TECHNISCHE HOCHSCHULE
OSTWESTFALEN-LIPPE
UNIVERSITY OF
APPLIED SCIENCES
AND ARTS

Autonomous Driving

Overview

Prof. Dr.-Ing. habil. Ulrich Büker

Artificial Intelligence in Automobiles

Images: Aptiv, Audi, Bosch, Fraunhofer

Levels of Automated Driving

Definition according to VDA

Driver permanently performs longitudinal **and** lateral guidance.

No intervening vehicle system active

Level 0
No automation

Driver performs longitudinal **or** transverse guidance permanently

System takes over the other function

Level 1
Assisted

Driver must permanently monitor the system

System takes over longitudinal and transverse guidance in a specific application

Level 2
Partly automated

Driver no longer has to monitor the system permanently. However, he must be able to take over.

System takes over longitudinal and lateral guidance in a specific application. Recognizes system limits and prompts driver to take over with sufficient time reserve.

Level 3
Highly automated

No driver required in the specific application

System can handle all situations automatically in the specific use case

Level 4
Fully automated

System can handle all situations automatically throughout the ride. No driver required.

Level 5
driverless

Partly Automated Driving : Level 2

Stage 2 is the current state of the art

Audi
BMW
Mercedes
Tesla
…

Features:
Intelligent cruise control, lane keeping systems.

Typically with hands-on detection

Driver must permanently monitor the system

System takes over longitudinal and transverse guidance in a specific application

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Highly Automated Driving: Level 3

Driver must permanently monitor the system

System takes over longitudinal and transverse guidance in a specific application

Level 2
Partly automated

Since 2022:
Highly automated driving in congestion situations on the highway up to 60 km/h (Mercedes S-, EQS-Class).

Next stage of development:
Highly automated driving on highways up to 130km/h (without road works, without toll stations,...)

Comfort and technology leap

Driver no longer has to monitor the system permanently. However, he must be able to take over.

System takes over longitudinal and lateral guidance in a specific application. Recognizes system limits and prompts driver to take over with sufficient time reserve.

Level 3
Highly automated

Image: Volvo

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Highly Automated Driving: Level 3

Image: Volvo

Driver may perform secondary activities (reading, email, video).

Driver must be able to resume driving task within 10 sec. after request of the system.

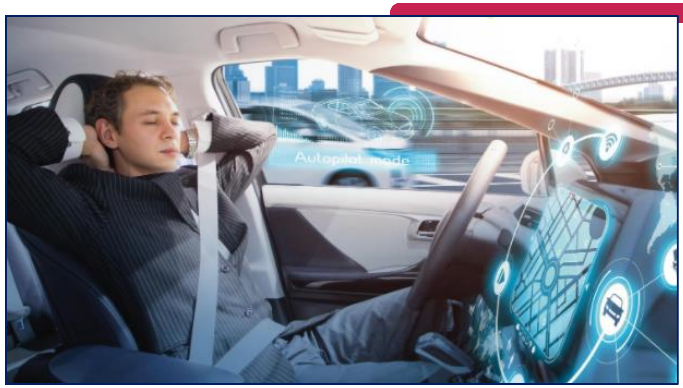
Driver no longer has to monitor the system permanently. However, he must be able to take over.

System takes over longitudinal and lateral guidance in a specific application. Recognizes system limits and prompts driver to take over with sufficient time reserve.

Level 3
Highly automated

first in market, 2022: Mercedes Benz : DRIVE PILOT (in traffic jams, up to 60km/h)

Fully automated driving: Stage 4



Fotos: iStock, Mercedes-Benz

e.g. Highly automated driving on highways up to 130km/h (incl. construction sites)

- Driver is allowed to sleep
- Driver seat may be turned to the interior,...

Driver is informed in time before leaving the use case (highway driving)

No driver required in the specific application

System can handle all situations automatically in the specific use case

Level 4
Fully automated

Driverless driving: Level 5

E.g.: Shuttle vehicles, autonomous cabs without drivers.

Initially in restricted environments
(geofenced area)

Vehicle needs no controls, no steering wheel, no pedals,....

Images: GM, Holon (Benteler)

System can handle all situations automatically throughout the ride. No driver required.

Level 5
driverless

What do we need ?

