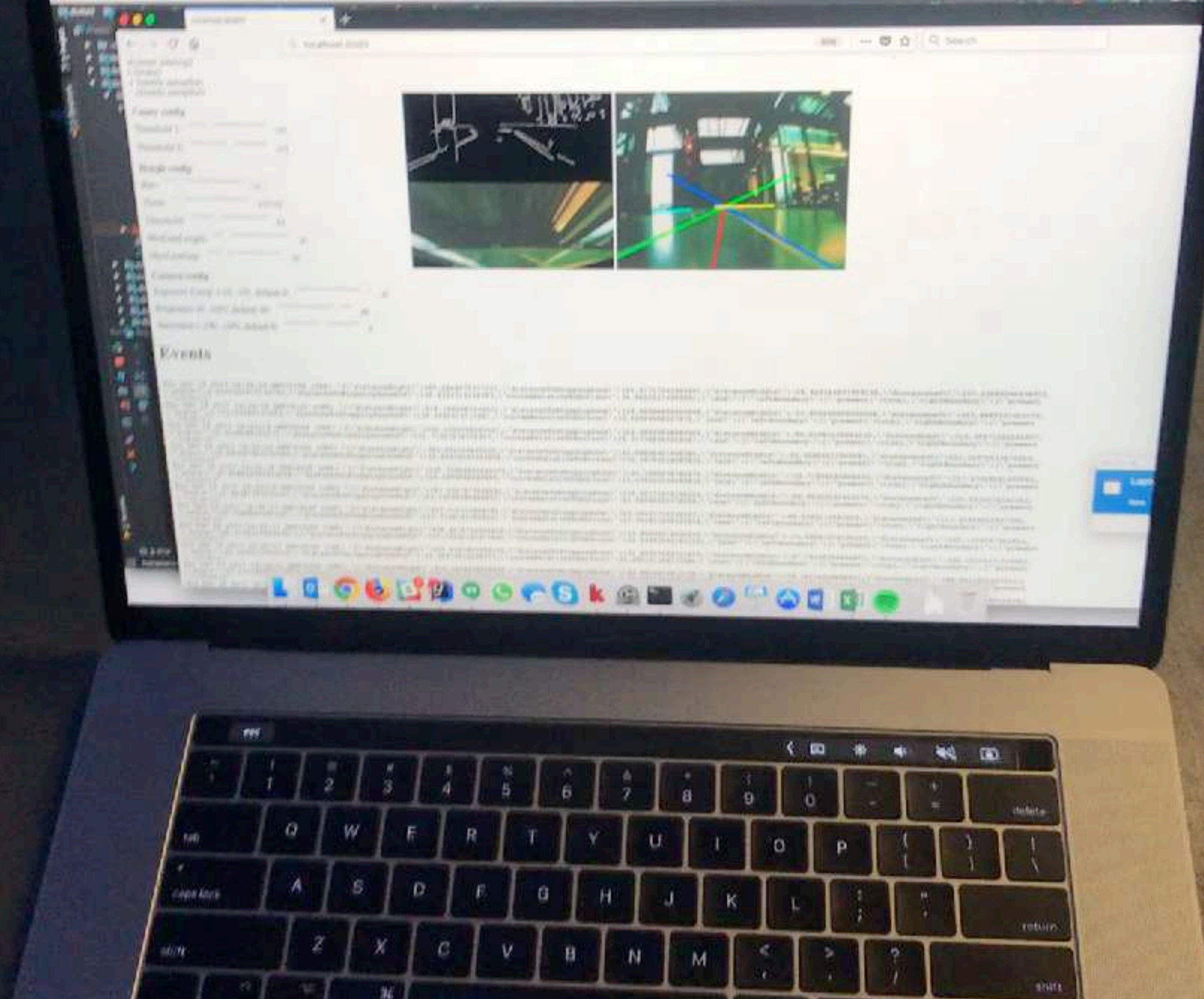


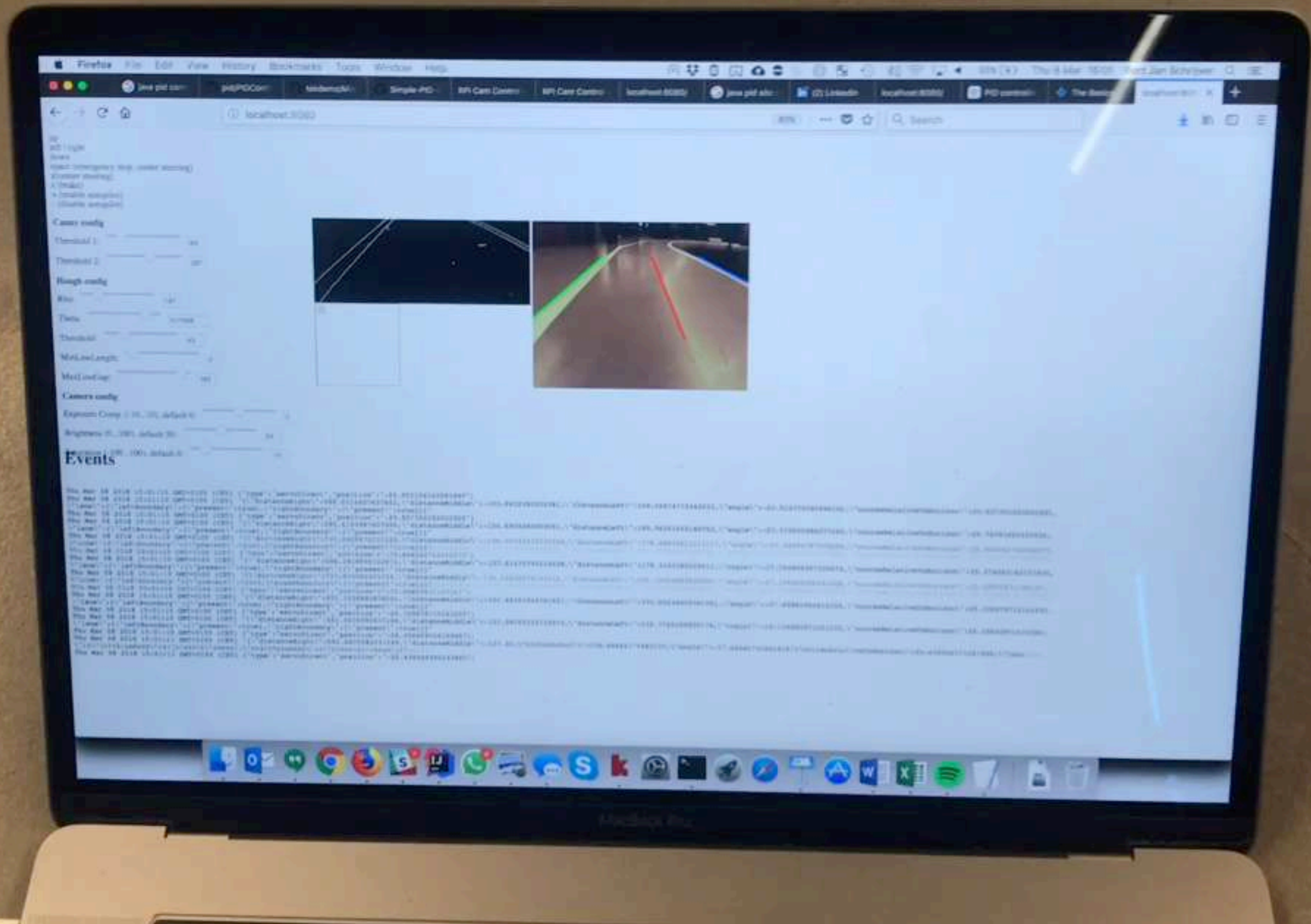




# Let's race!







# In the real world



## LEVEL 0



There are no autonomous features.

## LEVEL 1



These cars can handle one task at a time, like automatic braking.

## LEVEL 2



These cars would have at least two automated functions.

## LEVEL 3



These cars handle “dynamic driving tasks” but might still need intervention.

