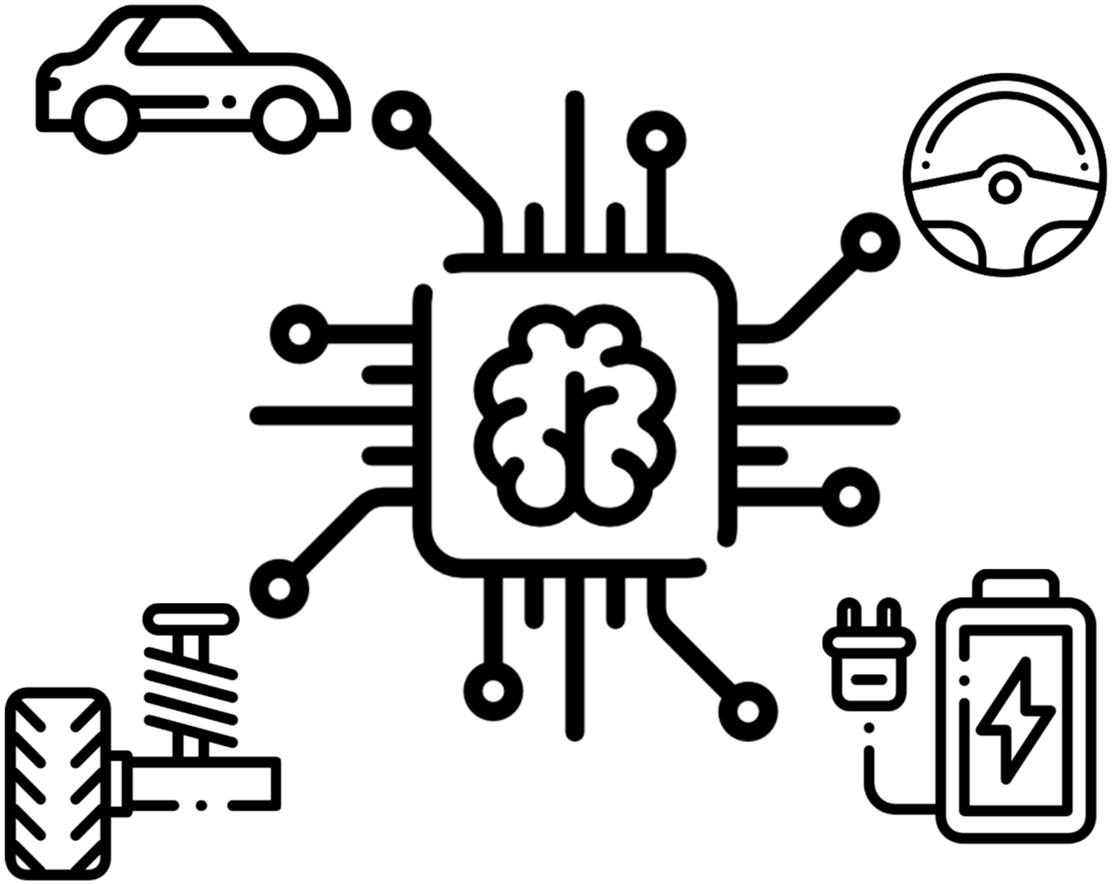
Institute of Automotive Technology
Faculty for Mechanical Engineering
Technical University of Munich

