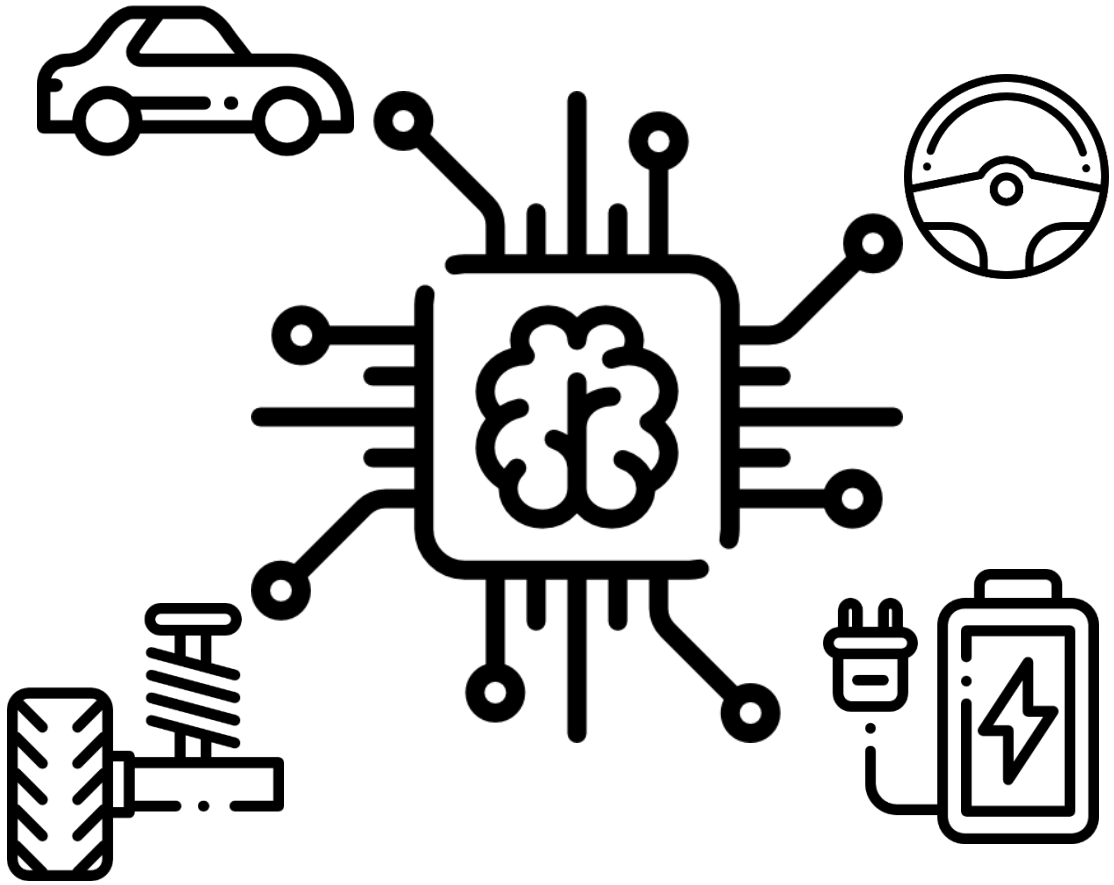
Institute of Automotive Technology
School of Engineering and Design
Technical University of Munich

Artificial Intelligence in Automotive Technology

Prof. Dr.-Ing. Markus Lienkamp



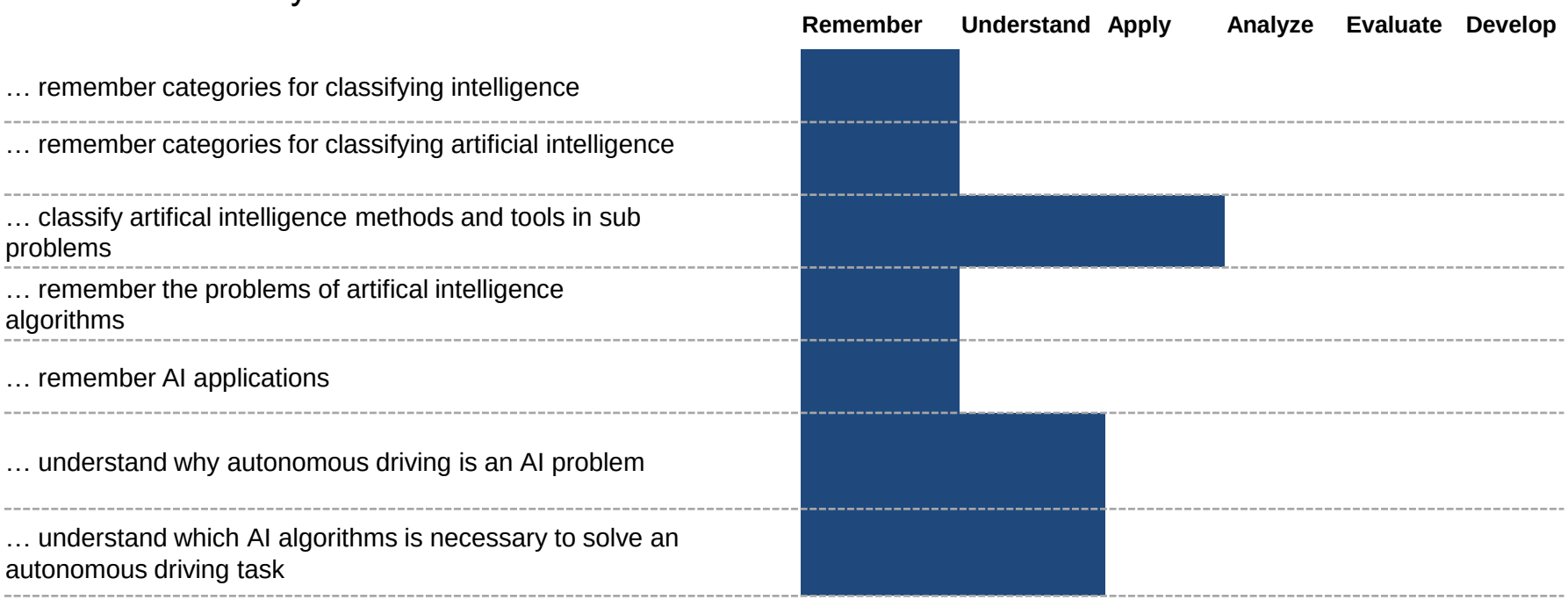
Lecture Overview

Lecture 16:15-17:45 | Practice 17:45-18:30	
1 Introduction: Artificial Intelligence	20.10.2022 – Maximilian Geißlinger
2 Perception	27.10.2022 – Sebastian Huber
3 Supervised Learning: Regression	03.11.2022 – Fabian Netzler
4 Supervised Learning: Classification	10.11.2022 – Andreas Schimpe
5 Unsupervised Learning: Clustering	17.11.2022 – Andreas Schimpe
6 Introduction: Artificial Neural Networks	24.11.2022 – Lennart Adenaw
7 Deep Neural Networks	08.12.2022 – Domagoj Majstorovic
8 Convolutional Neural Networks	15.12.2022 – Domagoj Majstorovic
9 Knowledge Graphs	12.01.2023 – Fabian Netzler
10 Recurrent Neural Networks	19.01.2023 – Matthias Rowold
11 Reinforcement Learning	26.01.2023 – Levent Ögretmen
12 AI-Development	02.02.2023 – Maximilian Geißlinger
13 Guest Lecture	09.02.2023 – to be announced

Objectives for Lecture 1: Introduction to AI

Depth of understanding

After the lecture you are able to…

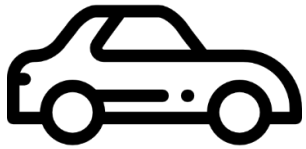


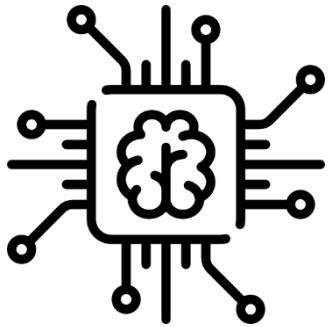
Introduction: Artificial Intelligence
Prof. Dr. Markus Lienkamp

(Maximilian Geißlinger, M. Sc.)

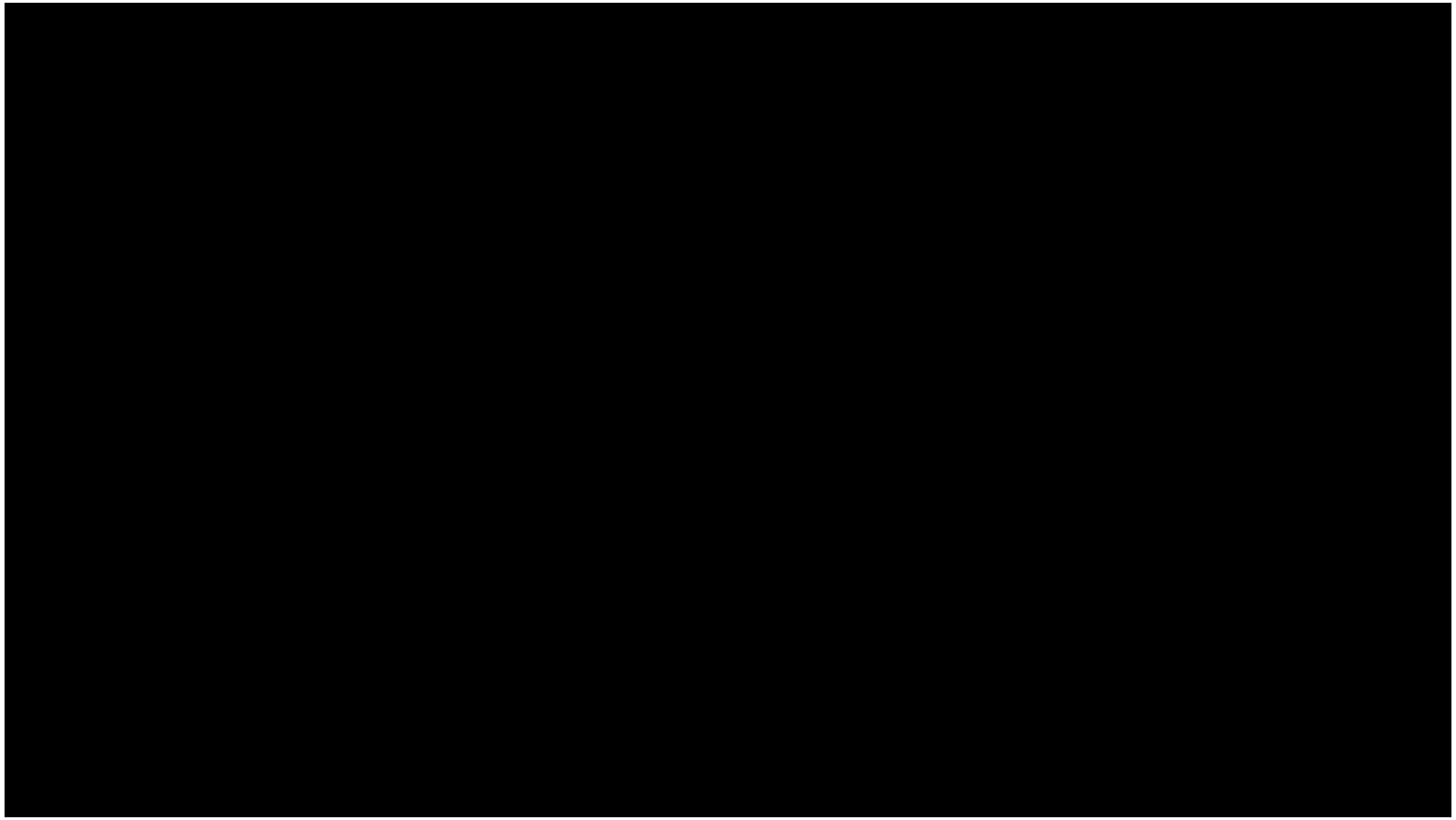
Agenda

1. **Chapter: Artificial Intelligence in the Spotlight**
2. Chapter: A brief History
3. Chapter: What is Intelligence?
4. Chapter: AI Methods
5. Chapter: AI Applications
6. Chapter: AI Application: Automotive Technology
7. Chapter: Summary





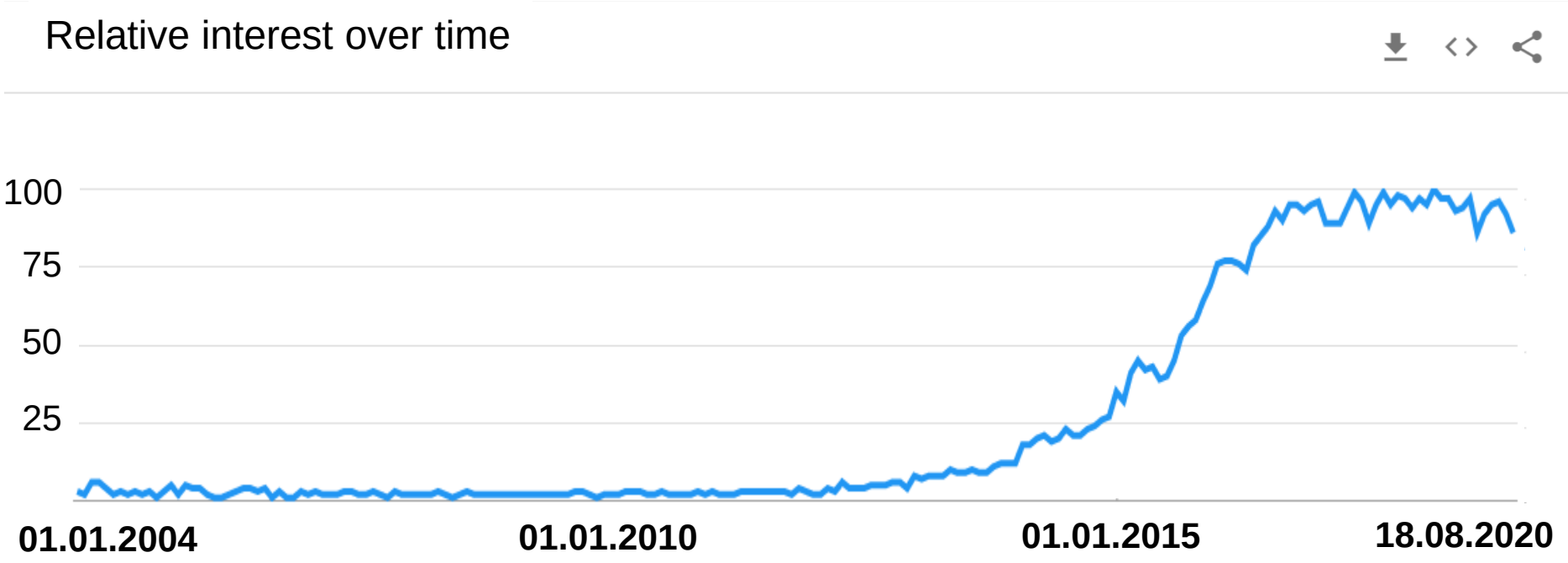
AI in the Spotlight



Nvidia GTC 2021 Conference Keynote

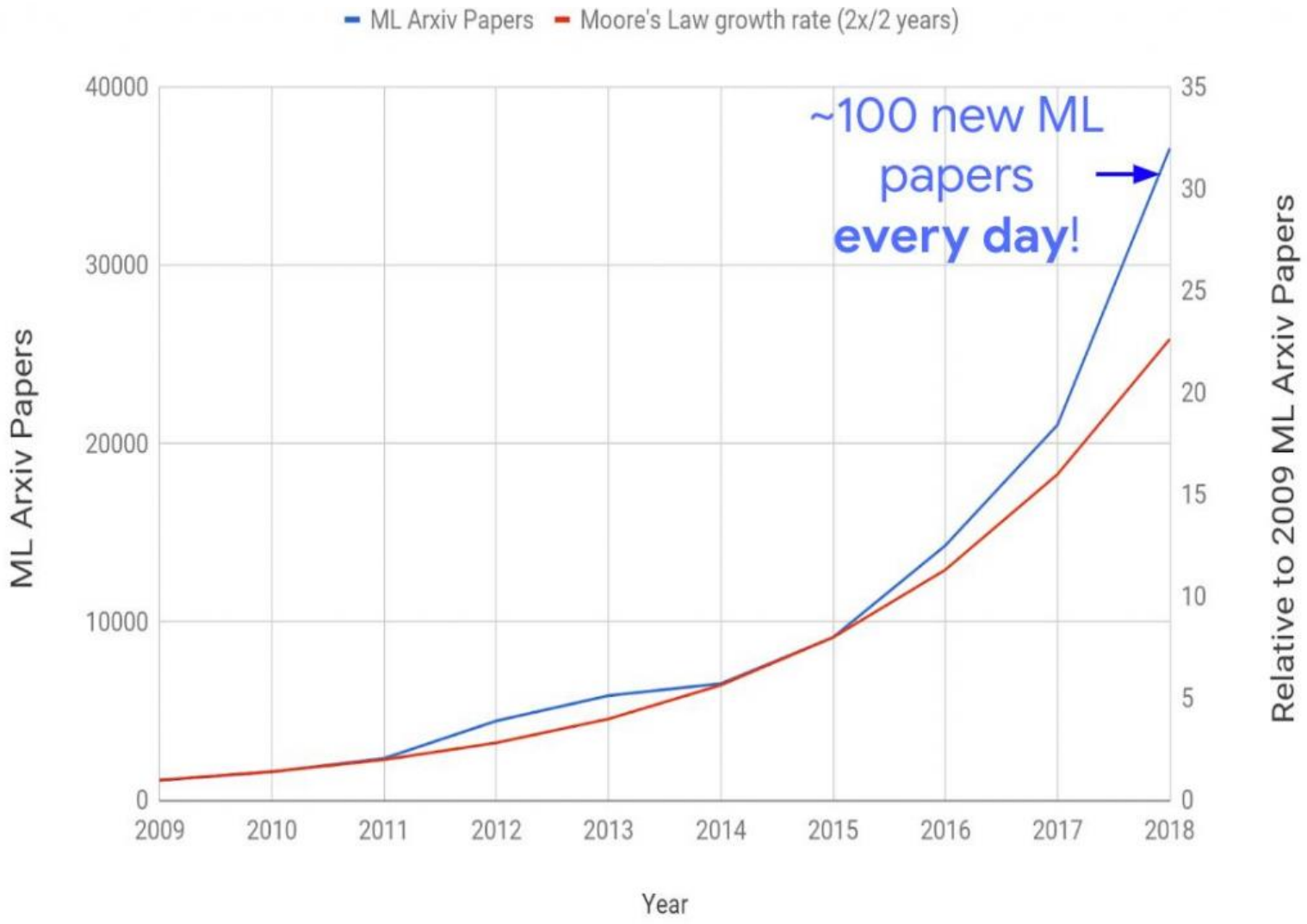
Source: https://www.youtube.com/watch?v=Dw4oet5f0dI