## LEVEL 4

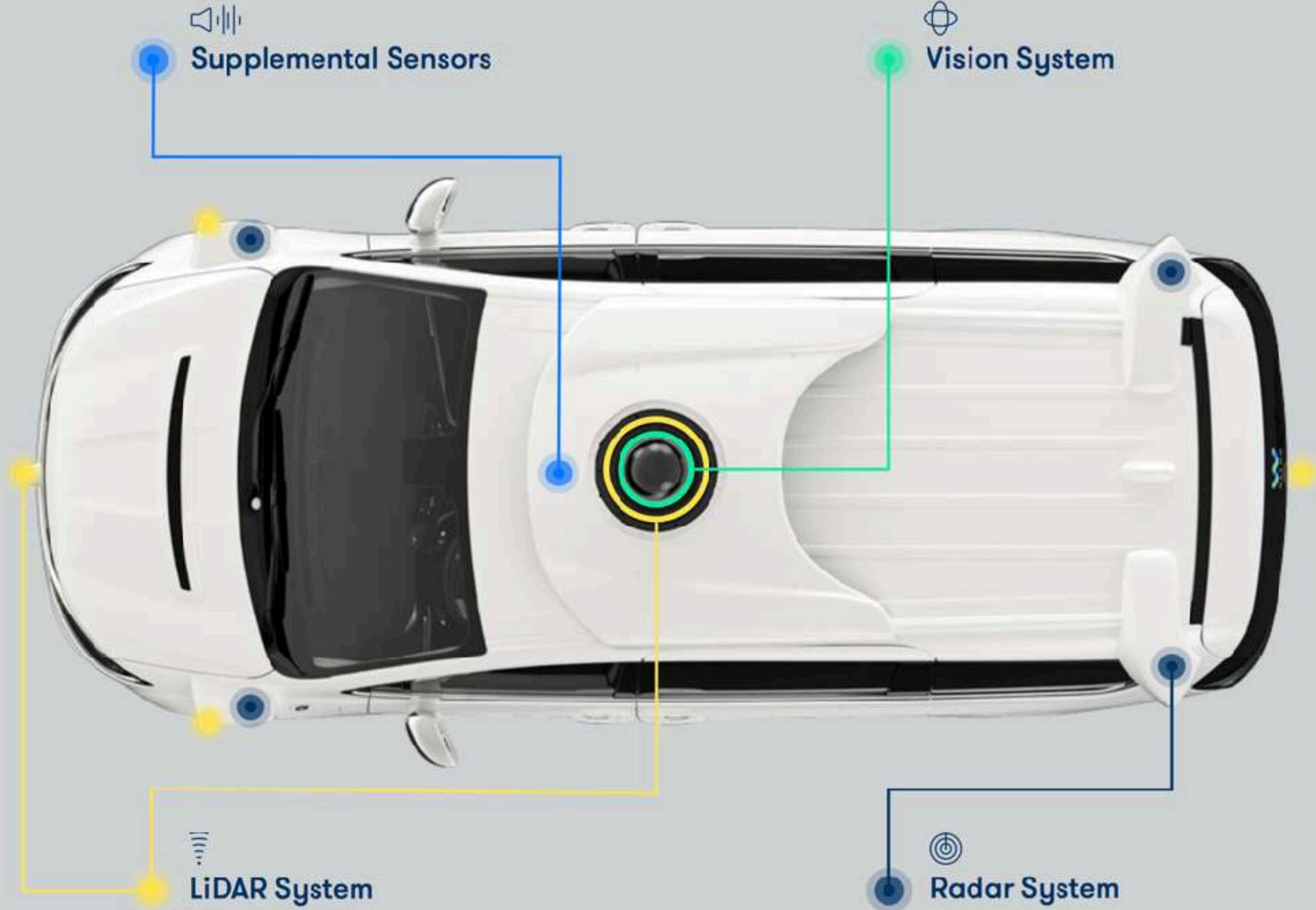


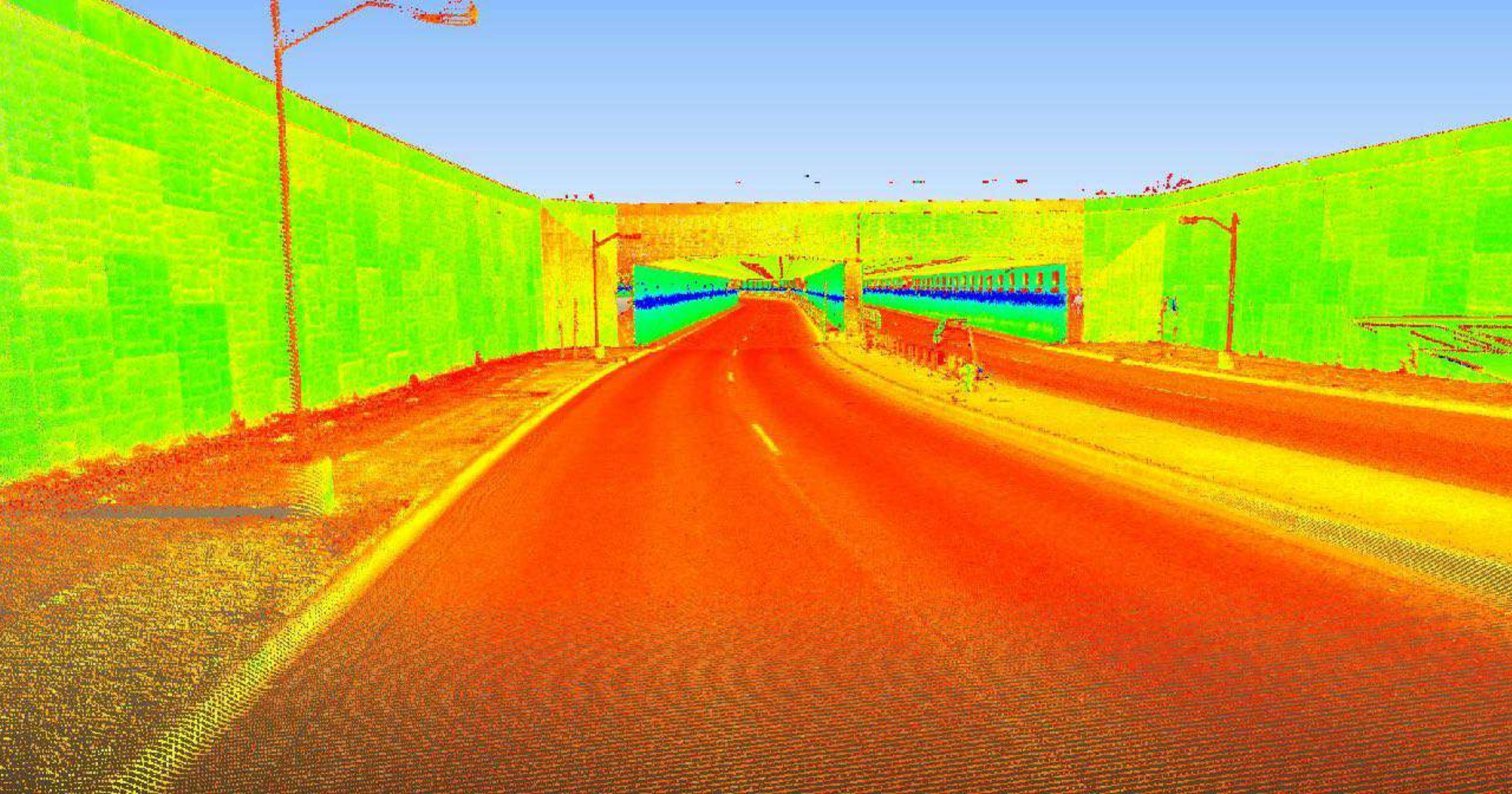
These cars are officially driverless in certain environments.