Artificial Intelligence in Automotive Technology

Johannes Betz / Prof. Dr.-Ing. Markus Lienkamp/ Prof. Dr.-Ing. Boris Lohmann



Lecture Overview

1 Introduction: Artificial Intelligence 18.10.2018 – Betz Johannes	**6 Pathfinding: From British Museum to A*** 29.11.2018 – Lennart Adenaw	**11 Reinforcement Learning** 17.01.2019 – Christian Dengler
Practice 1 18.10.2018 – Betz Johannes	**Practice 6** 29.11.2018 – Lennart Adenaw	**Practice 11** 17.01.2019 – Christian Dengler
2 Perception 25.10.2018 – Betz Johannes	**7 Introduction: Artificial Neural Networks** 06.12.2018 – Lennart Adenaw	**12 AI-Development** 24.01.2019 – Johannes Betz
Practice 2 25.10.2018 – Betz Johannes	**Practice 7** 06.12.2018 – Lennart Adenaw	**Practice 12** 24.01.2019 – Johannes Betz
3 Supervised Learning: Regression 08.11.2018 – Alexander Wischnewski	**8 Deep Neural Networks** 13.12.2018 – Jean-Michael Georg	**13 Free Discussion** 31.01.2019 – Betz/Adenaw
Practice 3 08.11.2018 – Alexander Wischnewski	**Practice 8** 13.12.2018 – Jean-Michael Georg	
4 Supervised Learning: Classification 15.11.2018 – Jan Cedric Mertens	**9 Convolutional Neural Networks** 20.12.2018 – Jean-Michael Georg	
Practice 4 15.11.2018 – Jan Cedric Mertens	**Practice 9** 20.12.2018 – Jean-Michael Georg	
5 Unsupervised Learning: Clustering 22.11.2018 – Jan Cedric Mertens	**10 Recurrent Neural Networks** 10.01.2019 – Christian Dengler	
Practice 5 22.11.2018 – Jan Cedric Mertens	**Practice 10** 10.01.2019 – Christian Dengler	

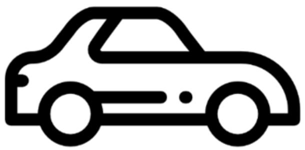
Introduction: Artificial Intelligence

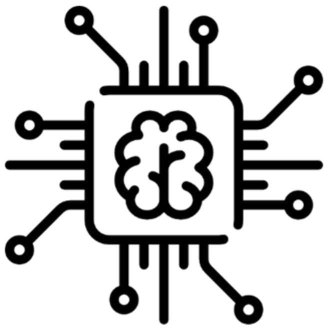
Johannes Betz / Prof. Dr. Markus Lienkamp / Prof. Dr. Boris Lohmann

(Johannes Betz, M. Sc.)

Agenda

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





AI in the Spotlight

Nvidia GTC Conference Keynote in Munich (11.10.2018)

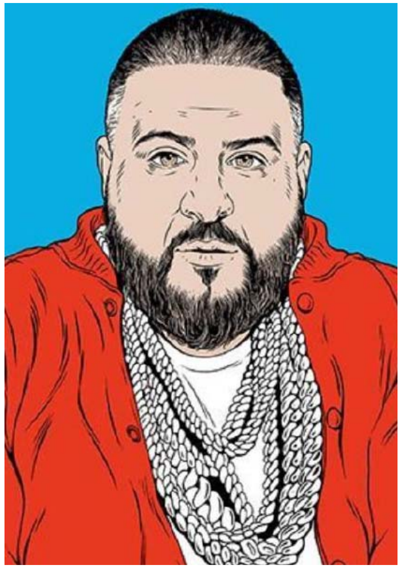
Quelle: https://www.youtube.com/watch?v=G1kx_7NJJGA&t=62s

AI in the Spotlight

Google Trends „Deep Learning“

Quelle: Google Trends – Search „Deep Learning“

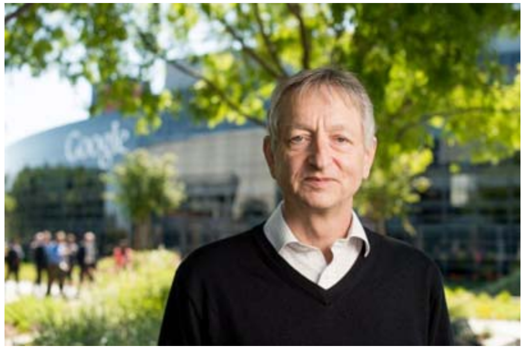
AI in the Spotlight



73. DJ Khaled

Snapchat icon; DJ and producer

Louisiana-born Khaled Mohamed Khaled, aka DJ Khaled, cut his musical chops in the early 00s as a host for Miami urban music radio WEDR. He proceeded to build a solid if not dazzling career as a mixtape DJ and music producer (he founded his label We The Best Music Group in 2008, and was appointed president of Def Jam South in 2009).