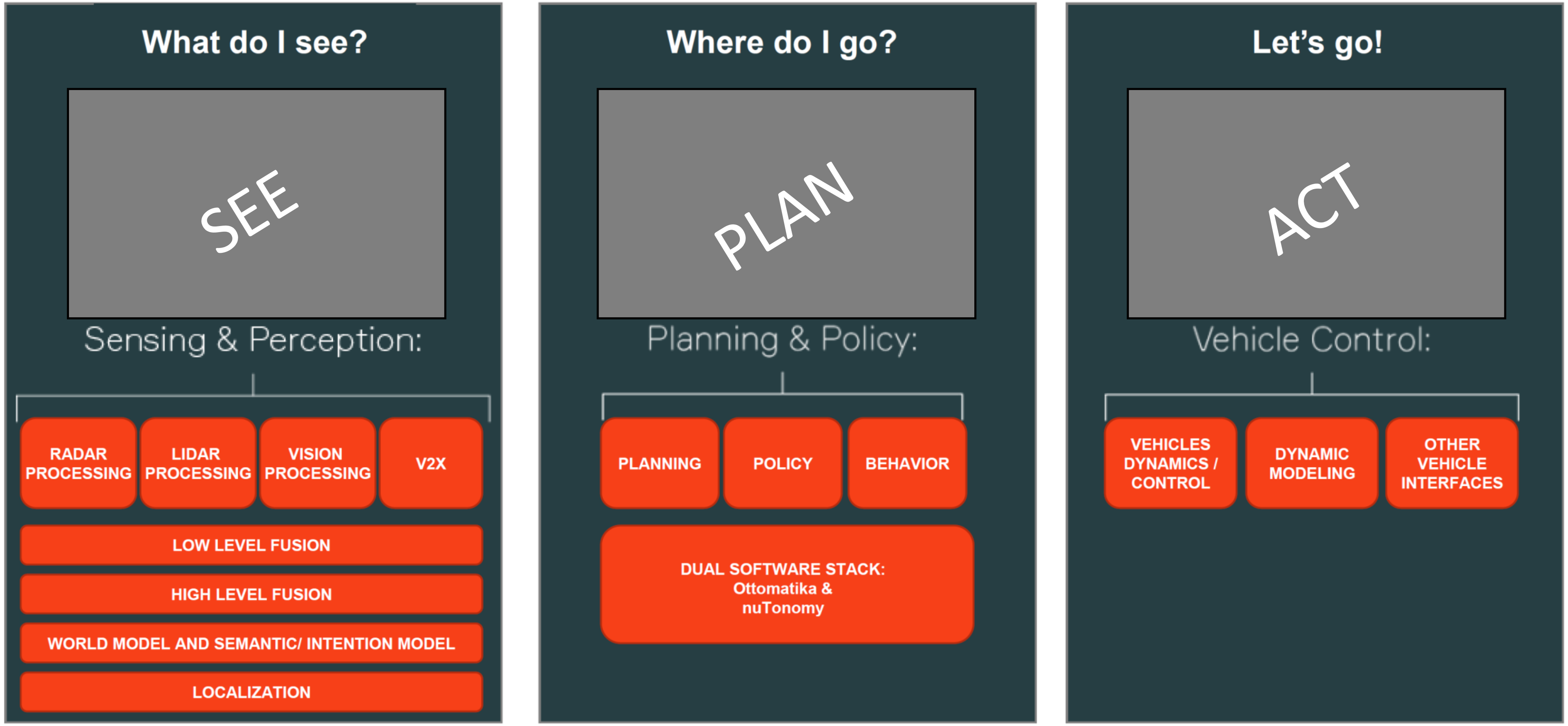


Image: Aptiv

Building blocks of an autonomous vehicle

What is my environment?

Sensory
Perception

- Signal processing
- Fusion
- Environment model
- Localization

Perception of surroundings

- Traffic lanes
- Traffic signs
- Road users
- Comparison with map material
- Localization

What should I do?

Plan

- Driving strategy
- Driving maneuvers

Maneuver planning

- Acceleration
- Braking
- Lane change
- Overtaking
- Turning

Action!

Vehicle control

- Dynamics models
- Vehicle interfaces

Vehicle control

- Trajectories
- Longitudinal control
- Transverse control

Perception

What is my environment?

Sensory
Perception

- Signal processing
- Fusion
- Environment model
- Localization

Perception of surroundings

- Traffic lanes
- Traffic signs
- Road users
- Comparison with map material
- Localization

What should I do?