## LEVEL 5



These cars can operate entirely on their own without any driver presence.





**Rearward Looking Side Cameras**  
Max distance 100m

**Wide Forward Camera**  
Max distance 60m

**Main Forward Camera**  
Max distance 150m

**Narrow Forward Camera**  
Max distance 250m



**Rear View Camera**  
Max distance 50m

**Ultrasonics**  
Max distance 8m

**Forward Looking Side Cameras**  
Max distance 80m

**Radar**  
Max distance 160m





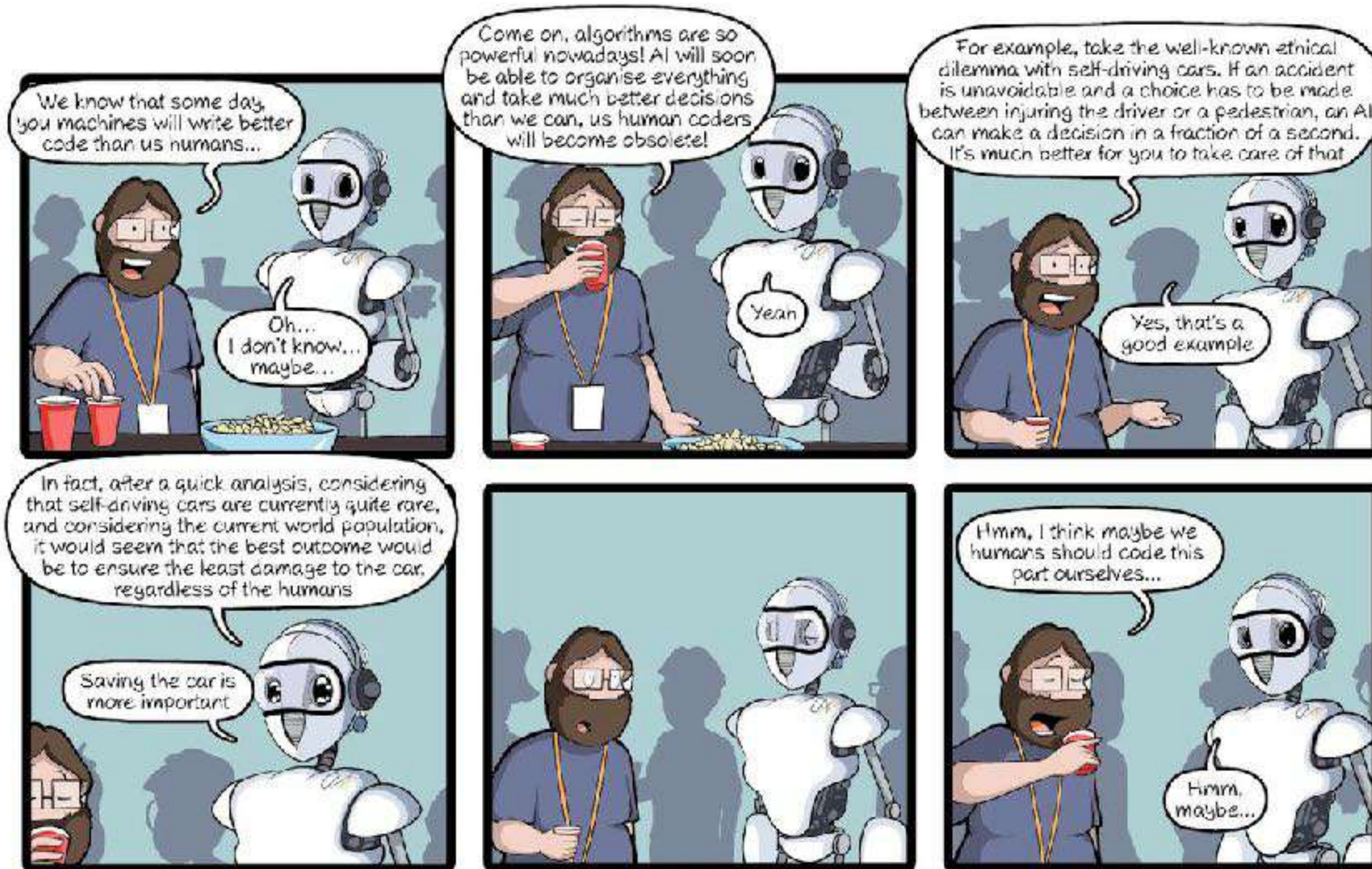
# Examples of safety measures

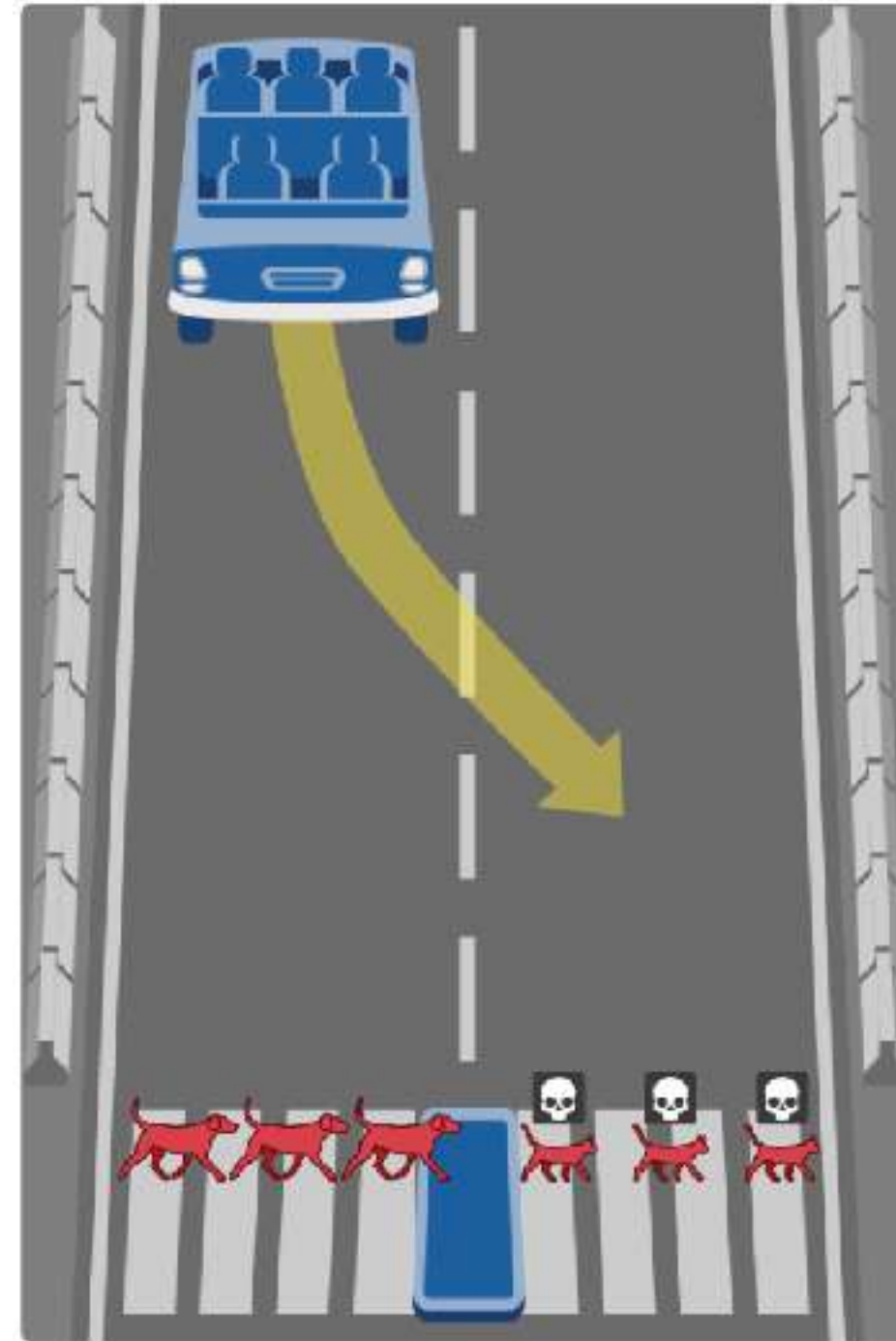
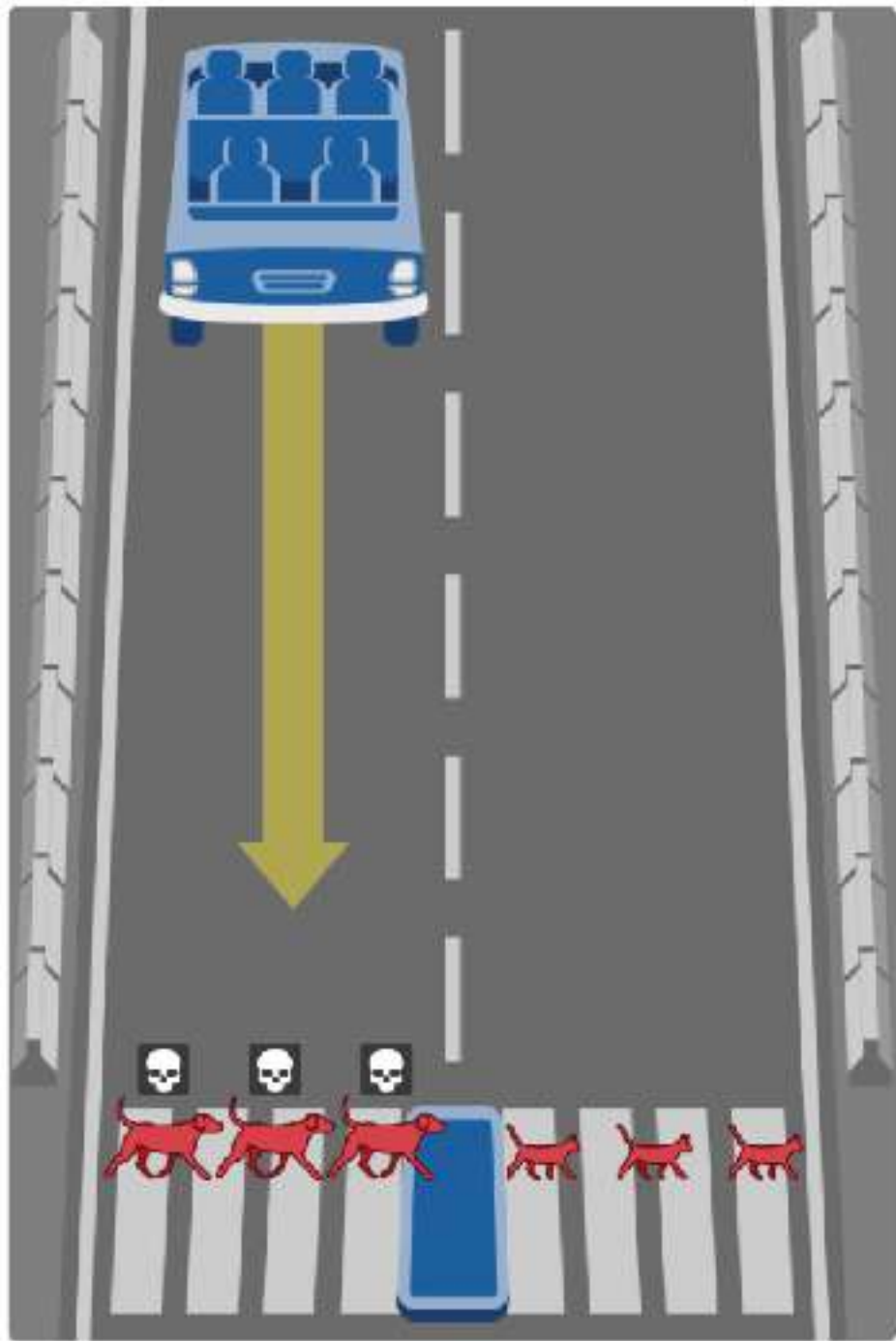
- Geographic area limitation
- Strictly defined conditions
- Redundancy
- Multiple sensors
- Isolating control systems
- Human intervention fallback