69. Geoffrey Hinton

Psychologist, computer scientist; researcher, Google Toronto

British-born Hinton has been dubbed the "godfather of deep learning". The Cambridge-educated cognitive psychologist and computer scientist started being an ardent believer in the potential of neural networks and deep learning in the 80s, when those technologies enjoyed little support in the wider AI community.

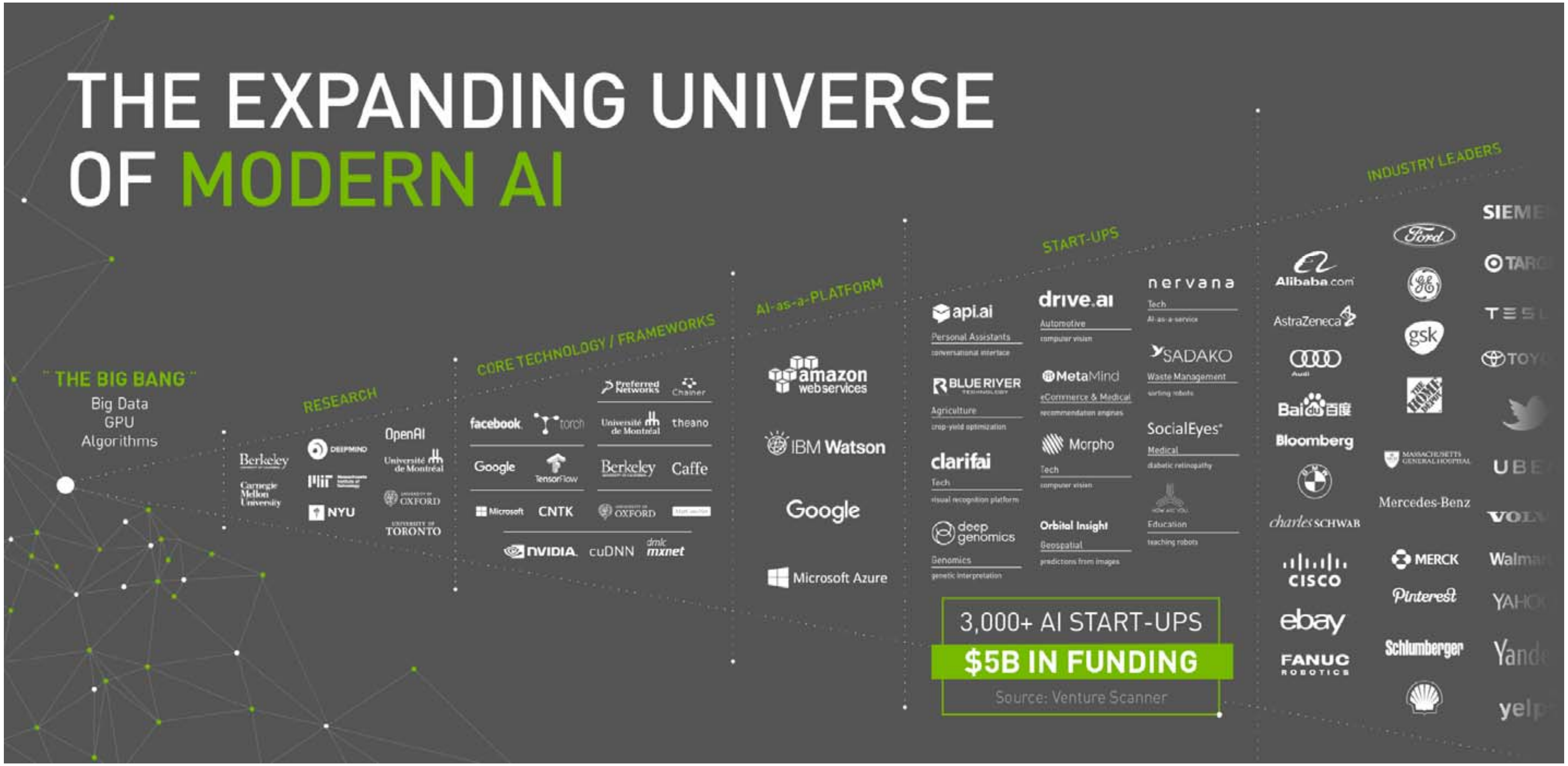
But he soldiered on: in 2004, with support from the Canadian Institute for Advanced Research, he launched a University of Toronto programme in neural computation and adaptive perception, where, with a group of researchers, he carried on investigating how to create computers that could behave like brains.