Google Trends „Deep Learning“

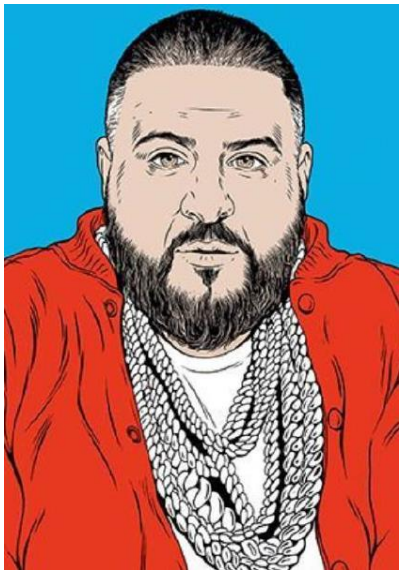


Source: Google Trends – Search „Deep Learning“

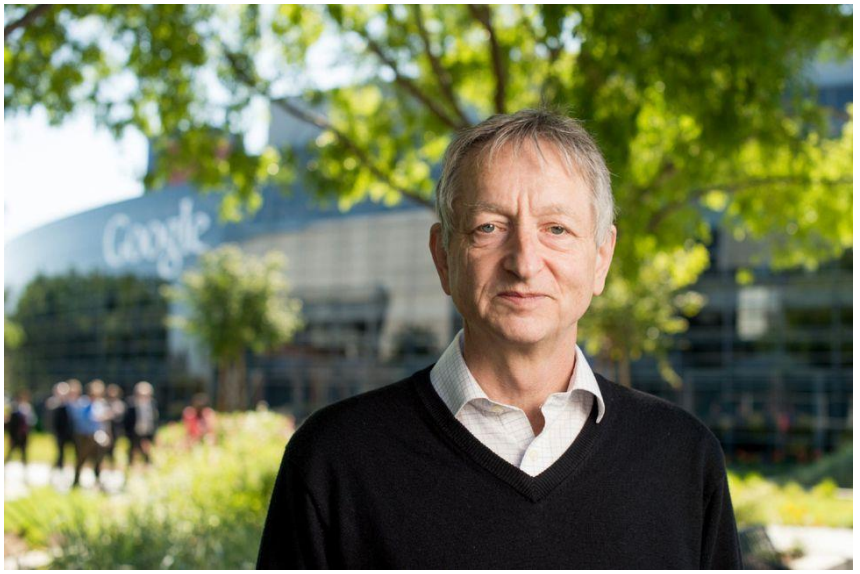
Machine Learning arXiv Paper



Wired 100 – who is shaping the world ?



73. DJ Kahled
(Snapchat icon, DJ, producer)



69. Geoffrey Hinton
(Psychologist, Computer scientist, „Godfather of Deep Learning“)

Source: https://www.wired.co.uk/article/wired-global-100

Hype Cycle for Emerging Technologies, 2020

Source: gartner.com/SmarterWithGartner

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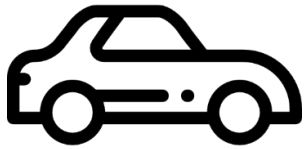
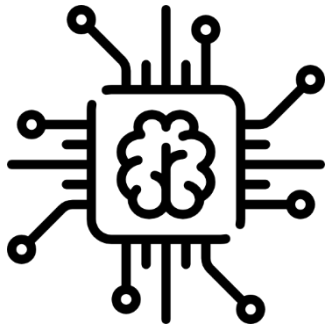
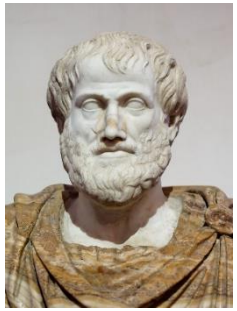




A brief History



300 BC: Aristoteles –
Described syllogism

Induction

Case: These beans are from this bag.
Result: These beans are white.
Rule: All the beans in this bag are white.

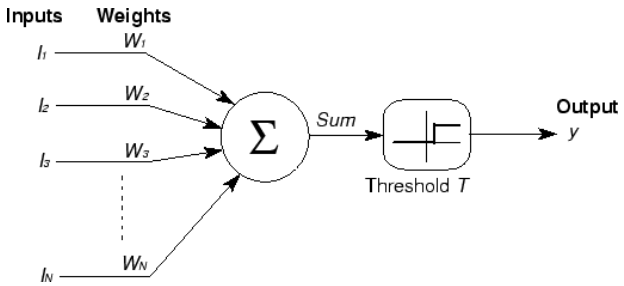
1739: Hume –
Empiricism, Induction

variables	$x, y, z, x_0, x_1, ...$
conjunction	$\wedge$
disjunction	$\vee$
negation	$\neg$
implication	$\rightarrow$
biconditional	$\leftrightarrow$
identity	$=$
universal quantifier	$\forall$
existential quantifier	$\exists$
predicates	$A, B, C, ..., A_0, A_1, ...$
functions	$a, b, c, ..., a_0, a_1, ...$
parentheses	$(,)$

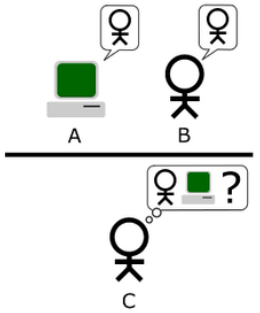
1913: Russel –
Formal Logic

Ax 1. • ∀x{[φ(x) → ψ(x)] ∧ P(φ)] → P(Ψ)
Ax 2. P(¬φ) ↔ ¬P(φ)
Th 1. P(φ) → ◊ ∃x [φ(x)]
Df 1. G(x) ↔ ∀φ[P(φ) → φ(x)]
Ax 3. P(G)
Th 2. ◊ ∃x G(x)
Df 2. φ ess x ↔ φ(x) ∧ ∀ψ{ψ(x) → • ∀x[φ(x) → ψ(x)]
Ax 4 P(φ) → • P(φ)
Th 3. G(x) → G ess x
Df 3. E(x) ↔ ∀φ[φ ess x → • ∃x φ(x)]
Ax 5. P(E)
Th 4. • ∃x G(x)

1931: Gödel –
Untestable Logic



1943: McCulloch & Pitts –
Foundations for artificial
neuronal network



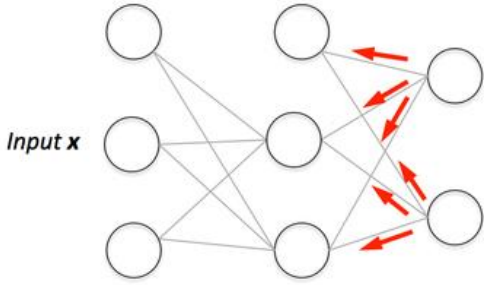
1951: Turing –
Machine Intelligence

A brief History

1956: McCarthy – Artificial Intelligence

```
> Hello, I am Eliza.
* I am afraid.
> How long have you been afraid?
* Since midterms.
> Tell me more...
* I am afraid that I will fail
my course.
> Do you enjoy being afraid that
you will fail your course?
```

1966: Weizenbaum – NLP Eliza



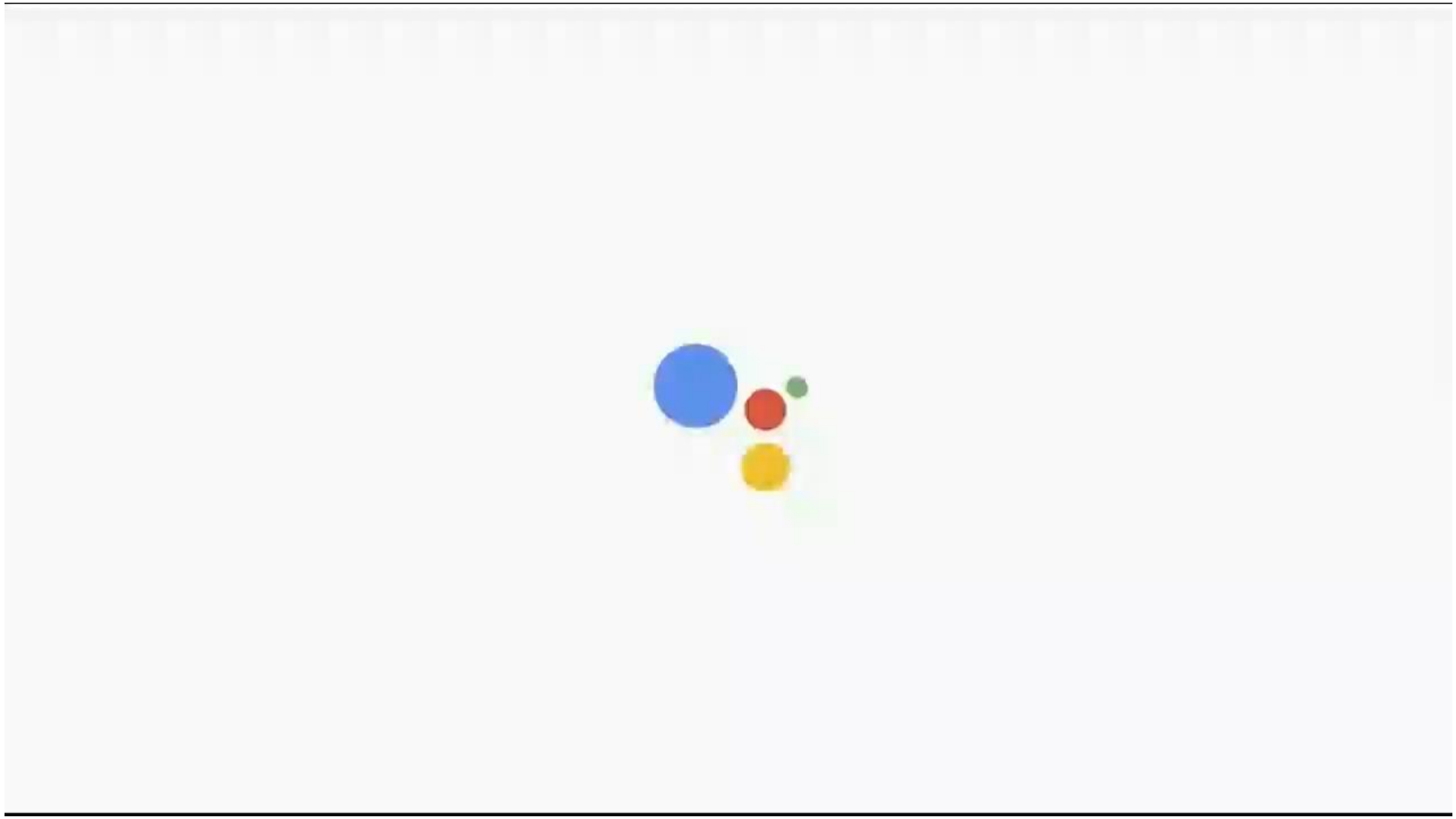
1986: Hinton – ANN Backpropagation

2009: Google – Self Driving Car

2011: IBM Watson – Defeat Human in Jeopardy Game

2018: Google Duplex – Personal Assistant

Google Duplex



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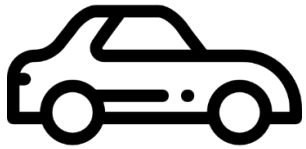
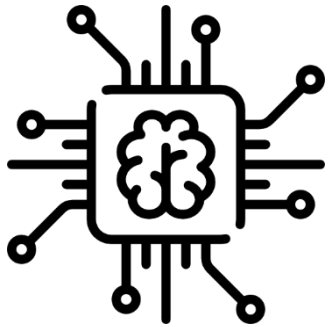
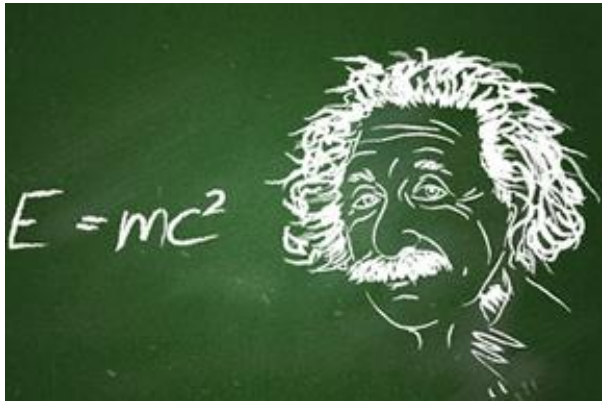


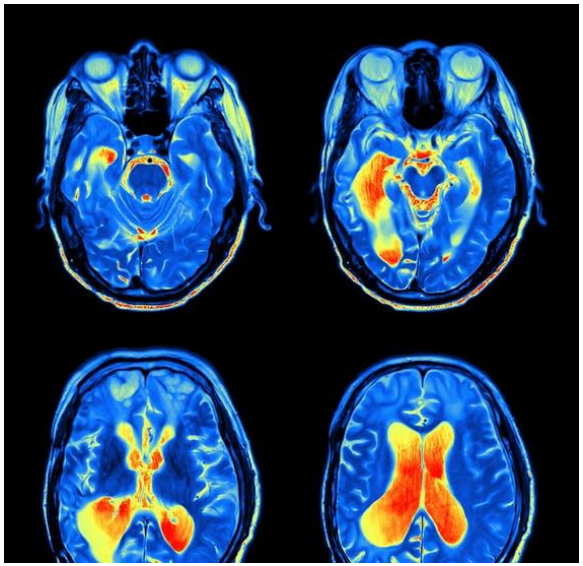


What is Intelligence?

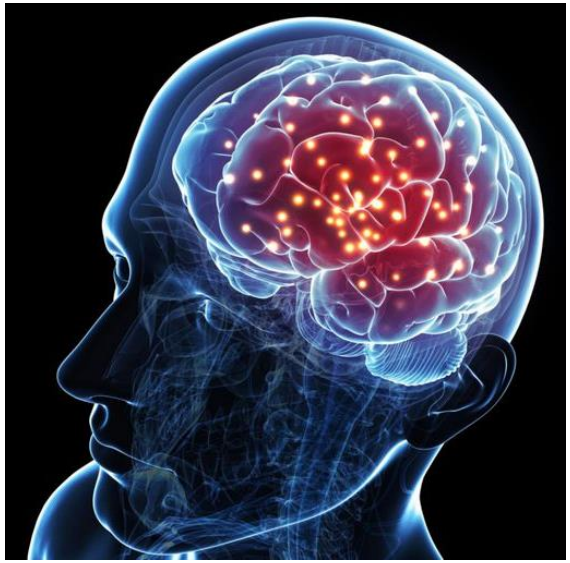
A few questions arise:



What is intelligence?



How can we measure intelligence?



How does the brain work?

Source: https://health.spectator.co.uk/brain-scans-show-physical-signs-of-depression/ /https://www.thoughtco.com/anatomy-of-the-brain-373479
https://www.neuronation.de/science/intelligenz-ist-trainierbar-studien-nachgewiesen

What is Intelligence?