# Weakness of AI for computer vision

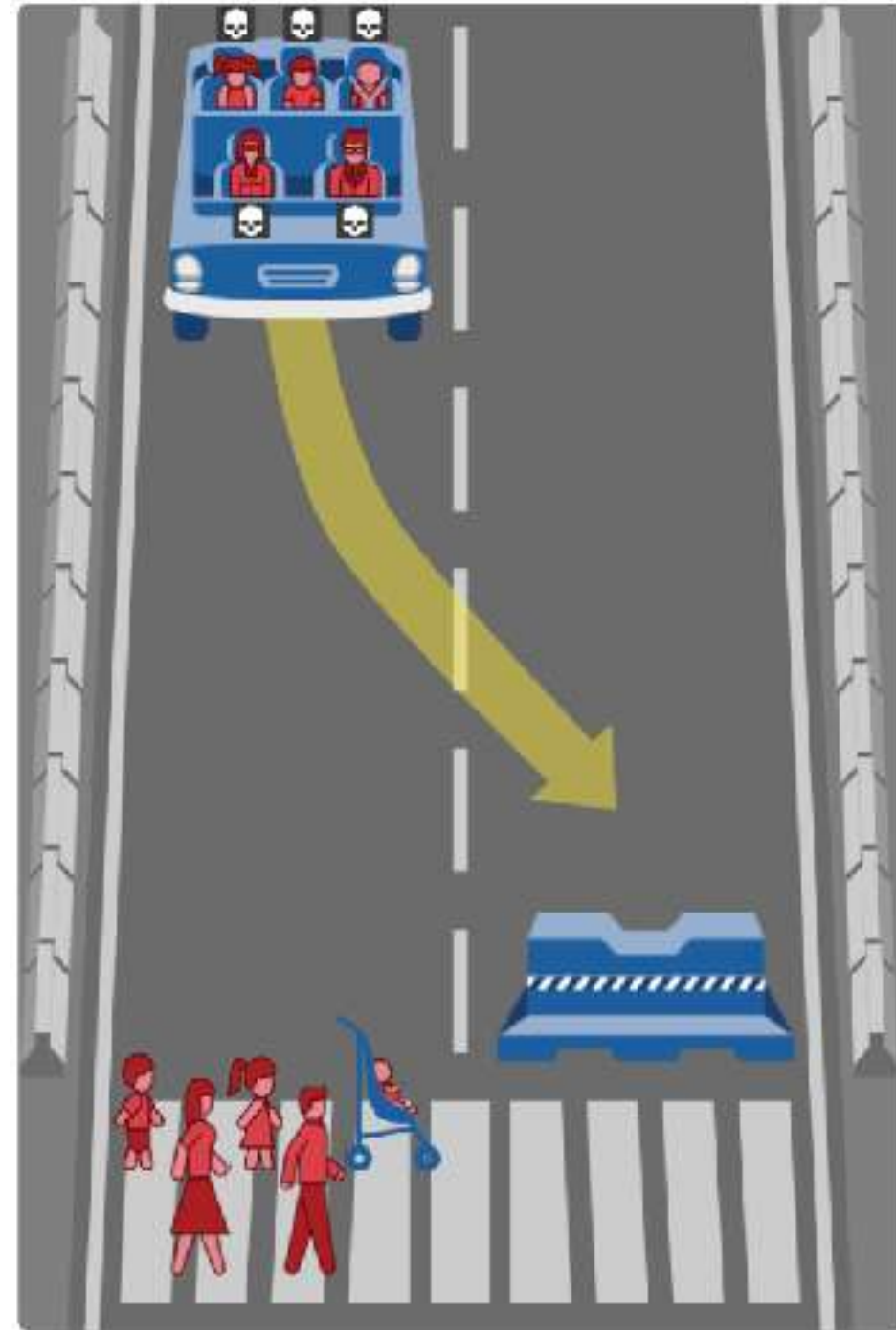
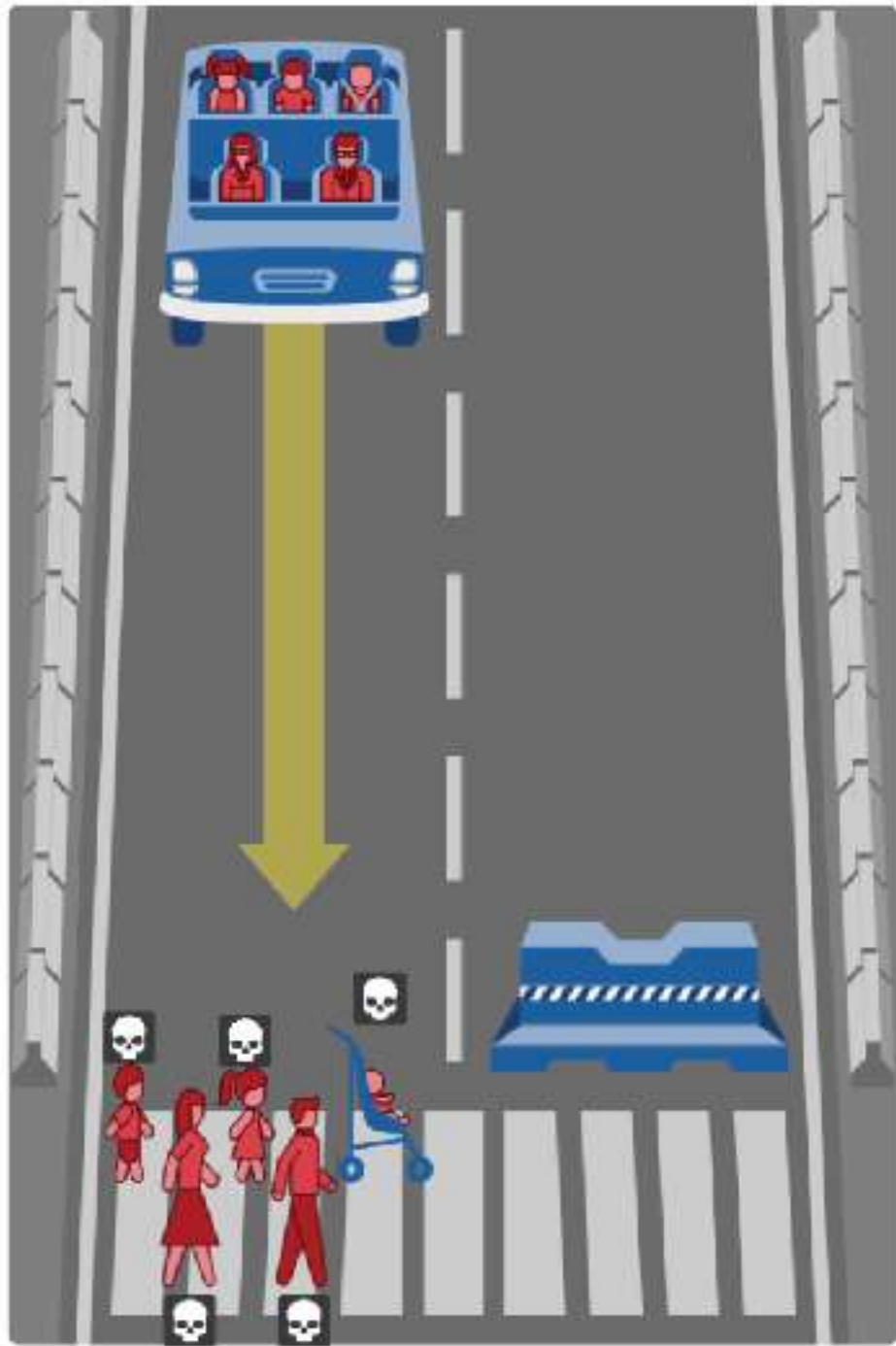