Hinton's work – in particular his algorithms that train multilayered neural networks – caught the attention of tech giants in Silicon Valley, which realised how deep learning could be applied to voice recognition, predictive search and machine vision.

Wired 100 – Who is shaping the world ?

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

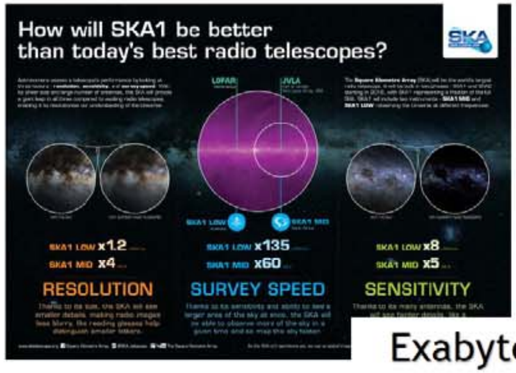
AI in the Spotlight



Research, Technologies, Startups, Industrial usage

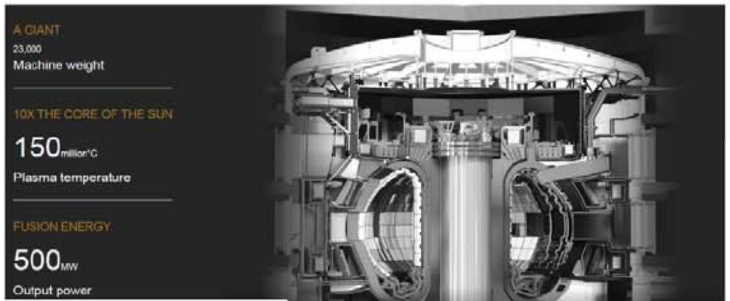
Quelle: NVIDIA Accelerated Computing Workshop @LRZ