Intelligence – a definition:

- **Intelligence** (from Latin *intellegere* "understanding", literally "choosing between..." from Latin *inter* "between" and *legere* "reading, choosing") is a collective term in psychology for human cognitive performance
- Individual cognitive abilities can vary in intensity and there is **no agreement on how to determine and distinguish** between them
- There is **no generally valid definition of intelligence**

→ We have to separate intelligence into different categories

Source: https://de.wikipedia.org/wiki/Intelligenz

What is Intelligence? – A proposal for categories

Emotional intelligence

- Feelings
- Empathie
- Harmony
- Motivation
- Synergie

Creative intelligence

- Imagination
- Innovation
- Visualization
- Intuition
- Creativity

Methodical intelligence

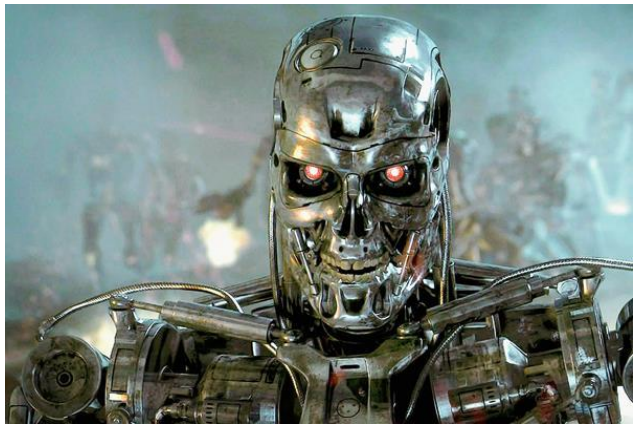
- Structure
- System
- Discipline
- Precision
- Safety

Analytical intelligence

- Critical analysis
- Strategic thinking
- Logic
- Objectivity

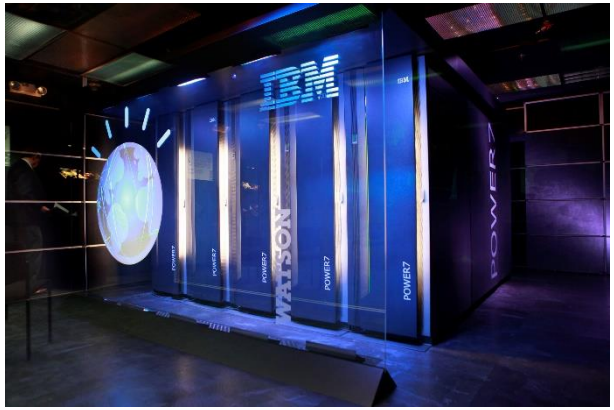
Source: https://koehlerkline.de/about/methode/die-vier-arten-der-intelligenz/ / https://en.wikipedia.org/wiki/Rules_of_chess#/media/File:ChessSet.jpg / http://www.brainfacts.org/thinking-sensing-and-behaving/thinking-and-awareness?page=3 / https://www.buerocheck24.de/leitz-tauenpapier-register-a-z-fuer-24-ordner-grau.html / https://koble.com/the-value-of-creating-a-business-network/istock_000013296501small-network-of-people/

What is Artificial Intelligence?



Robots ?

Virtual assistant?

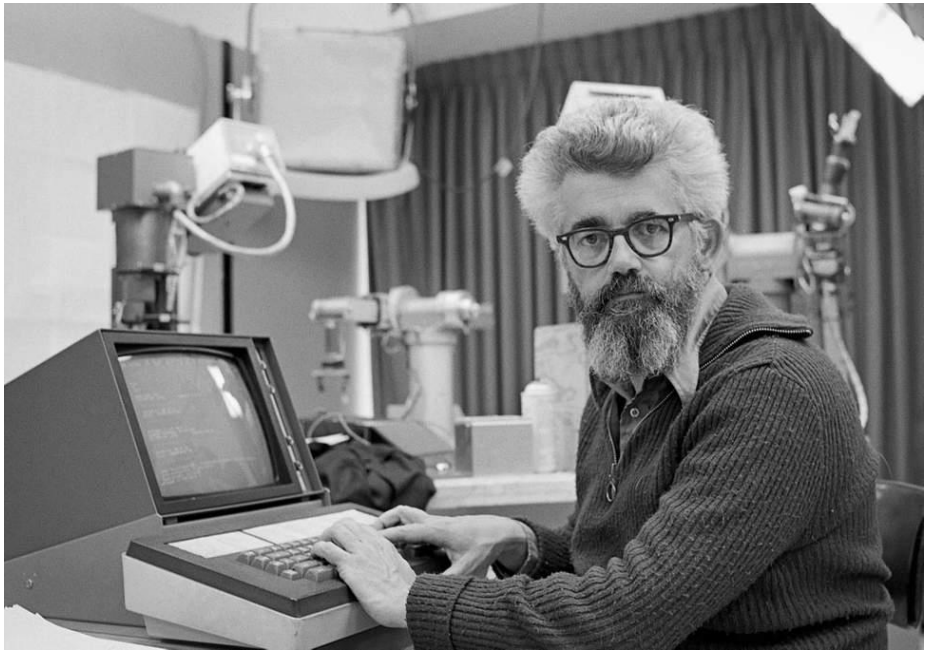


Supercomputers?

Source: http://www.prensalibre.com/vida/escenario/terminator-genesis-estrena-trailer-final / https://www.pri.org/stories/2018-01-05/garry-kasparov-and-game-artificial-intelligence
http://time.com/4281476/ibm-artificial-intelligence-watson-2016/ / https://nakedsecurity.sophos.com/2017/07/17/the-iphone-lockscreen-hole-that-we-cant-reproduce/

What is Artificial Intelligence?

Artificial intelligence (AI) – a definition:



AI's goal is to develop machines that behave as if they had intelligence.

John McCarthy, AI-Pioneer 1955

Source: https://www.independent.co.uk/news/obituaries/john-mccarthy-computer-scientist-known-as-the-father-of-ai-6255307.html

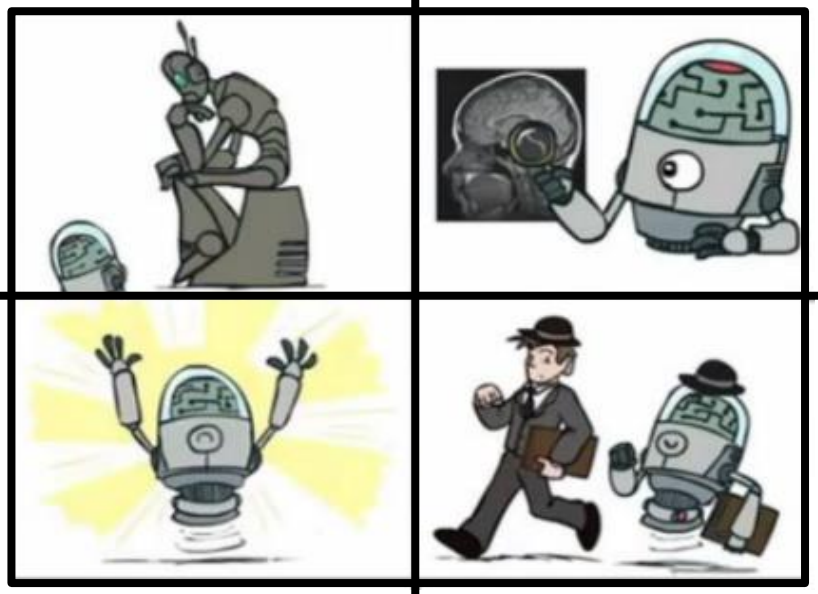
What is Artificial Intelligence? A Proposal for Categories

Thinking rationally

- Laws of thought
- Logic
- Correct reasoning

Thinking humanly

- Thought procedure
- Human performance
- Cognitive science



- Acting **agents**
- Act autonomously
- Persist long
- Adapt
- Create
- Persue goals

Acting rationally

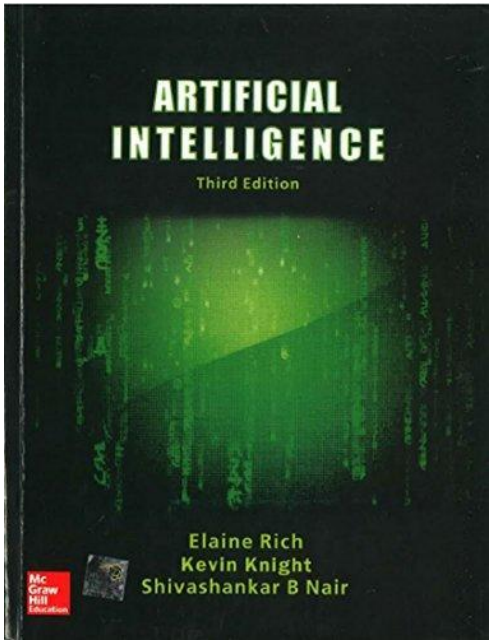
- Turing-Test
- Natural language
- Knowledge storage
- Perception
- Robotics: Movement
- Machine learning

Acting humanly

Source: Artificial Intelligence – A modern Approach / https://kartikkukreja.files.wordpress.com/2015/05/ai.jpg

What is Artificial Intelligence?

Artificial Intelligence (AI) – a second definition:



Artificial Intelligence is the study of how to make computers do things at which, at the moment, people are better. *Elaine Rich, 1991*

Source: https://www.pinterest.de/pin/163959861136520 87/?lp=true / https://booksbeka.com/artificial-intelligence-elaine-rich-and-kevin-knight-tata-mcgraw-hill-3rd-edition

What is Artificial Intelligence? A Second Proposal for Categories

Breaking down the general problem of creating AI into 9 sub-problems:

1. **Reasoning & problem solving:** A machine gets the ability for step-by-step reasoning by making logical deductions with uncertainty

2. **Knowledge representation:** A machine gets the ability for representing information about the world.

3. **Planning:** A machine gets the ability for an optimized automated planning or scheduling that leads to action sequences

4. **Learning:** A machine gets the ability to “learn” based on algorithms that improve automatically through experience and data without being explicitly programmed **(machine learning (ML))**

What is Artificial Intelligence? A Second Proposal for Categories

Breaking down the general problem of creating AI into 9 sub-problems:

5. **Natural language processing (NLP):** A machine gets the ability to read and understand human language

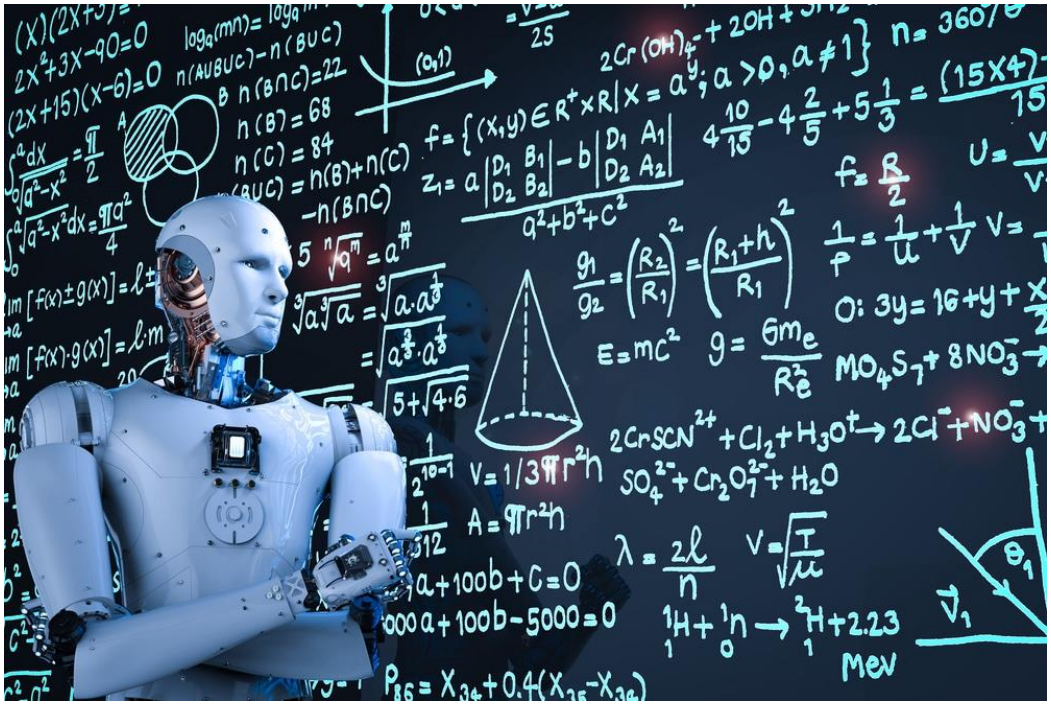
6. **Perception:** A machine gets the ability to use input from sensors for deducing aspects of the world and sensing the environment around the machine

7. **Motion and manipulation:** A machine gets the ability to learn how to plan their motion and move efficiently

8. **Social intelligence:** A machine gets the ability to recognize, interpret, process, and simulate human affects

What is Artificial Intelligence? A Second Proposal for Categories

Breaking down the general problem of creating AI into 9 sub-problems:



9. General intelligence: Achieving the full range of human cognitive abilities (= general AI or strong AI or full AI)

Source: https://inform.tmforum.org/catalyst/2018/01/smart-bpm-catalyst-makes-ai-explainable/

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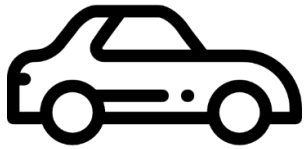
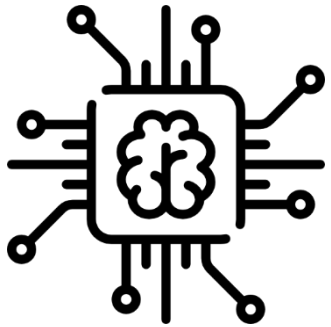




AI Methods

Breaking down the general problem of creating AI into **eight** sub-problems:

1. **Reasoning & problem solving**
2. **Knowledge representation**
3. **Planning**
4. **Learning**
5. **Natural language processing (NLP)**
6. **Perception**
7. **Motion and manipulation**
8. **Social intelligence**

Questions:

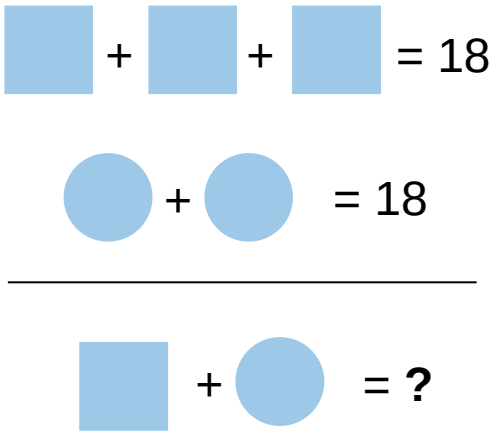
1. What is the problem behind those sub-problems?
2. Which **methods and algorithms** can we use to solve those sub-problems?