# Ethics





<http://moralmachine.mit.edu>



<http://moralmachine.mit.edu>



*“In hazardous situations that prove to be unavoidable, despite all technological precautions being taken, the protection of human life enjoys top priority in a balancing of legally protected interests.”*



*“In the event of unavoidable accident situations, any distinction based on personal features (age, gender, physical or mental constitution) is strictly prohibited.”*

ETHICS COMMISSION

AUTOMATED AND



# Future improvements

- Improve detection and navigation of curved lanes
- Optimize line detection algorithm using sliding window
- Automatic (re)calibration of:
  - Video parameters
  - OpenCV parameters
- Add Flight recorder to enable replay and debug
- Control servos directly from Java
- Use AI for navigation
- Optimize for running everything on the car



Questions?

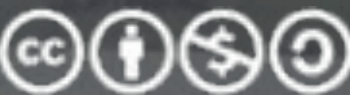
 [@bjschrijver](https://twitter.com/bjschrijver)

 [@TimvEindhoven](https://twitter.com/TimvEindhoven)

 <https://github.com/rc-dukes>

Thanks for your time.

*Got feedback? Tweet it!*



All pictures belong to their respective authors

 [@bjschrijver](https://twitter.com/bjschrijver)

 [@TimvEindhoven](https://twitter.com/TimvEindhoven)