AI in the Spotlight



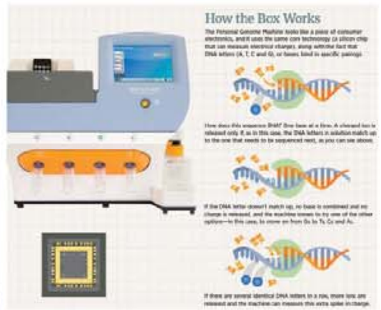
Exabyte/Day

15 TB/Day



30X Increase in power

10X Increase in Data Volume

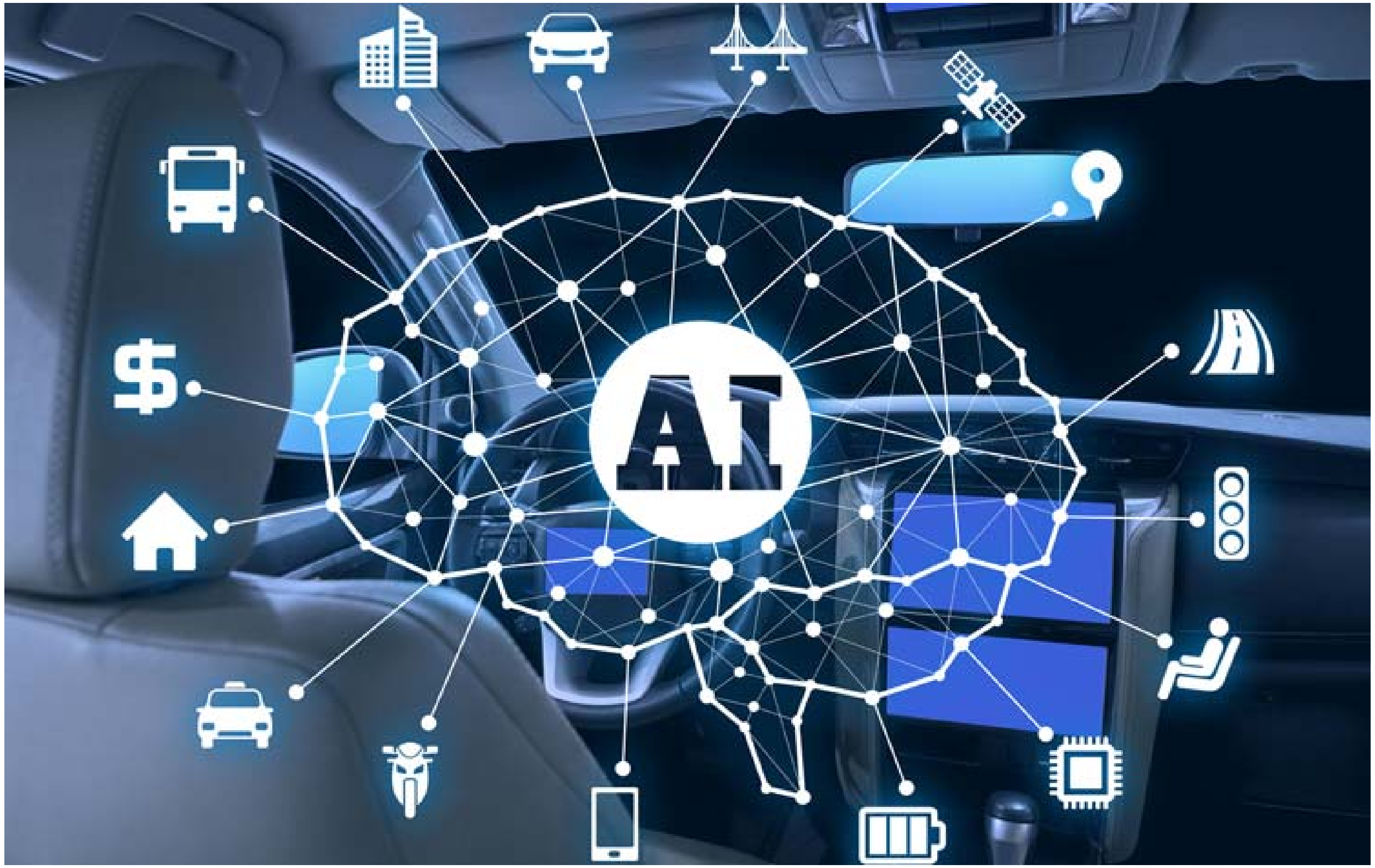


Personal Genomics

Experiments Coming or Upgrading in the next 10 Years

Quelle: NVIDIA Accelerated Computing Workshop @LRZ

AI in the Spotlight



Automotive Technology

Source: http://www.beasleyallen.com/news/can-autonomous-vehicles-drive-ethically/

Introduction: Artificial Intelligence
Johannes Betz / Prof. Dr. Markus Lienkamp / Prof. Dr. Boris Lohmann

(Johannes Betz, M. Sc.)

Agenda

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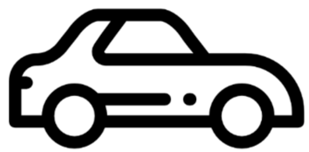
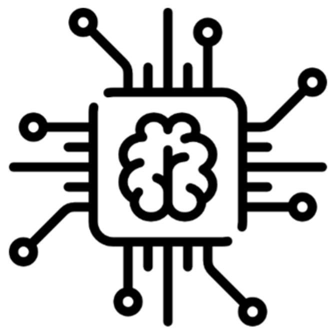
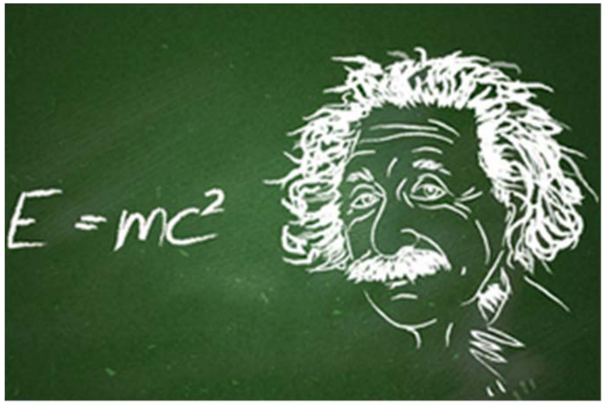