AI Methods – 1. Reasoning & Problem Solving

Problem Description

- A given problem or task should be solved
- A machine can use step-by-step argumentation/reasoning for solving this task
- A machine can use formal logic for solving this task
- Integration of uncertainty and probability

Example



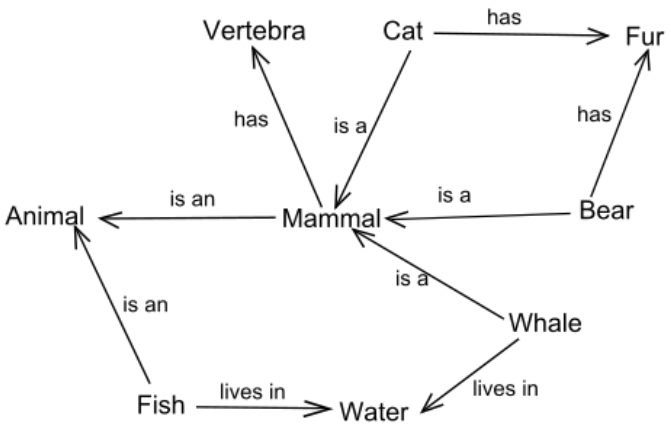
AI Methods – 1. Reasoning & Problem Solving

Method	Algorithms
Searching Intelligently searching through many possible solutions	Tree search, Dijkstra, Kruskal, Nearest Neighbour, A*-search
Optimization Minimize/Maximize a given problem with boundary conditions	Linear Programming, Quadratic Programming, Heuristics, Bayesian Optimization
Evolutionary Computation Optimization search based on evolutions	Genetic Algorithms, Particle Swarm Optimization, Ant Colony Optimization

AI Methods – 2. Knowledge Representation

Problem Description

- A computer is represented as an autonomous agent
- The goal is to represent information about the world for this agent
- Abstract knowledge should now be illustrated formally
- To solve this we are builidng knowledge-based systems or a knowledge database
- Knowledge is implemented as axioms/sentences which are facts and rules about the world



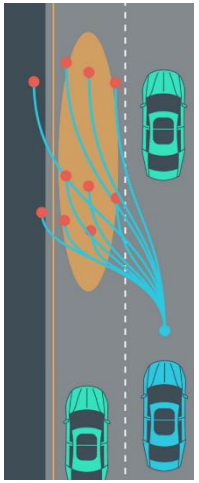
AI Methods – 2. Knowledge Representation

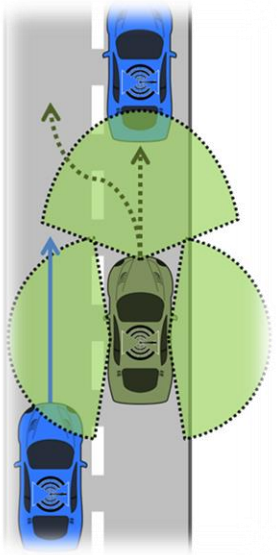
Method	Algorithms
Logic A set of sentences in logical form expressing facts and rules about a problem	Propositional Logic, First order Logic, Fuzzy Logic

AI Methods – 3. Planning

Problem Description

- A computer is represented as an agent
- The goal is that this agent acts autonomously, sets goals and achieves those goals
- We have to represent the world and future for this agent
- The agent has to make choices and maximize his utility under uncertainty





Source:http://velodynelidar.com/docs/news/How%20Ford%27s%20autonomous%20test%20vehicles%20make%203D%20LiDAR%20maps%20of%20the%20world%20around%20them%20_%20PCWorld.pdf / https://medium.com/udacity/self-driving-path-planning-brought-to-you-by-udacity-students-13c07bcd4f32

AI Methods – 3. Planning

Method	Algorithms
Searching Intelligently searching through many possible solutions	Tree search, Dijkstra, Kruskal, Nearest Neighbour, A*-search
Agent-systems Computer program that acts for a user or other program in a relationship of agency	Multi-Agents, Intelligent Agents
Uncertainty Reasoning Operate with incomplete information	Bayesian Network, Hidden Markov Model, Kalman Filter

AI Methods – 4. Learning

Problem Description

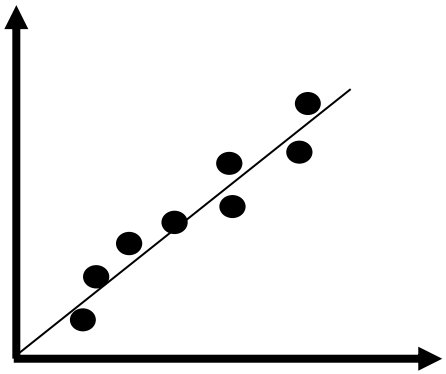
- A computer is given an amount of data
- The computer can process the data with an algorithm
- The algorithm gives the computer the ability to **recognize patterns**
- The computer is „learning“ from the data → **machine learning**
- The computer can now make predictions based on data
- The computer is not following strictly static program instructions

AI Methods – 4. Learning

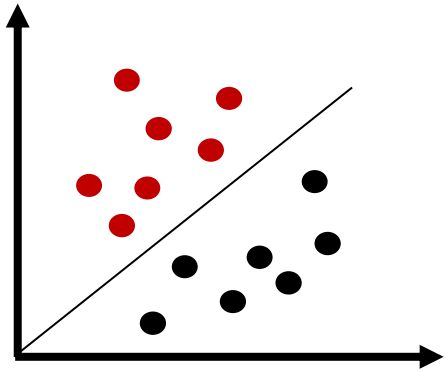
Supervised

Find a predictive model based on input and labeled output data

Regression



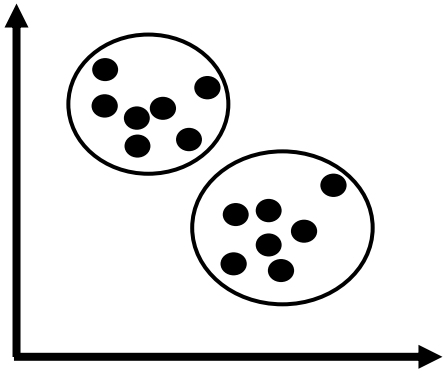
Classification



Unsupervised

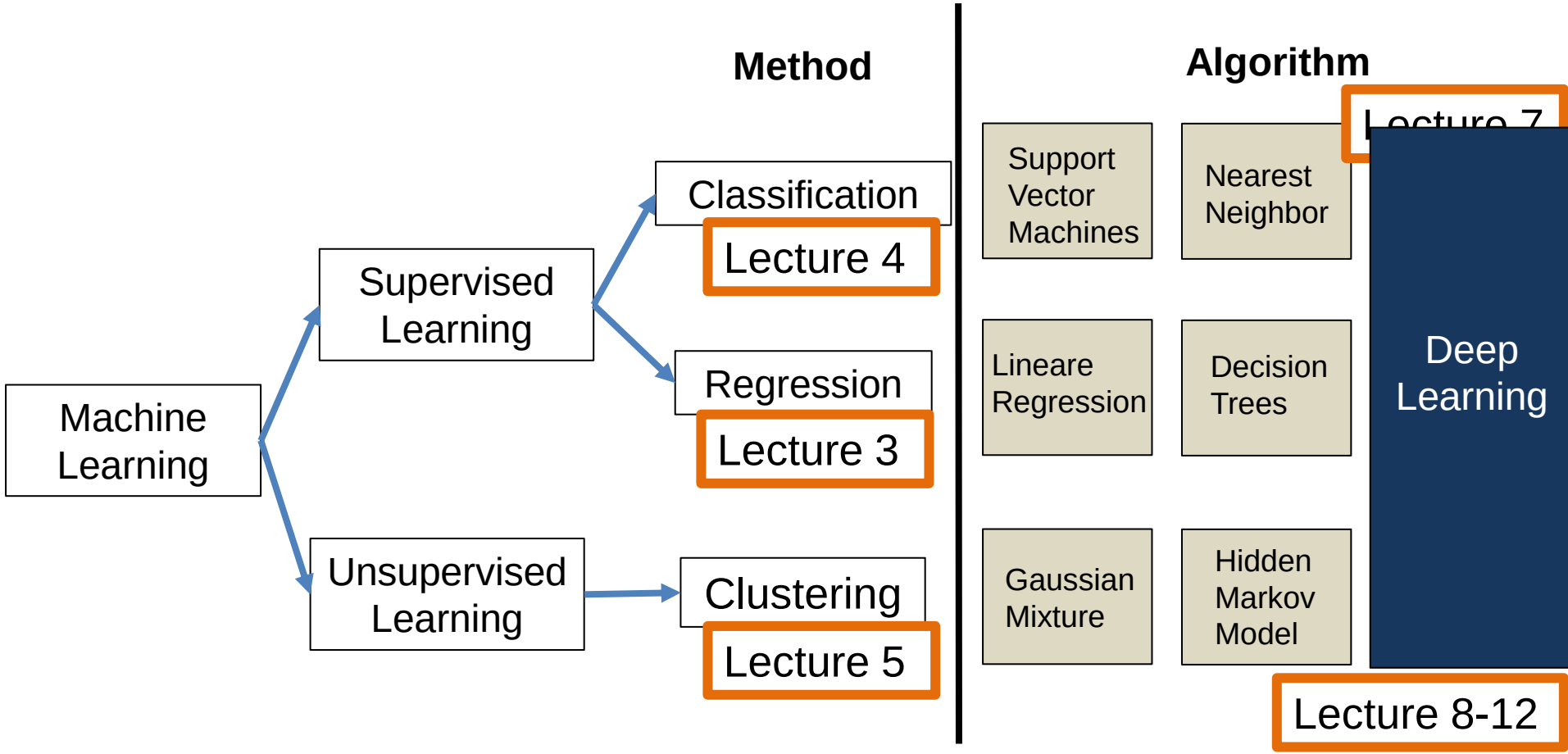
Find similarities in input data and interpret them

Clustering



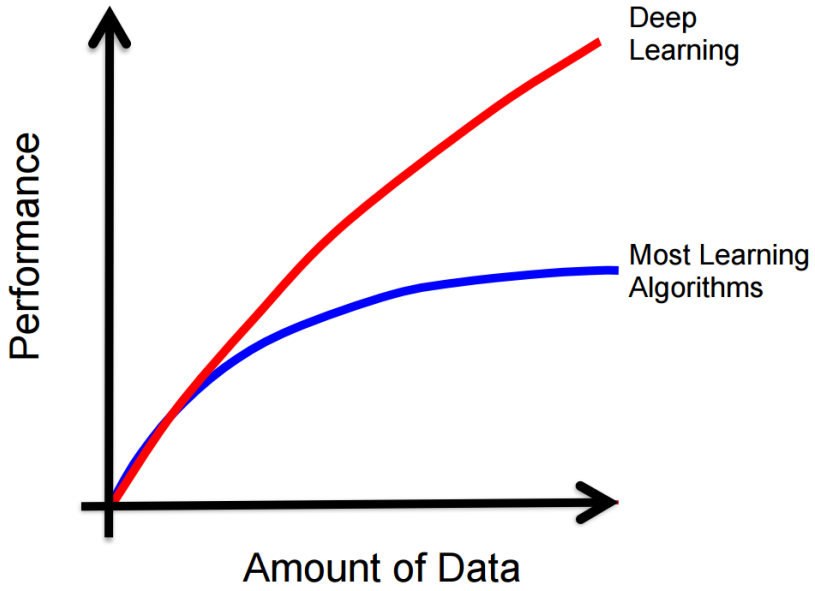
AI Methods – 4. Learning

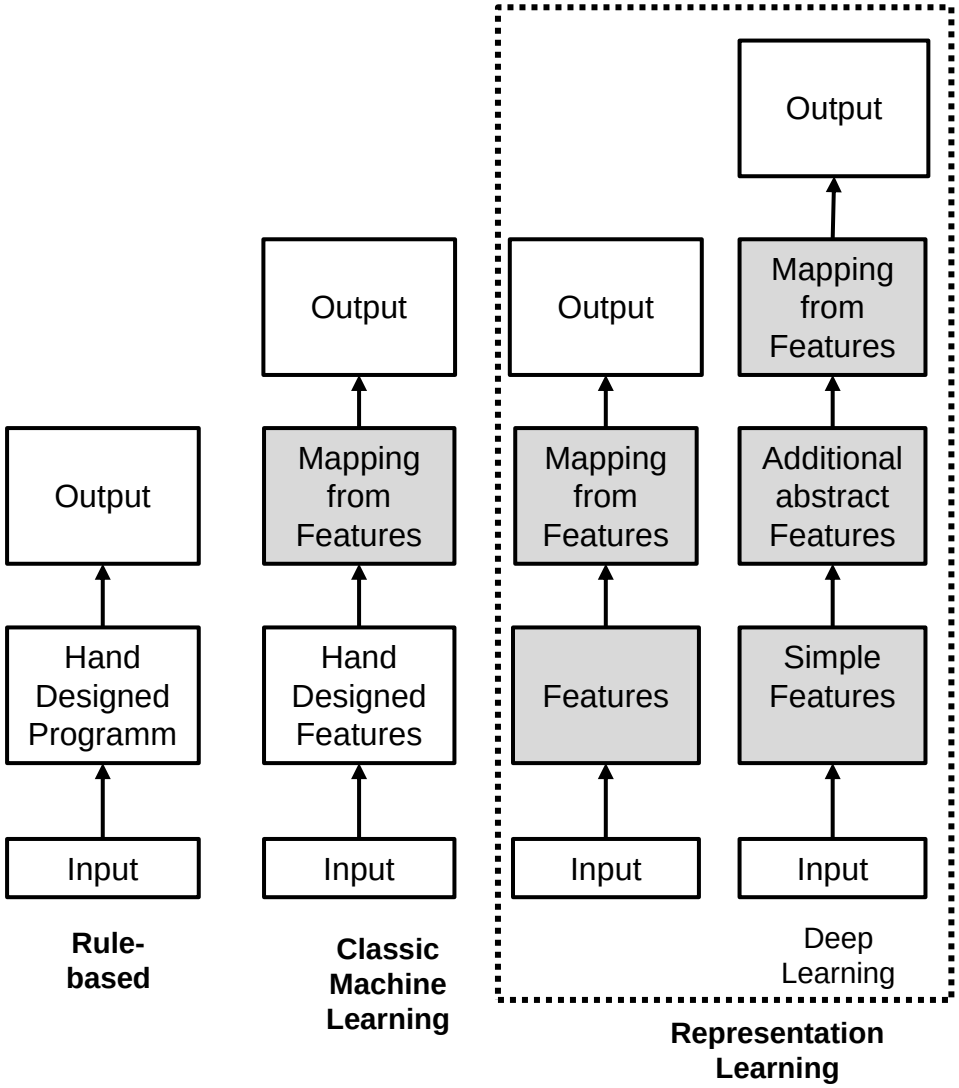
Methods & Algorithms



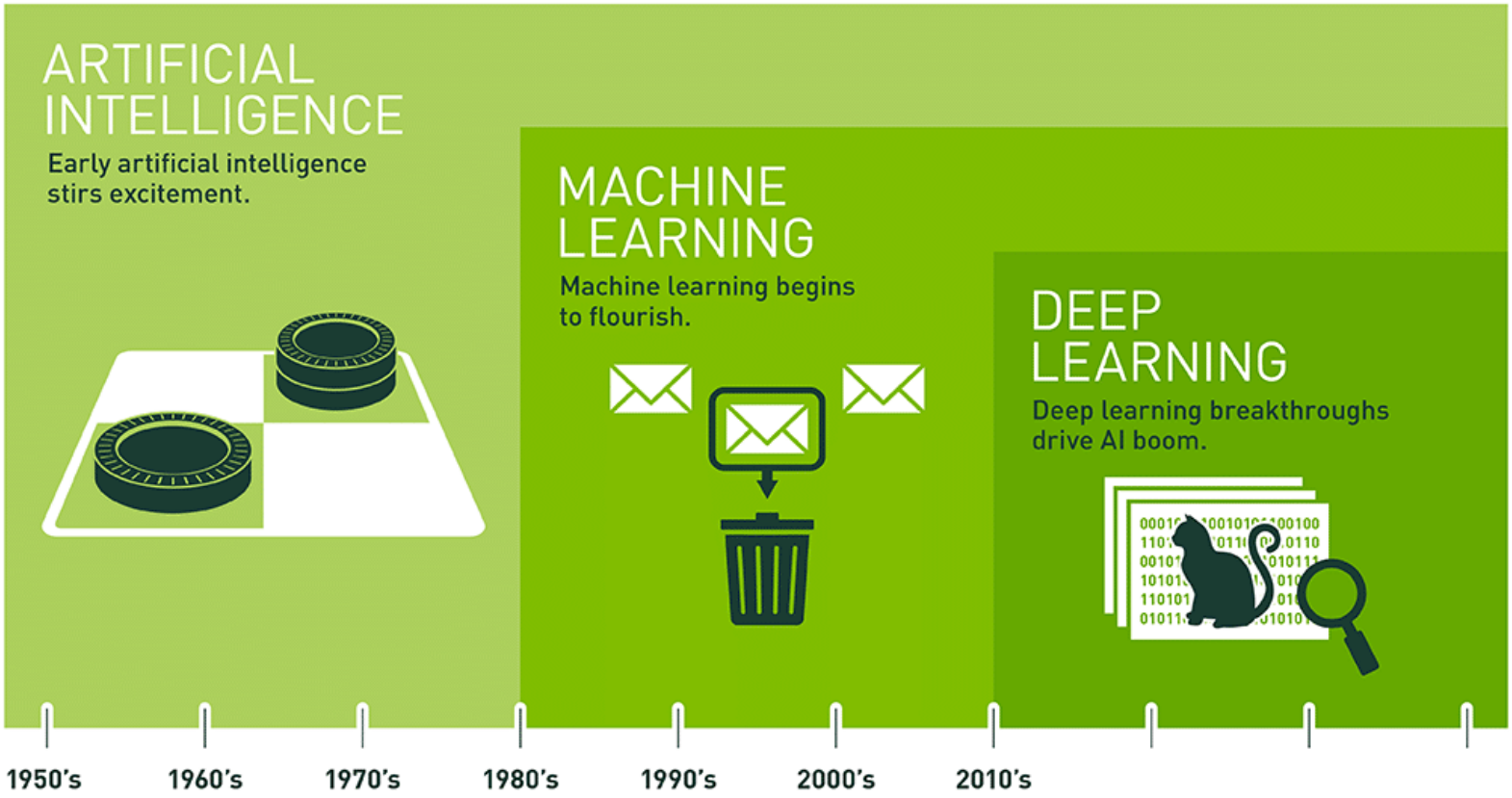
AI Methods – 4. Learning

Why Deep Learning?