Plan

- Driv
- D

Perceptio

- Traffic la
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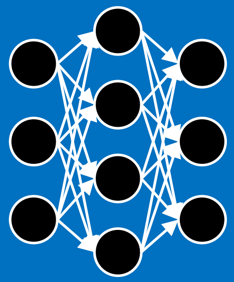
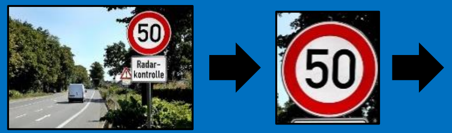
Artificial Neural Networks
Deep Learning





„Speed limit 50“

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Environment Perception

360° sensor technology for environment perception

- 8-10 cameras
- 8-10 radars
- 4-6 Laser scanners (lidars)

- Data fusion to increase robustness
- Fail-safe through redundancy
- Differentiation of static and dynamic objects

Goal:

- Creation of an environment model
- Evaluation of the driving situation

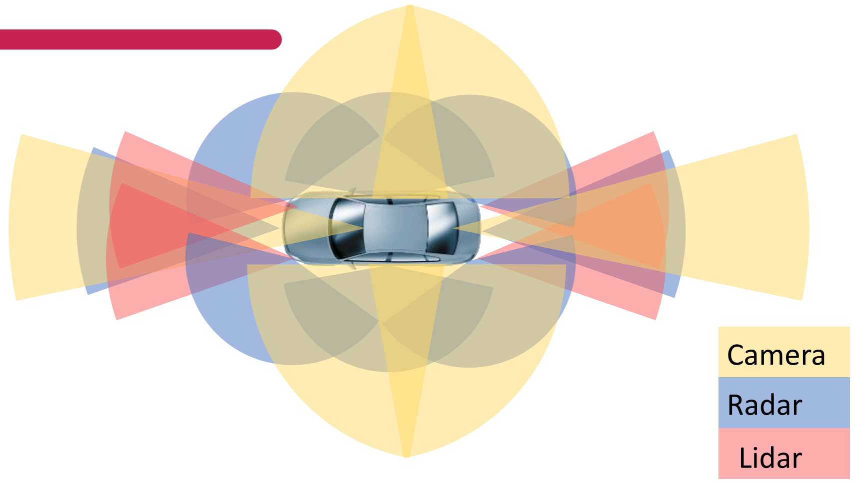

Image: Hella

Environment Perception

- Recognizing the lane
- Recognizing road users
- Recognizing obstacles
- Recognition of traffic signs

- Recognition of intention and anticipation of behavior patterns

Images: Hella

Maneuver Planning

What should I do?

Plan

- Driving strategy
- Driving maneuvers

Maneuver planning

- Acceleration
- Braking
- Lane change
- Overtaking
- Turning

What is my envir

Sensory
Perceptio

Perceptio

- Traffic la
- Traffic signs
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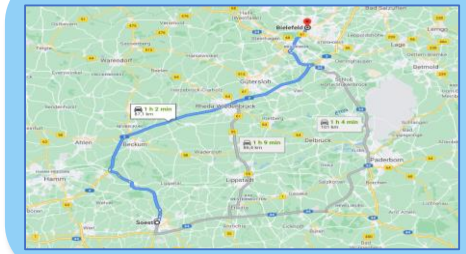
- Comparison with
- Localization

Rule-based

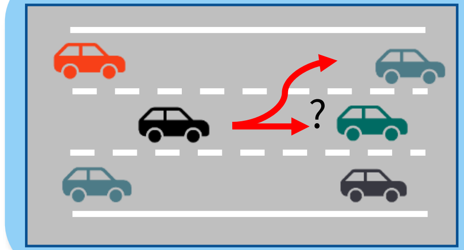
vehicle in front is slower?
↓yes
Left lane is free?
↓yes
Action: Overtaking