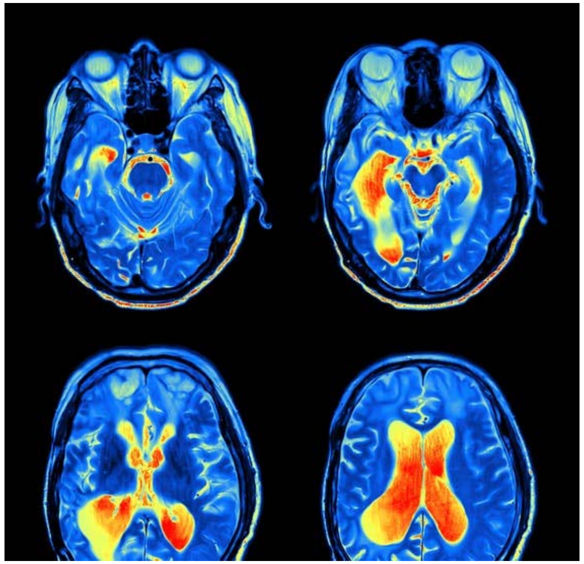


What is Intelligence?

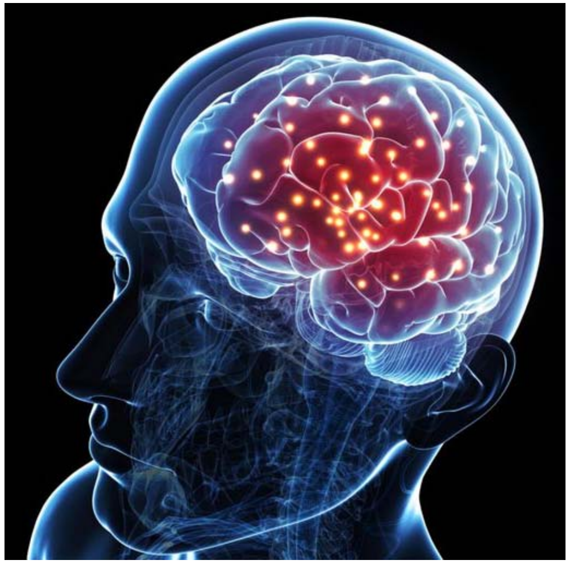
A few questions arise:



What is intelligence?



How can we measure intelligence?



How does the brain function?

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 seperate 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

- Structure
- System
- Discipline
- Precision
- Safety

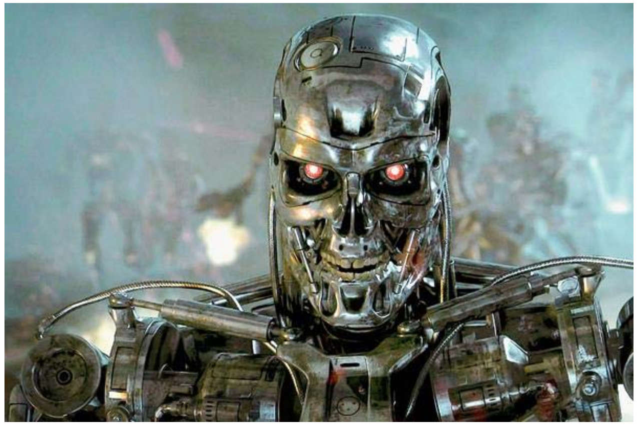
- Critical analysis
- Strategic thinking
- Logic
- Objectivity

Methodical Intelligence

Analytical Intelligence

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 ?