AI – Machine Learning and Deep Learning



Since an early flush of optimism in the 1950s, smaller subsets of artificial intelligence – first machine learning, then deep learning, a subset of machine learning – have created ever larger disruptions.

Source: https://blogs.nvidia.com/blog/2016/07/29/whats-difference-artificial-intelligence-machine-learning-deep-learning-ai/

AI Methods – 5. Natural Language Processing (NLP)

Problem description:

- Language is highly complex because of syntax (grammar), semantics (meaning) and pragmatics (purpose)
- A computer gets the ability to understand human natural language
- A computer gets the ability to understand hand-written sources
- If a computer is represented as an agent, NLP allows the interaction between the human and a computer

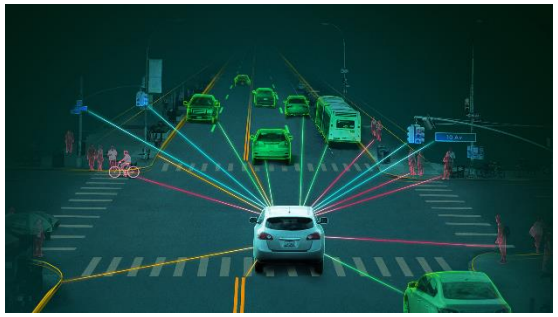
Methods & algorithms:

- Logic: A set of sentences in logical form expressing facts and rules about a problem, e.g., propositional logic, first-order logic, knowledge-based
- Classical machine learning, e.g., classification
- Deep learning, e.g., LSTM networks

AI Methods – 6. Perception

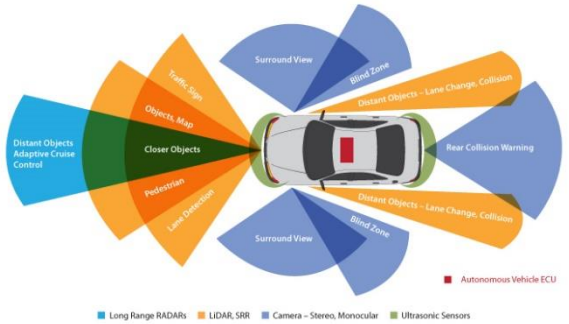
Problem description:

- A computer is represented as an agent
- This agent is getting the ability to perceive the environment
- The agent is using sensors as input: Camera, Lidar, ultrasonic, radar, microphones, …
- **Machine perception:** Capability to interpret data which is related to the environment world
- **Computer vision:** Input from a camera (images/videos) is analyzed and information is extracted



Methods & algorithms:

- **Classical** computer vision, e.g., color extraction, Canny edge, Hough lines,…
- **Modern** computer vision, e.g., deep neuronal networks, recurrent neuronal networks,…



Source: http://www.thewhollysee.com / https://itrade.gov.il/uk/2018/10/19/vayavisions-autonomous-vehicle-perception-system-raised-8m/ https://www.tataelxsi.com/ip-solution/automotive/Autonomai.html

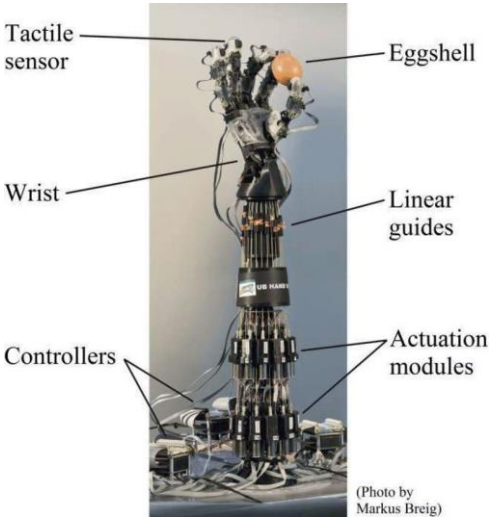
AI Methods – 7. Motion and Manipulation

Problem Description:

- A computer is represented as an agent
- The agent is getting the ability to move
- We have to plan the behavioral and motion of the agent
- We have to choose the locomotion (rolling, walking, ...)
- We have to sense the environment (touch, vision, …)
- We have to control the actuators of the agent (electrical motors, air muscles, …)

Methods & algorithms:

- Behavioral planning: What should I do? E.g., logic-based (state-machine), knowledge-based (network-graph),
- Motion planning: How can I achieve something? E.g., search algorithms, optimization algorithms
- Control: Steering and control of all the actuators, e.g., classical control (PID), model predictive control, …



Source: https://www.pinterest.es/pin/484559241142752519/?nic=1 / http://gamma.cs.unc.edu/PROBOT/

AI Methods – 8. Social Intelligence

Problem description:

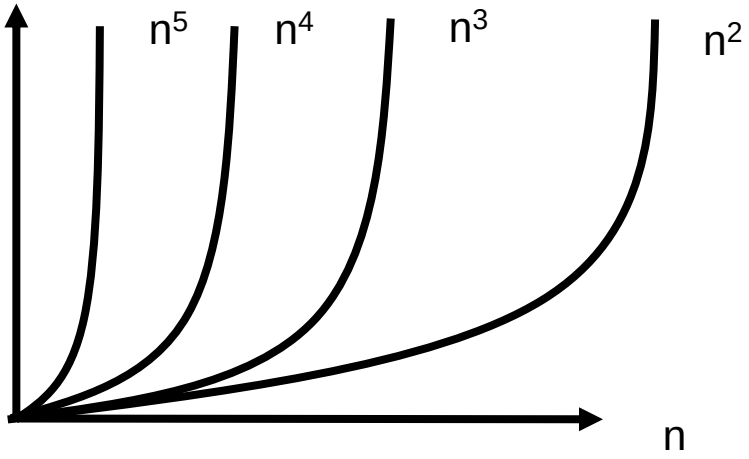
- A computer is represented as an agent
- This agent can understand and reproduce social skills: Confidence, responsibility, respect, ability to contact,…
- This agent can do **affective computing**: Recognize, interpret, process and simulate human effects
- This agent can do speech detection, facial affect detection, body gesture detection and physical monitoring

Methods & algorithms:

- Database, e.g., logic based (state-machine), knowledge-based
- Classification: What emotion could this be? E.g., support vector machines, k-nearest neighbor, deep learning,..
- Game theory: mathematical interaction between intelligent rational decision-makers, e.g., cooperative game, simultaneous game, evolutionary game,…

Source: https://www.keystepmedia.com/emotional-social-intelligence-leadership-competencies/

AI Methods – What is the Problem?



Computational complexity:

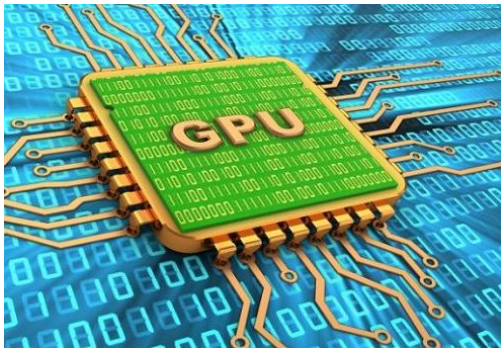
- Lot of problems are NP-hard
- Exponential explosion of time

Information complexity:

- Information is limited
- Uncertainty is existent
- Knowledge acquisition required

Source: https://jalopnik.com/for-48-000-could-this-2008-factory-five-gtm-super-car-1786246861

AI Methods – Why now?



1. Data, labeled data, knowledge is available: **Big data**

2. New AI algorithms are available: **Deep learning**

3. Computer power is available: **GPU**

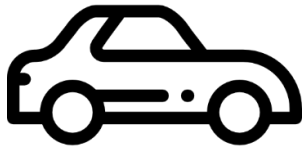
Source: https://qlu.ac.pa/english/3-de-diciembre-conferencia-internacional-gratuita-competitividad-sustentable-utilizando-analytics-big-data/
https://ai.googleblog.com/2017/05/using-machine-learning-to-explore.html
https://www.hpcwire.com/2018/03/27/nvidia-riding-high-as-gpu-workloads-and-capabilities-soar/

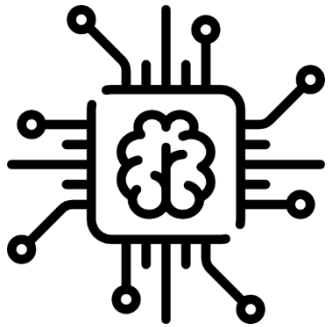
Introduction: Artificial Intelligence
Prof. Dr. Markus Lienkamp

(Maximilian Geißlinger, M. Sc.)

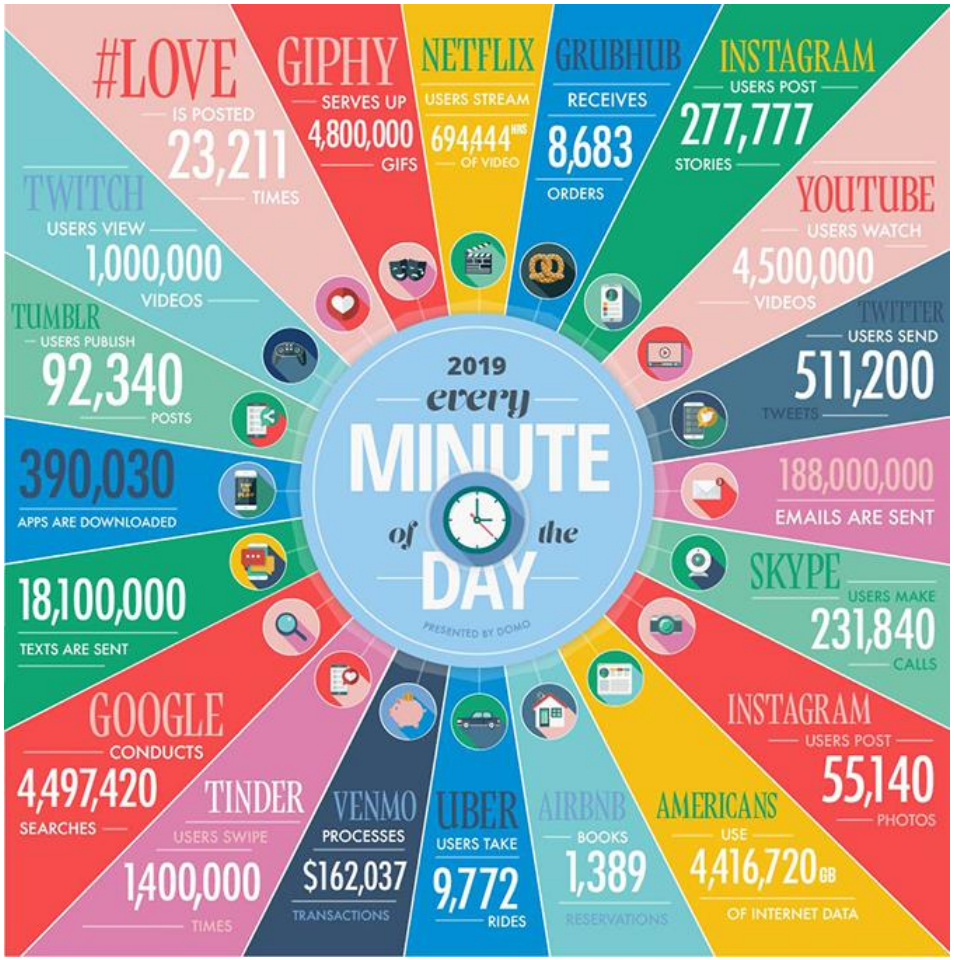
Agenda

1. Chapter: Artificial Intelligence in the Spotlight
2. Chapter: A brief History
3. Chapter: What is Intelligence?
4. Chapter: AI Methods
5. **Chapter: AI Applications**
6. Chapter: AI Application: Automotive Technology
7. Chapter: Summary





AI Applications – Big Data Analysis

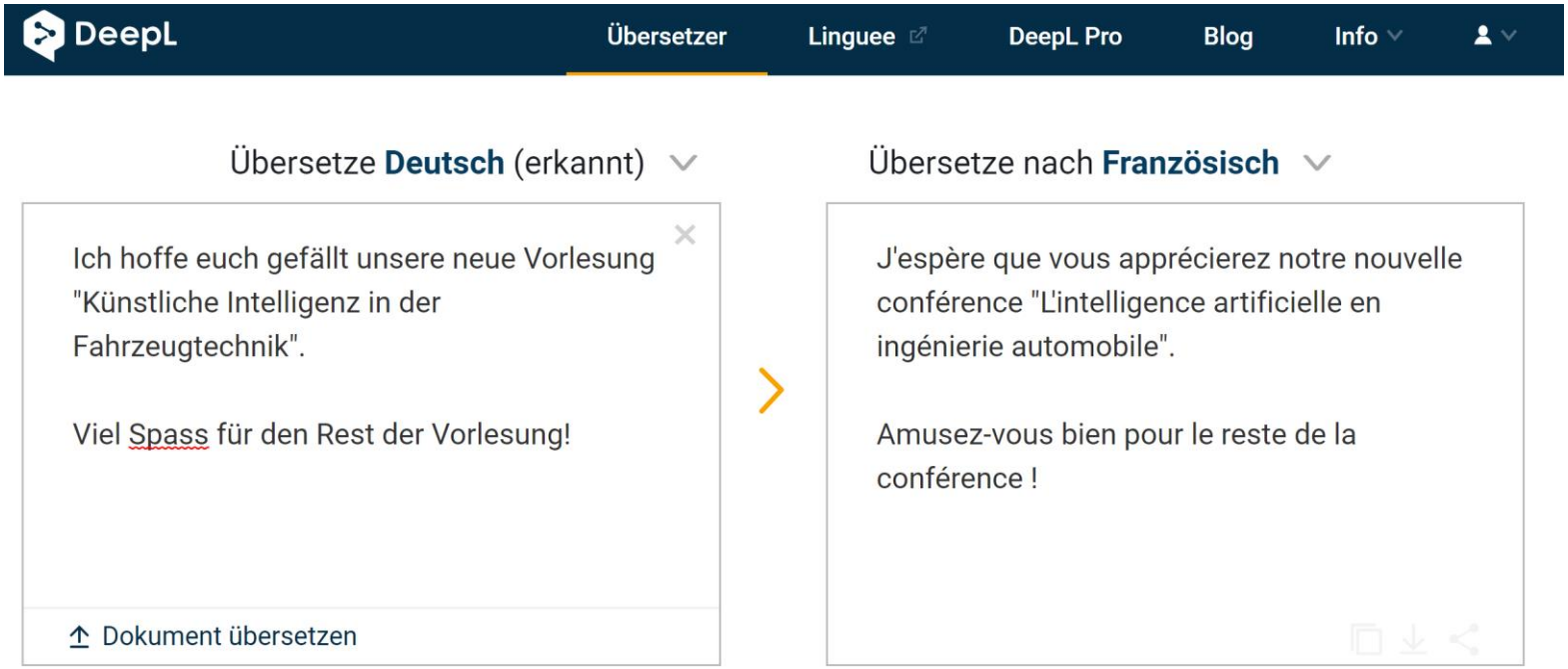


2019: Big data is everywhere

Source: https://blog.microfocus.com/how-much-data-is-created-on-the-internet-each-day/

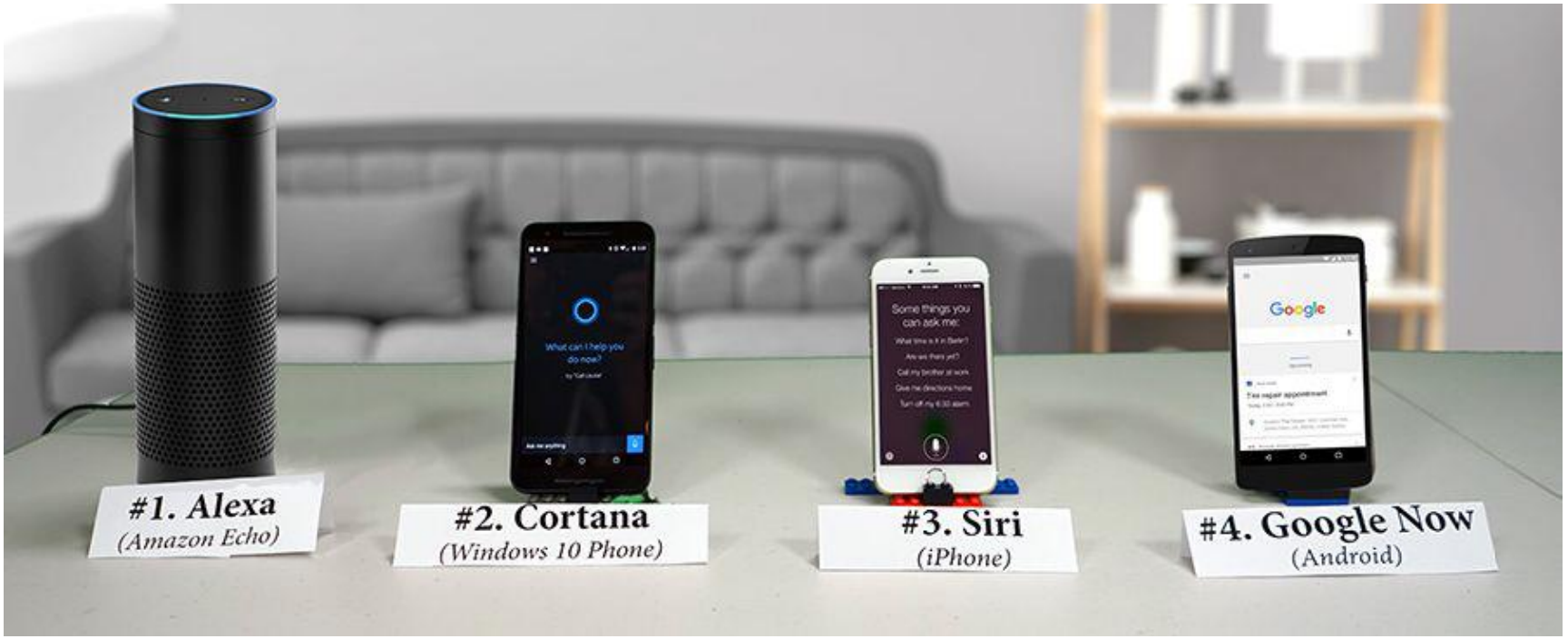
AI Applications – Faster Matrix Multiplication