Neural networks with reinforcement learning for maneuver planning

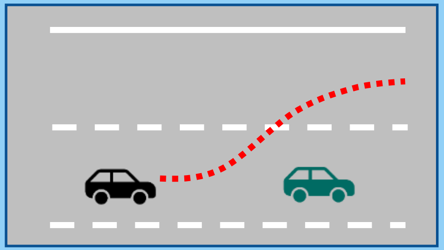
Maneuver Planning



Navigation Route



Driving strategy



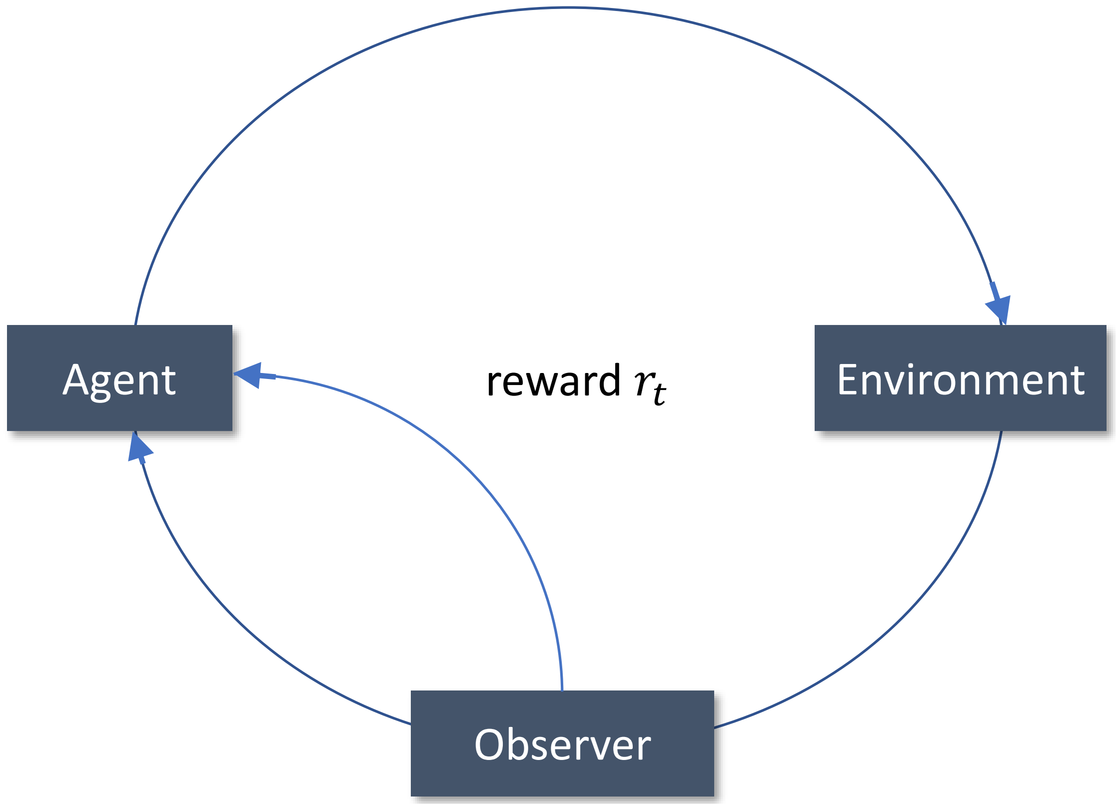
Trajectory

Some rules for autonomous driving

1. Avoid collisions with other vehicles or people
2. Stay on the road
3. Obey speed limits
4. Prefer the right lane

- It is not always possible to follow all rules at the same time.
- Low-priority rules are often "recommendations" or "best practice"

Reinforcement Learning



- Agent interacts with the environment
- Environment including agent is described by state s_t at time t
- Agent chooses an action a_t
- This results in a new state $s_{(t+1)}$ and a reward $r_{(t+1)}$.
- The goal of reinforcement learning is to learn a policy that maximizes the expected cumulative reward.

- Reward
  - reward wanted behavior
  - punish unwanted situations

Reinforcement Learning

Observation

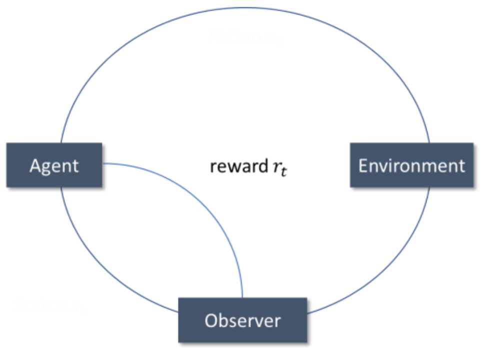
- environment model
- traffic lanes
- traffic signs
- other road users
- obstacles
- ...

Reward

- avoid collisions
- move forward as quickly as possible
- stay within the speed limit
- do not overtake on the right
- stay within the lane
- limit lane changes
- ...