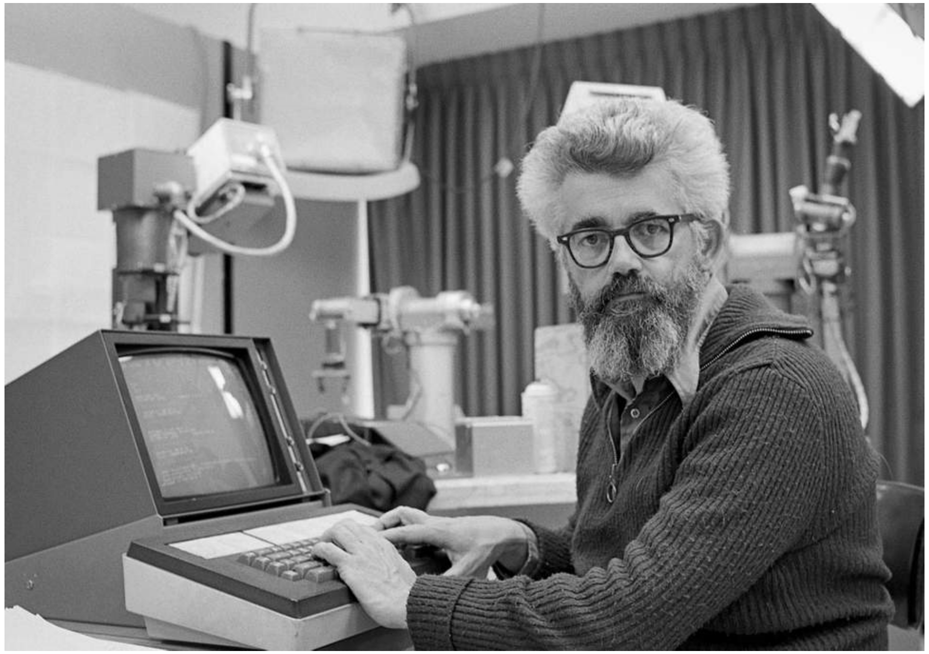
Virtual Assistant?

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

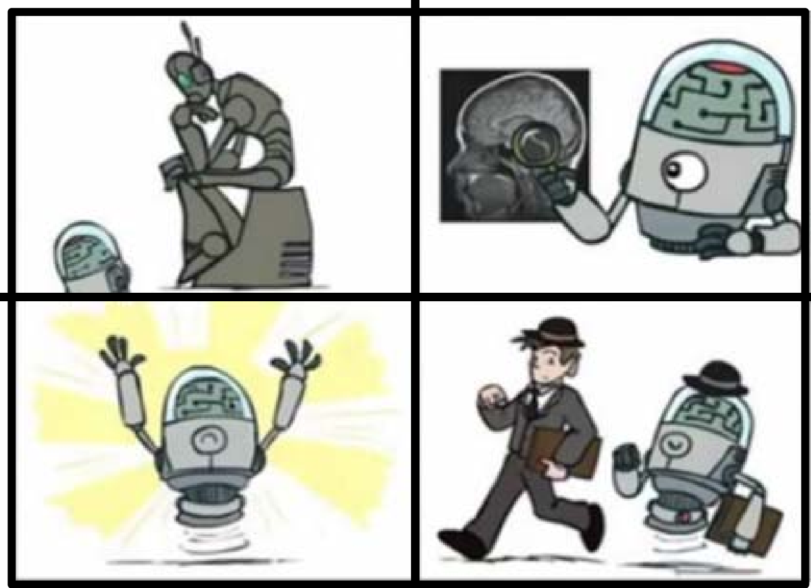
What is Artificial Intelligence? A proposal for categories

Thinking Rationally

- Laws of Thought
- Logic
- Correct Reasoning

Thinkingy 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
- Machine Learning