AI Applications – Machine Translation



- Machine translation starting in 1960s
- In the 1990s and 2000s, statistical machine translation, aided by large amounts of example translations,
- 2015: Google Translate supports 90 languages + 200 million user per day

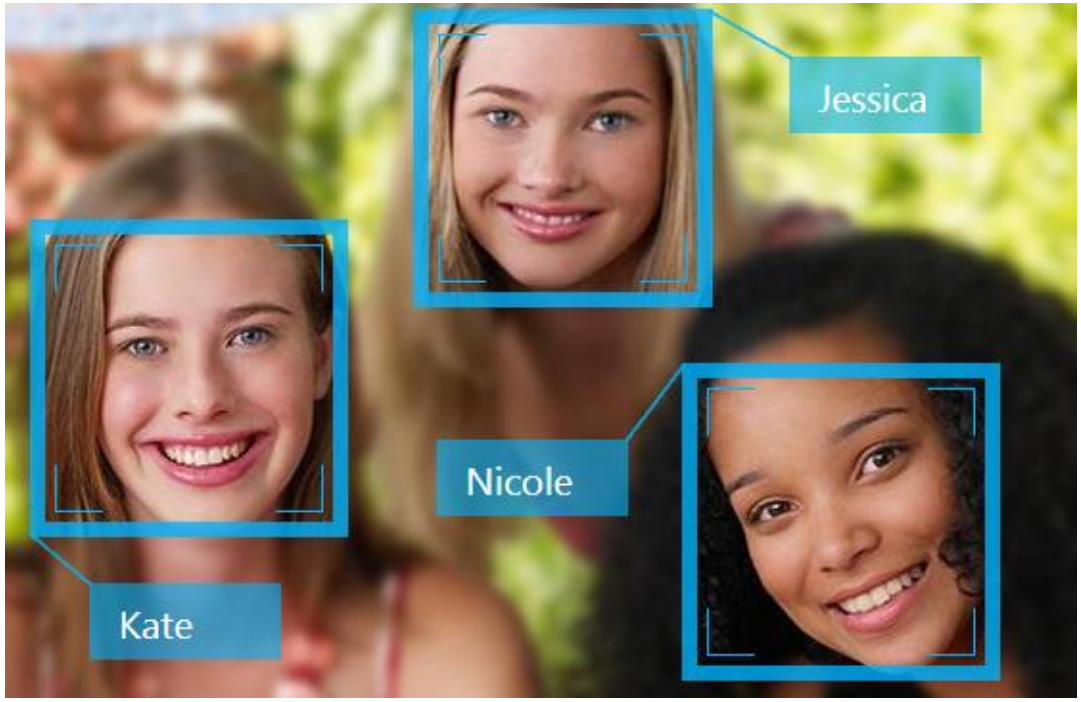
AI Applications – Natural Language Processing



- Speech recognition
- Speech segmentation
- Text-to-speech

Source: https://finance.yahoo.com/news/battle-of-the-voice-assistants-siri-cortana-211625975.html

AI Applications – Security

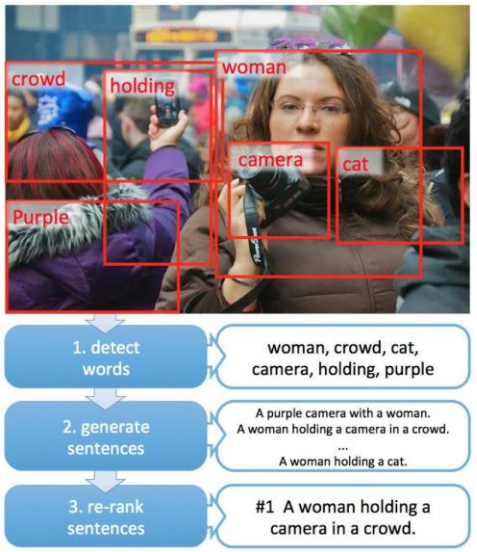


- Face detection: Spatial allocation
- Feature extraction: Nose, mouth, eyes,…
- Face recognition: Comparison with data base

Source: https://medium.com/the-21st-century/face-detection-using-python-a04b08118ae6
https://www.welt.de/politik/deutschland/article167290600/Gesichtserkennung-die-naechste-Stufe-der-Ueberwachung.html

AI Applications – and 1000 more…

Image colorization



Caption generation

Artistic style transfer

Source: https://arxiv.org/pdf/1603.08511.pdf/ https://arxiv.org/pdf/1411.4952v3.pdf

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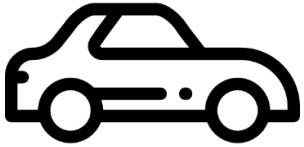
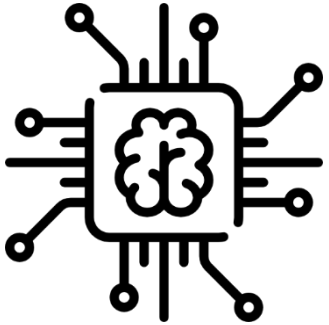
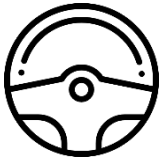
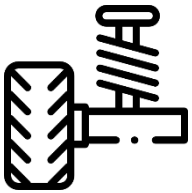




AI Applications – Automotive Technology

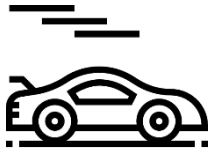


Electric/
Electronic

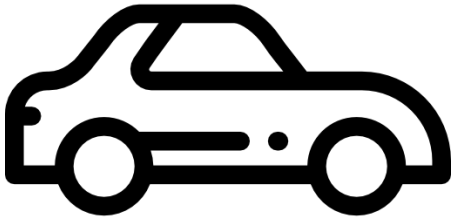


Vehicle
Dynamics

Electric/
Electronic

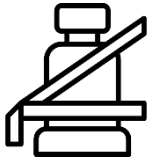


Package/
Design



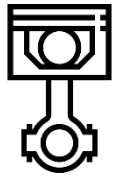
Automotive
Technology

Maintanence



Safety

Drivetrain

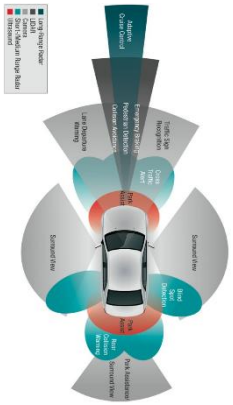


Engine

AI Applications – Automotive Technology

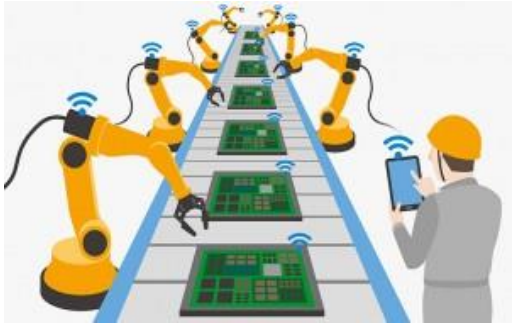
AI can be applied in different sectors regarding automotive technology

Automotive development:
Data analysis tool



Vehicle functions:
ADAS functions, predictive maintanence

Complete vehicles:
Autonomous driving



Automotive production:
Production improvement, automatic operations, monitoring

Source: https://www.springboard.com/learning-paths/data-analysis/ / https://medium.com/frontier-tech/the-next-seat-belt-60e980c3ea8b / https://hothardware.com/news/google-stops-publishing-waymo-self-driving-car-accident-reports http://www.bhs-business.com/the-production-process.html

AI Applications – Autonomous Cars

Motivation for autonomous driving:

- **Safety improvement:** Over 90 % of all accidents can be attributed to human error
- **Comfort improvement:** People can sleep or work in the vehicle
- **Energy saving:** Perfect planned velocity and trajectory profiles
- **Traffic reduction:** Exchange of information between vehicles and adaptation to traffic
- **New mobility services**: Goods transport, taxi, …
- **New software function development:** AI software

AI Applications – Autonomous Cars

AUTOMATION LEVELS OF AUTONOMOUS CARS

LEVEL 0

There are no autonomous features.

LEVEL 1

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

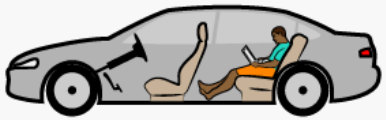
LEVEL 2

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

Source: https://www.businessinsider.de/what-are-the-different-levels-of-driverless-cars-2016-10?r=US&IR=T

AI Applications – Autonomous Vehicles

80s: Project Promotheus

2005: Darpa Grand Challenge

2007: Darpa Urban Challenge

AI Applications – Autonomous Vehicles

2009: Google
Research

2010: Audi TT
Autonomous Pikes Peak

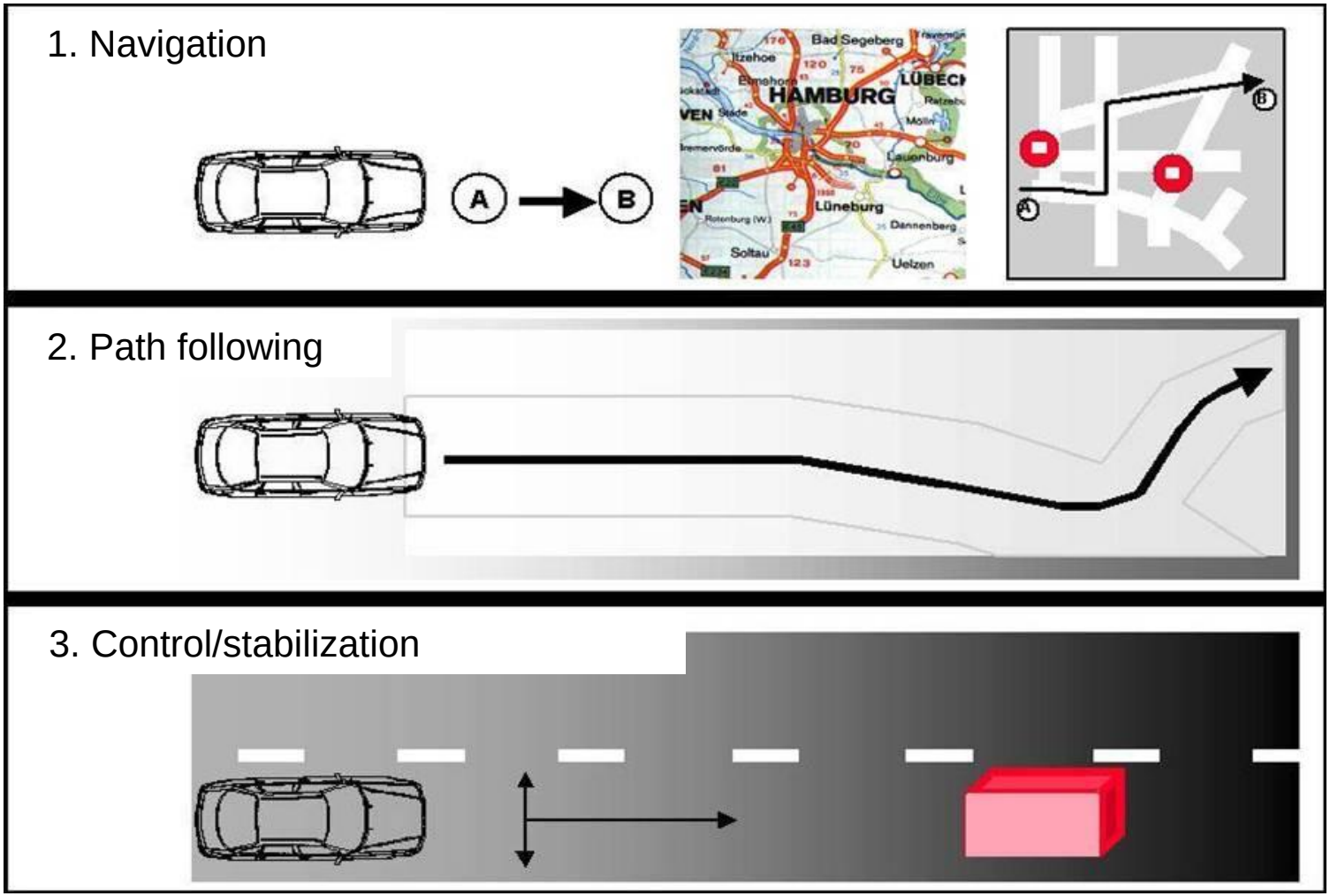
2014: Tesla
Model S Autopilot

2015: Audi RS7
Piloted Driving

2016: Nutonomy
Self-Driving Taxi

2021 Indy Autonomous
Challenge

AI Applications – The Primary Driving Task



Time

Hours to minutes

Minutes to seconds

Seconds to miliseconds

AI Applications – The Primary Driving Task




Problem:

The world is a complex and dynamic place

Source: NVIDIA – LRZ Deep Learning Workshop

AI Applications – The Primary Driving Task

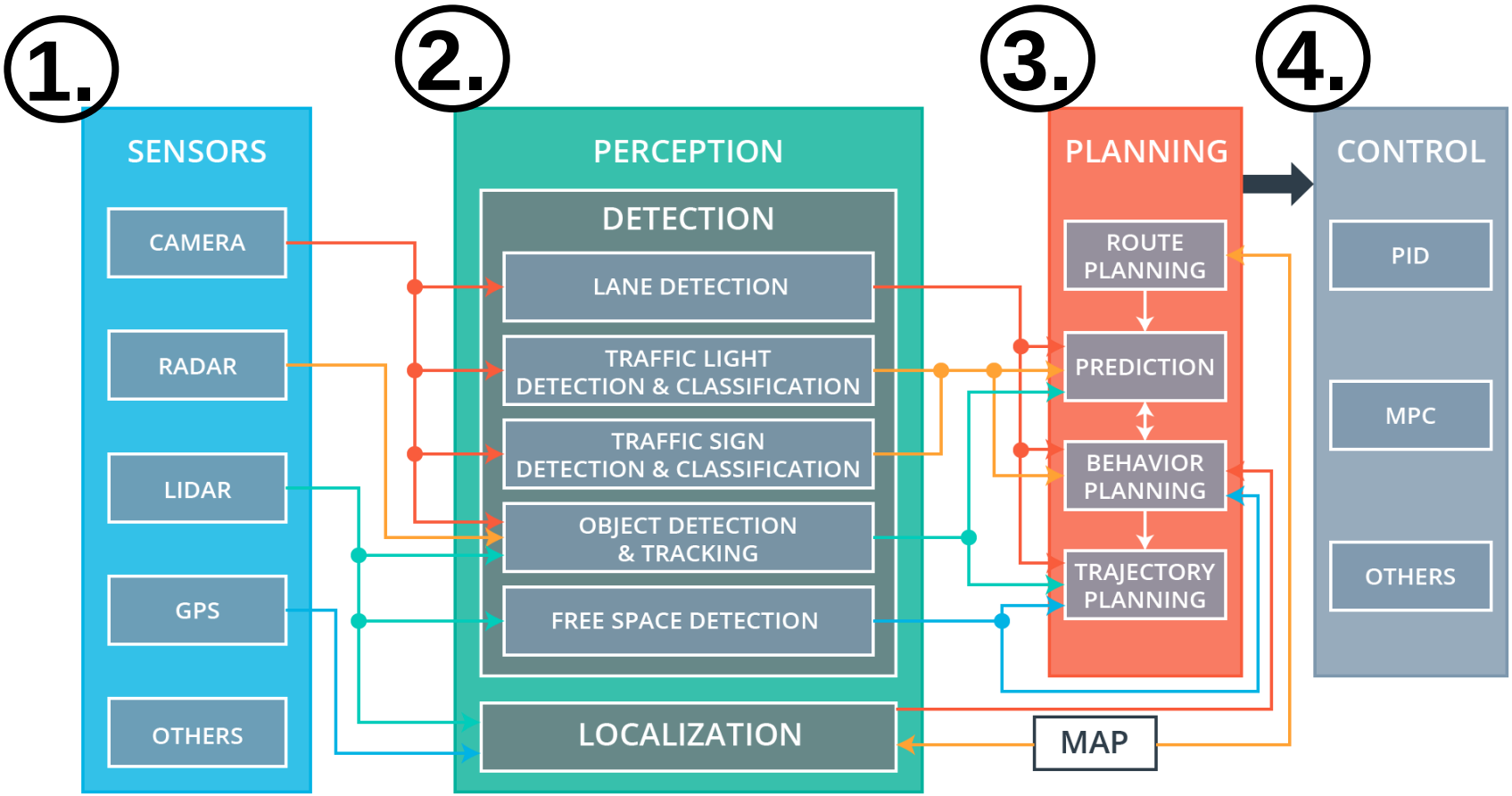
Solution:

Our car has **to learn how** to drive like a human

→ **Using machine learning algorithms**

Source: https://www.istockphoto.com/de/foto/cyborg-gm483422089-37471772
https://www.tagesspiegel.de/weltspiegel/knapp-37-prozent-fahrschueler-fallen-immer-oefter-durch-die-pruefung/21244016.html

AI Applications – Automotive Technology



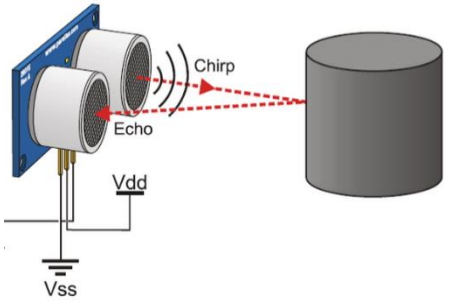
Autonomous level 5 car pipeline

Source: Udacity – Self Driving Nanodegree Programm

AI Applications – Sensors

Radar

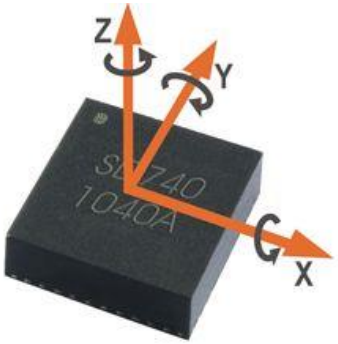
Lidar



Ultrasonic

Camera

GPS

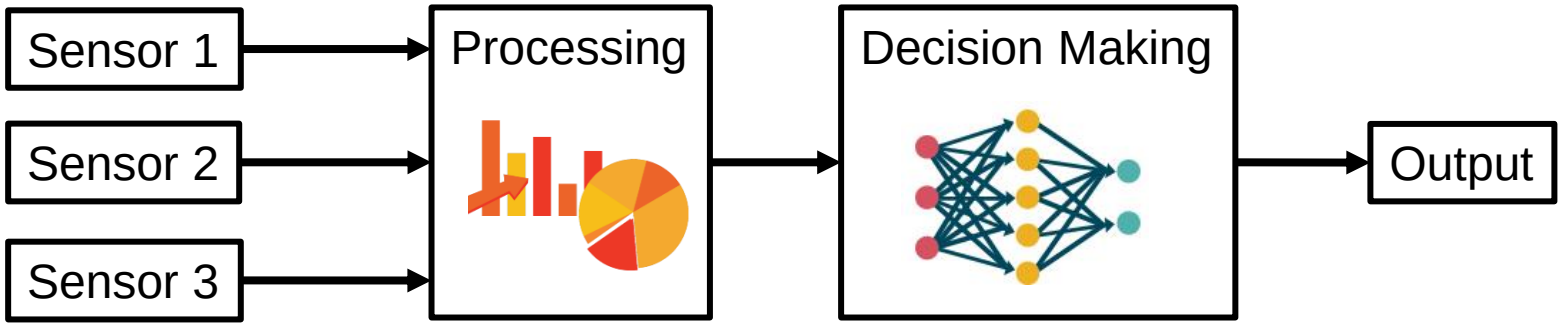


IMU

Source https://www.made-in-china.com/showroom/haoduomomo/product-detailhScmBMdyeKkw/China-360-Degree-Laser-Scanner-Development-Kit-Distance-Sensor-Lidar.html
https://www.elphel.com/www3/stereo_setup
http://richmondsystems.net/2017/07/23/ultrasonic-sensor-hc-sr04-arduino/
http://reliantmonitoring.com/gps-how-does-it-actually-work/gps-track/
https://www.designworldonline.com/6dof-sensors-improve-motion-sensing-applications/

AI Applications – AI Algorithm for Sensor Processing

- **Sensor fusion:**

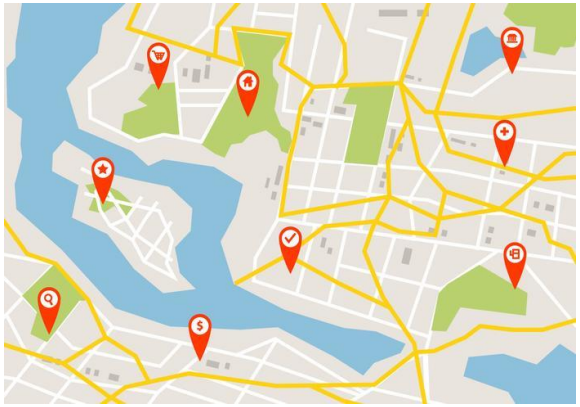


- **Faster data processing**

Radar	0.1 - 15 Mbit/s
Lidar	20 - 100 Mbit/s
Camera	500-3500 Mbit/s
Ultrasonic	<0.01 Mbit/s
GPS, IMU	< 0.1 Mbit/s

AI Applications – Perception

Scene understanding: **Where is the road?**



Input Information:

- Camera images
- HD maps
- GPS location

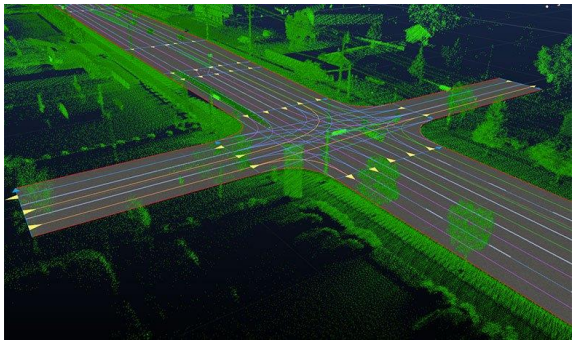
AI Method:

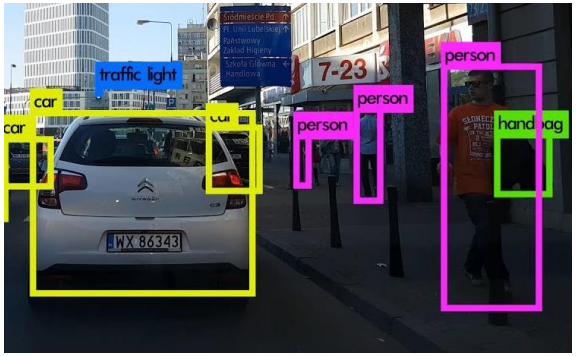
- Sensor fusion
- Computer vision
- Faster map comparison

Source: https://www.linkedin.com/pulse/udacity-self-driving-car-engineering-project-4-advanced-de-boer

AI Applications – Perception

Scene understanding: **What is around me?**





Input Information:

- Camera images
- Lidar laser scans
- Radar scans
- Ultrasonic scans

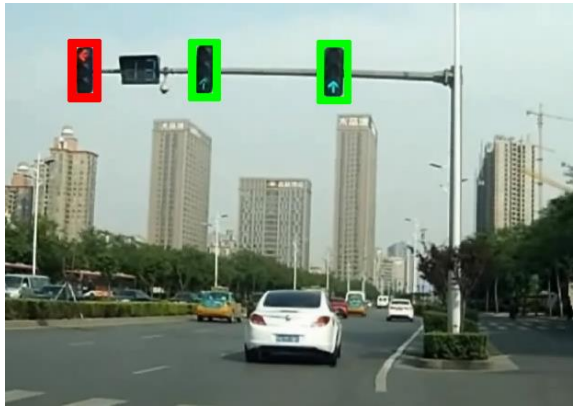
AI Method:

- Sensor fusion
- Computer vision
- Classification
- Uncertainty planning
- Mapping

Source: https://www.ideatovalue.com/curi/nickskillicorn/2018/04/this-innovating-software-can-now-recognise-thousands-of-objects-in-real-time/attachment/yolo-object-recognition/

AI Applications – Perception

Scene understanding: **Driving restrictions?**



Input Information:

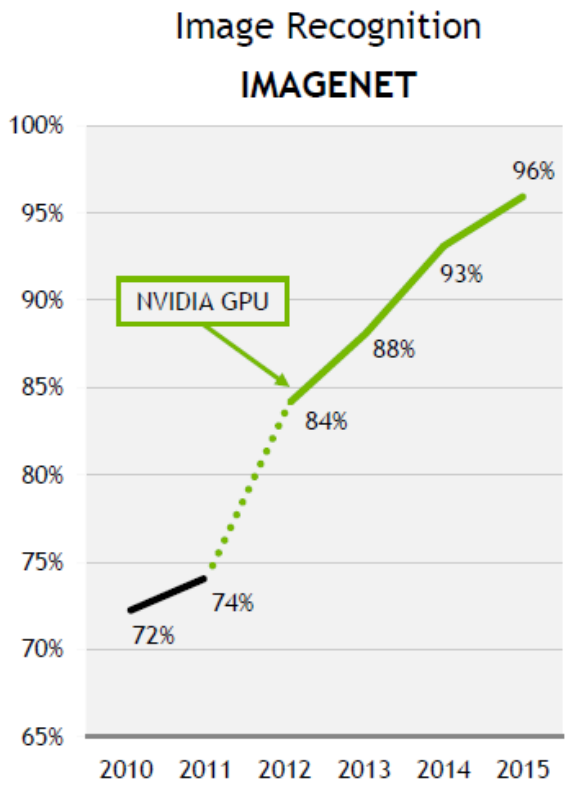
- Camera images

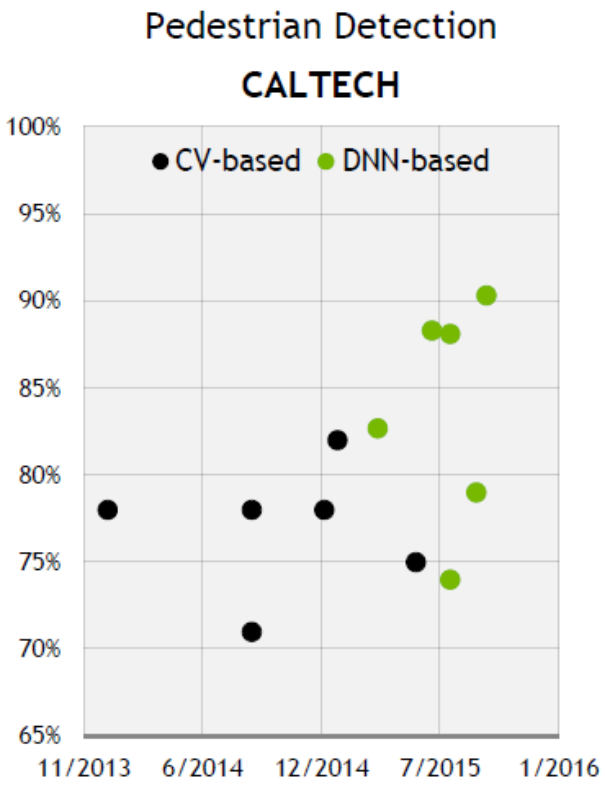
AI Method:

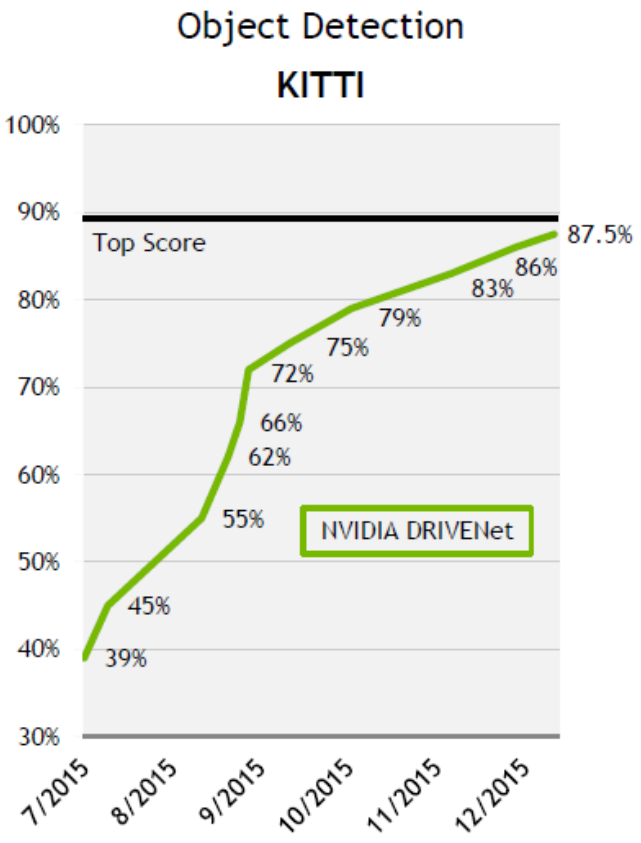
- Computer vision
- Classification

AI Applications – Perception

Scene understanding: **Improvement with AI**



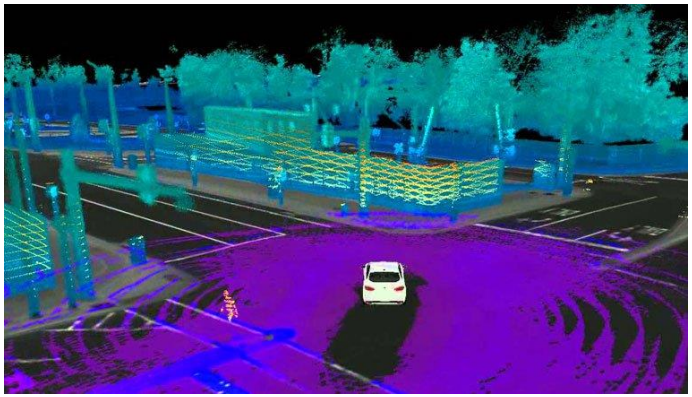


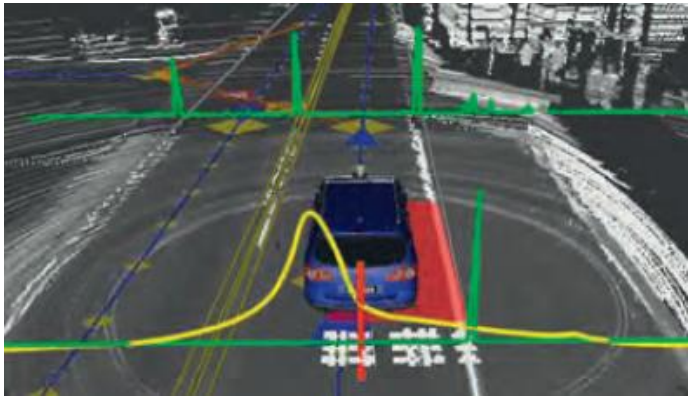


Source: NVIDIA Accelerated Computing Workshop @LRZ

AI Applications – Perception

Where am I: **Have I seen that before?**





Input Information:

- Camera images
- HD maps
- Lidar laser scans
- GPS location

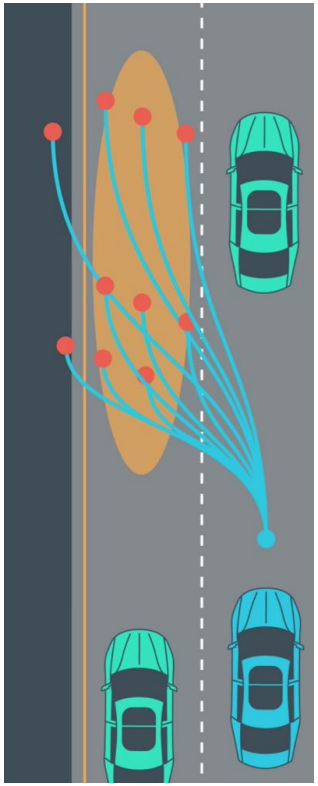
AI Method:

- Sensor fusion
- Computer vision
- Faster map comparison
- Particle filter

Source:
http://velodynelidar.com/docs/news/How%20Ford%27s%20autonomous%20test%20vehicles%20make%203D%20LiDAR%20maps%20of%20the%20world%20around%20them%20_%20PCWorld.pdf