Action

- Trajectory
  - Steering movement
  - Acceleration



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Examples of cost/reward

- Top priority: avoid accidents
  - *if accident then*
    Cost = infinity
  - Learned solution: The vehicle simply stops!

- Another priority: reach the destination quickly
  - *if not Unfall then*
    Cost = $(velocity - desired\_velocity)^2 * c_1$

  - Costs are therefore incurred if the vehicle travels slower than desired (e.g. specified maximum speed or guideline speed)

  ➔ es fährt und bleibt nicht einfach stehen, um Kosten zu minimieren!

Safety and comfort

- Learned policy should
  - avoid accidents
  - get the vehicle from A to B quickly
  - ensure compliance with traffic regulations

- Introducing comfort
  - Above policy may mean that the vehicle drives "aggressively" or uncomfortably. (e.g. late and abrupt braking or steering).

Reinforcement Learning

- Training with the help of simulation
  - Enables training in a wide range of driving situations
    - Road configurations and trajectories
    - Number of road users and their behavior (trajectories)
    - Weather conditions
- Validation
  - Test in simulator and by real driving
- Black box planning module in conflict with functional safety requirements
  ➔ Explainable AI?
- End-to-end neural network (from sensor signal to action) is currently still avoided, as safeguarding is completely unclear.

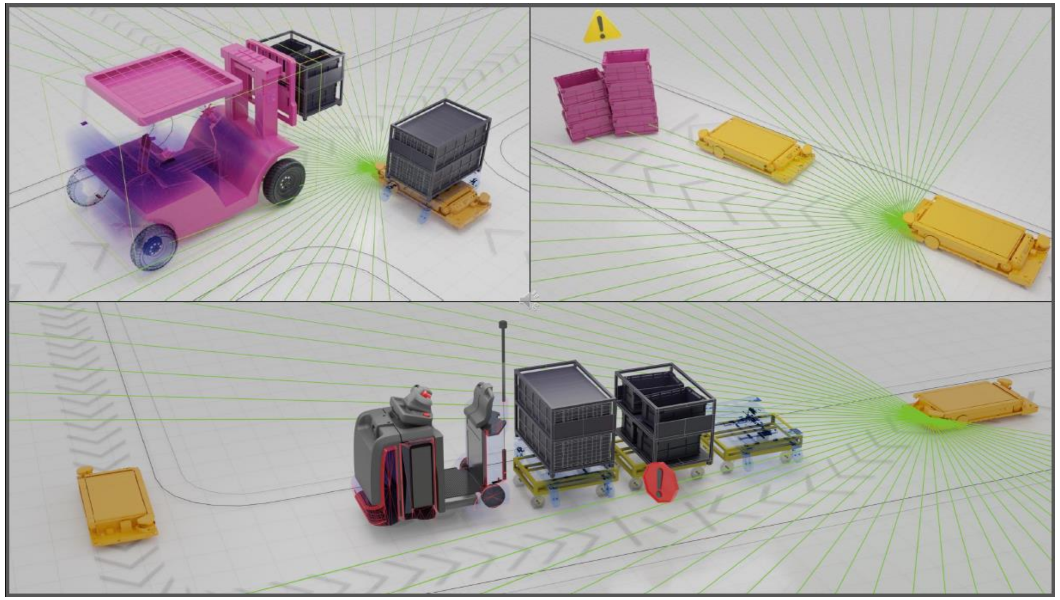
Videos

- Valet Parking (Mercedes-Benz, Bosch)

- APTIV during CES in Las Vegas (excerpt)

Further application areas of autonomous driving and its technologies

- Industry 4.0
  - Autonomous transport systems in production facilities that
  - can react flexibly to obstacles in their travel path
  - can avoid obstacles
  - search for alternative routes/paths