AI Applications – Planning

Path planning of own vehicle: **Where should I drive?**



Input Information:

- Vehicle data: a_x/a_y, v_x/v_y,…
- GPS location
- Camera images
- Lidar laser scans

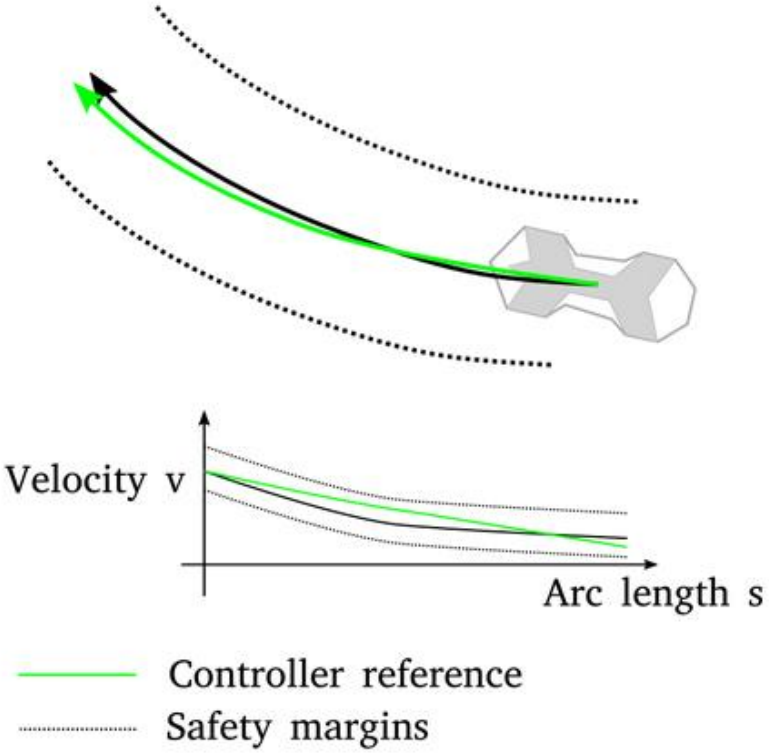
AI Method:

- Sensor fusion
- Path planning
- Motion planning

Source: https://medium.com/udacity/self-driving-path-planning-brought-to-you-by-udacity-students-13c07bcd4f32

AI Applications – Control

Vehicle control: **How much do I actuate something?**



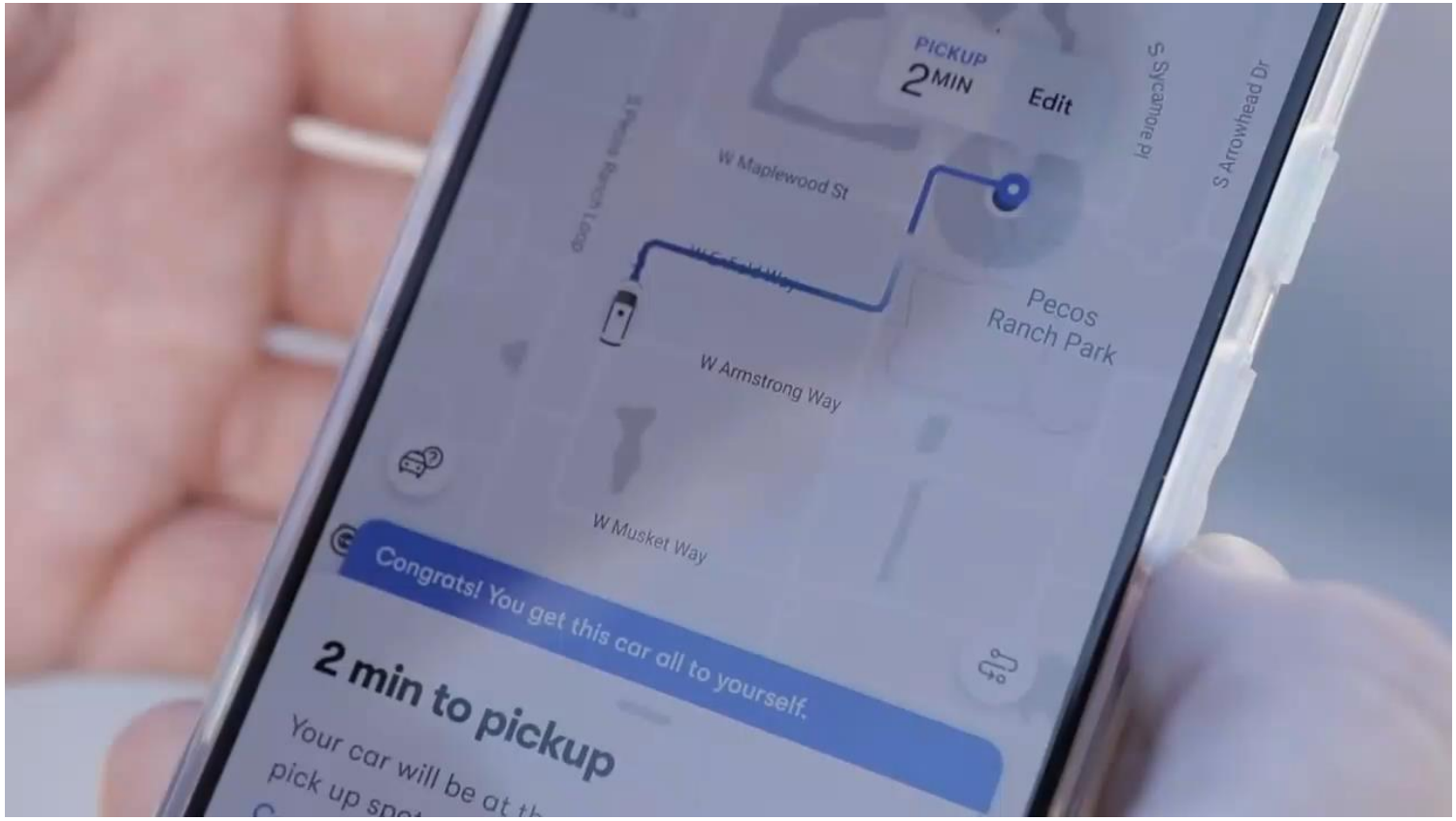
Input information:

- Vehicle data: a_x/a_y, v_x/v_y,…

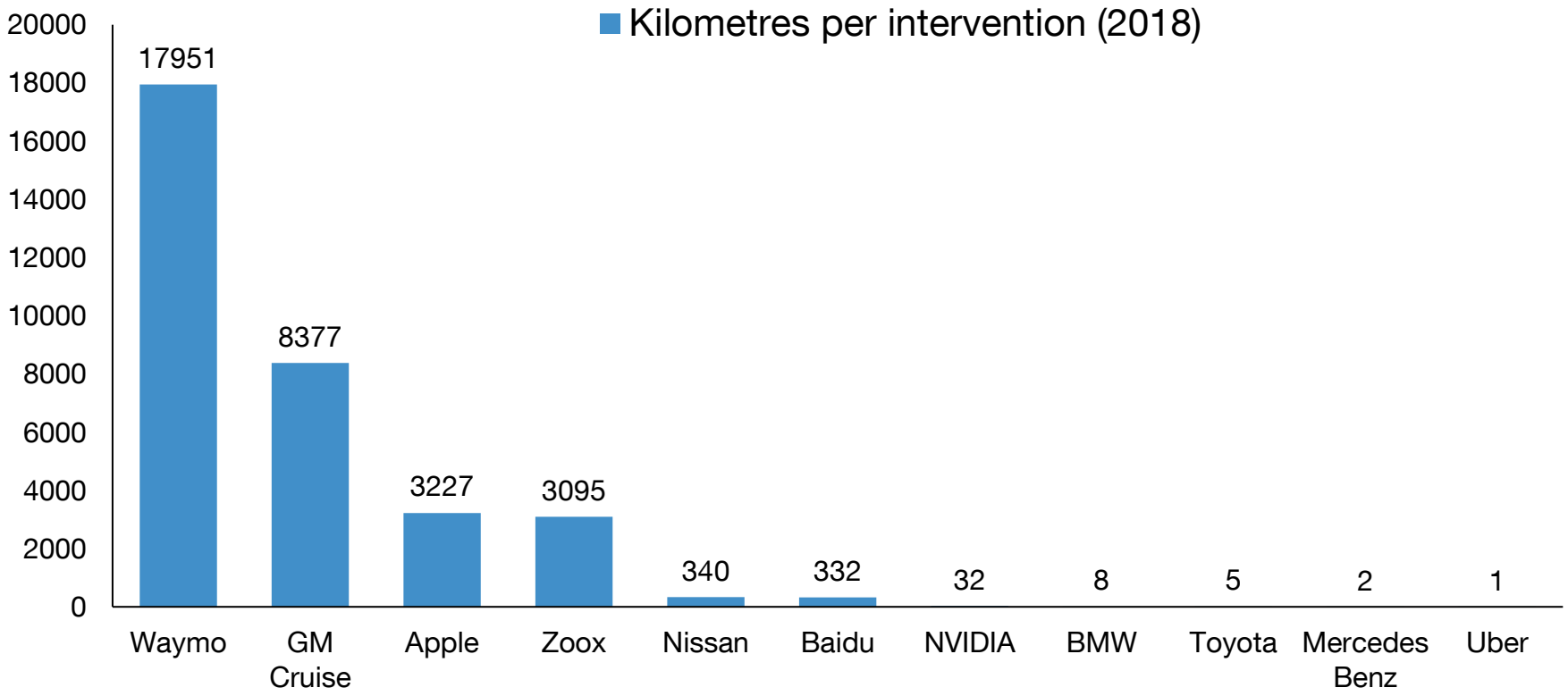
AI method:

- Sensor fusion
- Uncertainity planning
- Feedforward
- Model adaption
- Regression

Waymo Robotaxi

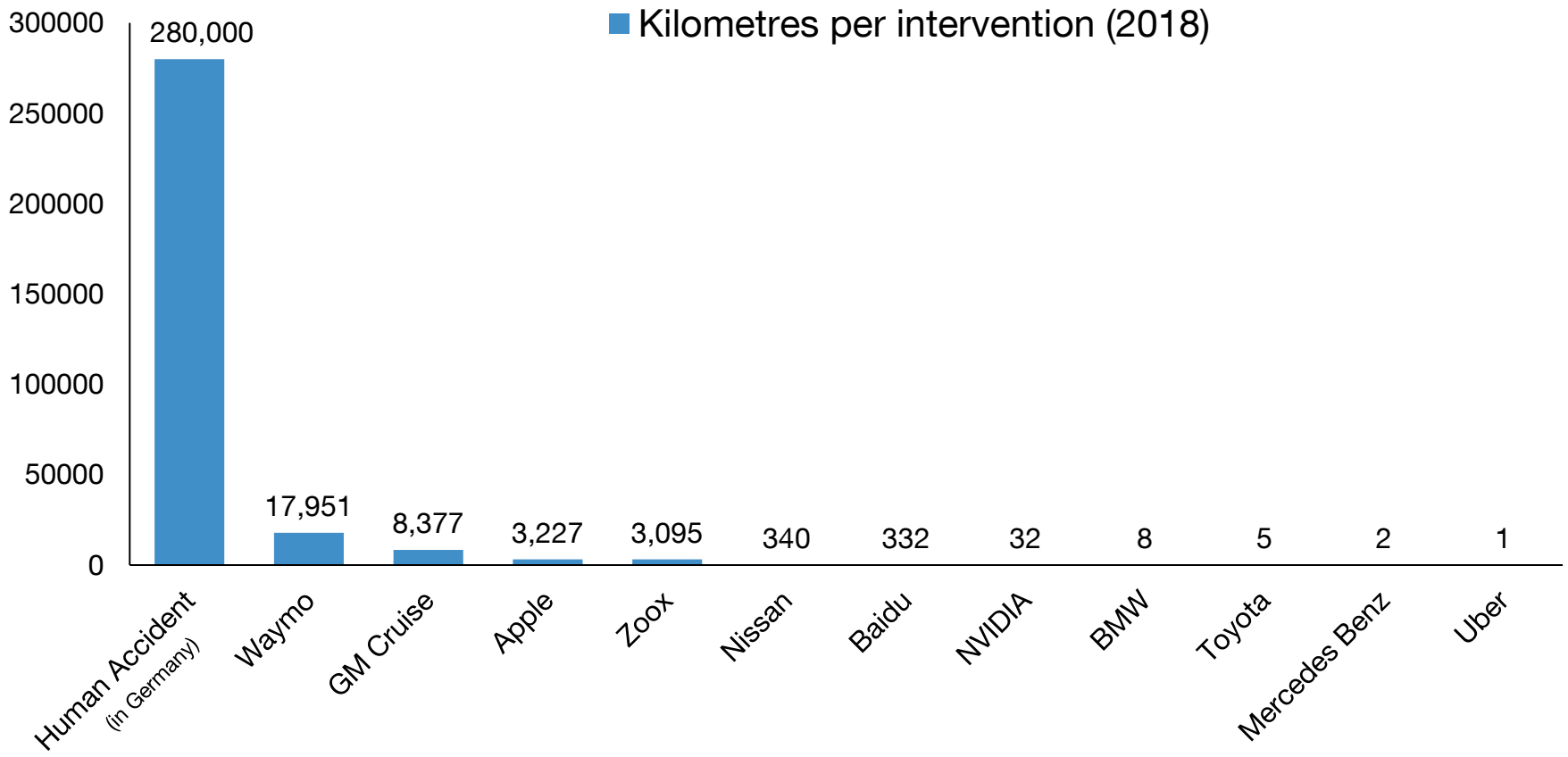


Level 4: Automated test drives in California 2018



Source: J. Knecht „Wie oft autonome Autos wirklich versagen“, auto motor sport [online], URL: https://www.auto-motor-und-sport.de/tech-zukunft/wie-oft-autonome-autos-versagen/

Level 4: Comparison with human driver



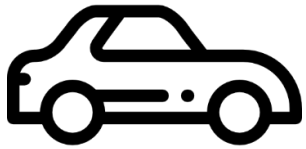
Source: J. Knecht „Wie oft autonome Autos wirklich versagen“, auto motor sport [online], URL: https://www.auto-motor-und-sport.de/tech-zukunft/wie-oft-autonome-autos-versagen/

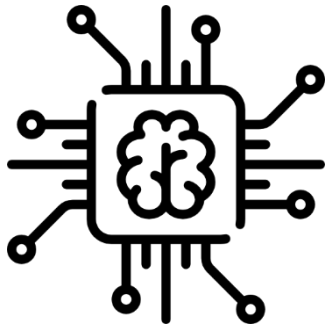
Introduction: Artificial Intelligence
Prof. Dr. Markus Lienkamp

(Maximilian Geißlinger, M. Sc.)

Agenda

1. Chapter: Artificial Intelligence in the Spotlight
2. Chapter: A brief History
3. Chapter: What is Intelligence?
4. Chapter: AI Methods
5. Chapter: AI Applications
6. Chapter: AI Application: Automotive Technology
7. **Chapter: Summary**





Summary – What did we learn today

- The industry attributes the field of **artificial intelligence** a big potential. The big problem with using artificial intelligence is that we **need a lot of data which is labeled** and that we **need high computer performance.**
- An overall definition for intelligence is complex so we **classify intelligence** into different styles of intelligence: **Emotional, creative, methodical and analytical.**
- Artificial Intelligence, more or less, is the **ability of a computer to do special tasks better than a human.**
- An overall definition for artificial is complex so we **classify AI** into different sub-problems we have to conquer, if we want to make a computer better than a human:

1. **Reasoning & problem solving**
2. **Knowledge representation**
3. **Planning**
4. **Learning**
5. **Natural language processing (NLP)**
6. **Perception**
7. **Motion and manipulation**
8. **Social intelligence.**

Summary – What did we learn today

- Philosophers (going back to 400 B.C.) made AI conceivable by considering the ideas that the mind is in some ways like a machine, that it operates on knowledge encoded in some internal language, and that thought can be used to choose what actions to take.
- **Mathematicians provided the tools** to manipulate statements of **logical certainty** as well as **uncertain, probabilistic statements**. They also set the groundwork for understanding computation and reasoning about algorithms.
- For every sub-problem in artificial intelligence we can **use mathematic tools and methods** to solve one of these problems.
- The focus in artificial intelligence is on **machine learning**, which gives the computer the **ability to recognize patterns and to “learn” from data.**
- We classify Machine Learning into three big problems: **Regression, classification, clustering.**

Summary – What did we learn today

- A major task for using machine learning algorithms is automotive technology.
- Especially for **autonomous driving**, we need machine learning algorithm: **The world is a complex place** with different weather, lights, people and vehicle on the streets and special situations like traffic jams, roadworks or parking lots.
- We classify autonomous driving into 4 sub-functions: **Sensor processing, perception, path & behavioral planning and control.**
- Each of those sub-functions can be accomplished by machine learning methods.