Images: Clearpath Robotics, BMW

Further application areas of autonomous driving and its technologies

Driverless tractors

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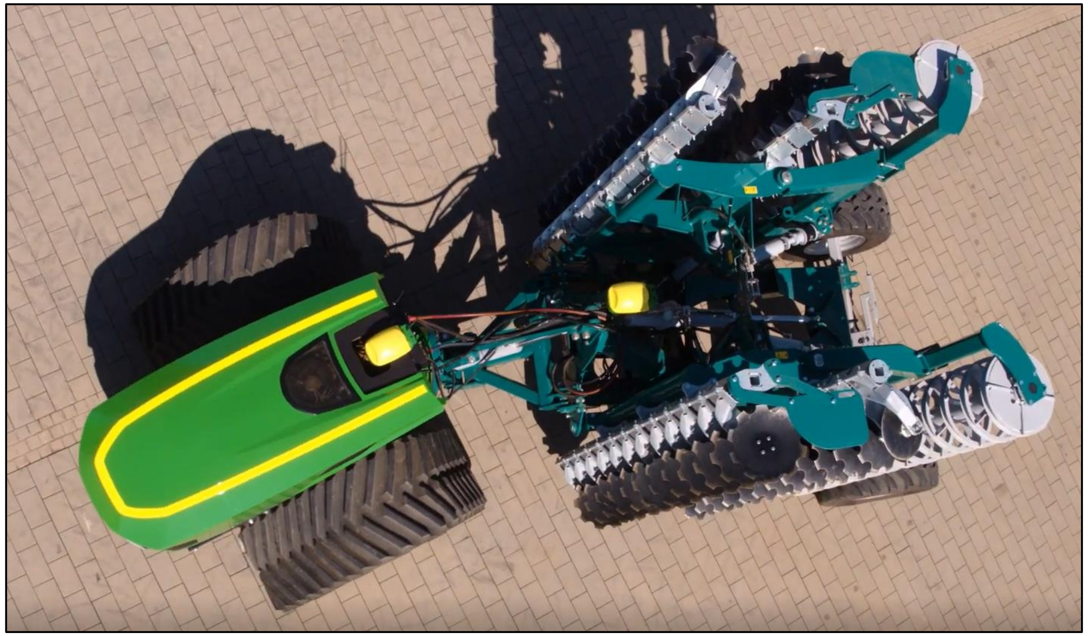

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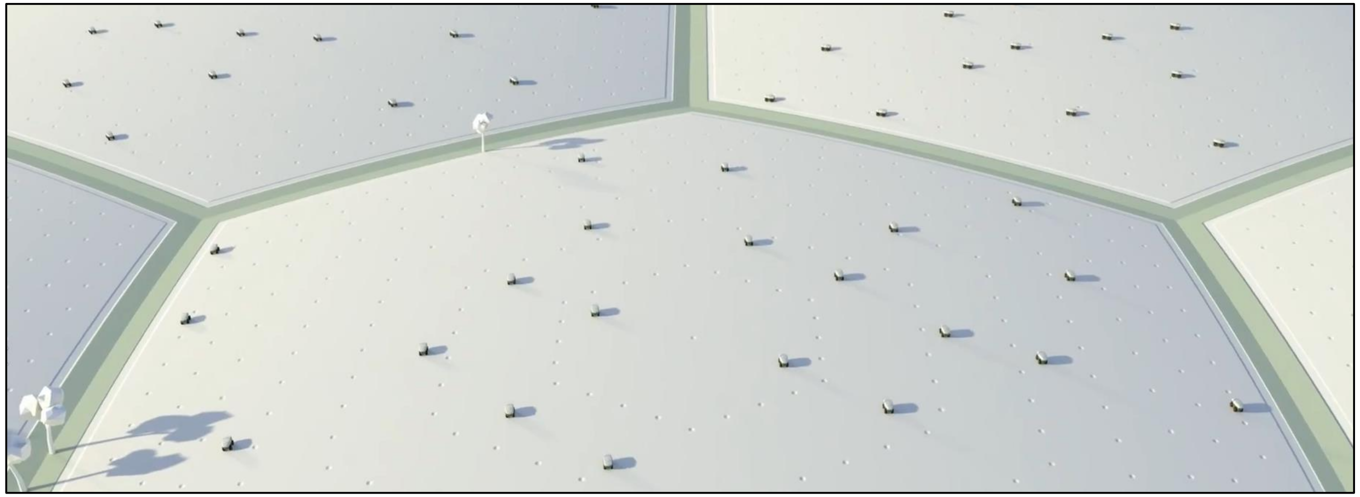
Further application areas of autonomous driving and its technologies

- Driverless agricultural machinery
  - Fully autonomous tractors
  - Swarm robots
  - Autonomous fruit harvesters
  - Autonomous hoeing for weed control
  - Smart spraying solutions

Images: Fendt, Suzhou Botian, Naio Technologies

Further application areas of autonomous driving and its technologies

Swarm based farming



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