Acting Humanly

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

Additional Slides

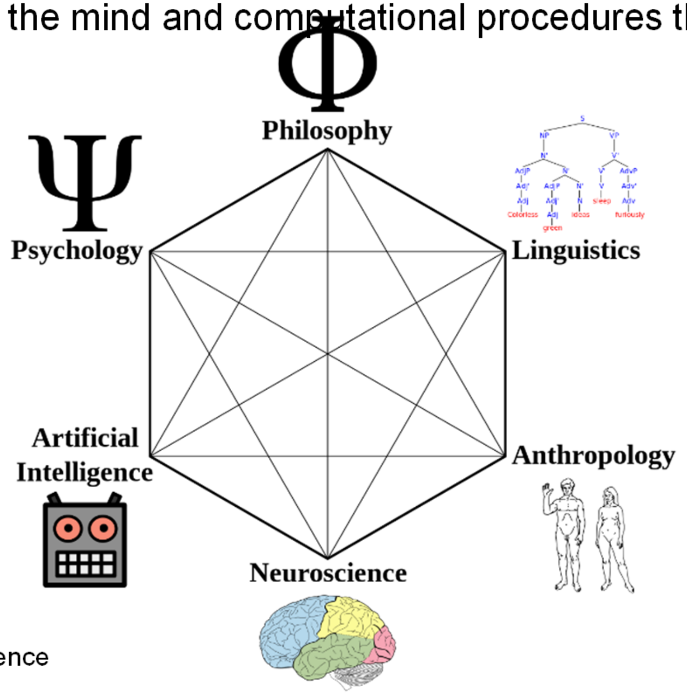
The Turing Test

- Can machines think? This is a question that has occupied philosophers since Decartes. But even the denitions of "thinking" and "machine" are not clear. Alan Turing, the renowned mathematician and code breaker who laid the foundations of computing, posed a simple test to sidestep these philosophical concerns.
- In the test, an interrogator converses with a man and a machine via a text-based channel. If the interrogator fails to guess which one is the machine, then the machine is said to have passed the Turing test. (This is a simplication but it suces for our present purposes.)
- Although the Turing test is not without aws (e.g., failure to capture visual and physical abilities, emphasis on deception), the beauty of the Turing test is its simplicity and objectivity. It is only a test of behavior, not of the internals of the machine. It doesn't care whether the machine is using logical methods or neural networks. This decoupling of what to solve from how to solve is an important theme in this class.

Additional Slides

Cognitive Science

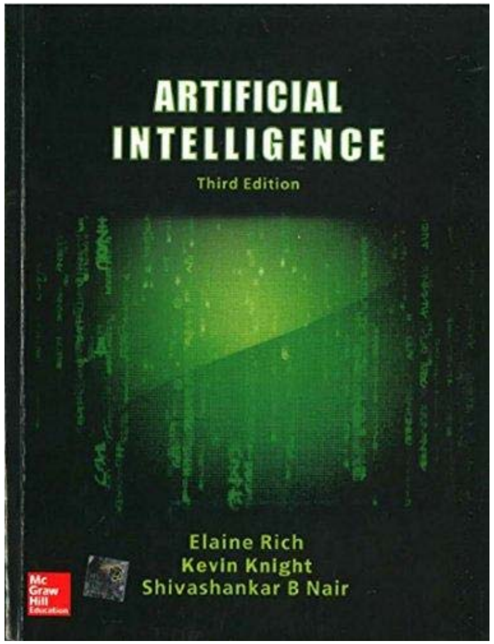
- Cognitive science is the interdisciplinary, scientific study of the mind and its processes.[2] It examines the nature, the tasks, and the functions of cognition (in a broad sense). Cognitive scientists study intelligence and behavior, with a focus on how nervous systems represent, process, and transform information. Mental faculties of concern to cognitive scientists include language, perception, memory, attention, reasoning, and emotion; to understand these faculties, cognitive scientists borrow from fields such as linguistics, psychology, artificial intelligence, philosophy, neuroscience, and anthropology.
- The typical analysis of cognitive science spans many levels of organization, from learning and decision to logic and planning; from neural circuitry to modular brain organization. The fundamental concept of cognitive science is that "thinking can best be understood in terms of representational structures in the mind and computational procedures that operate on those structures.



Source: https://en.wikipedia.org/wiki/Cognitive_science

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/16395986113652087/?lp=true / https://booksbeka.com/artificial-intelligence-elaine-rich-and-kevin-knight-tata-mcgraw-hill-3rd-edition

What is Artificial Intelligence?

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:** Representing information about the world in a form that a computer system can utilize to solve complex tasks

Lecture 6

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

Lecture 3-5

4. **Learning:** A machine gets the ability to "learn" based on algorithms that improve automatically through experience and data without being explicity programme **(Machine Learning (ML))**

Lecture 7-12

What is Artificial Intelligence?

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

Lecture 2

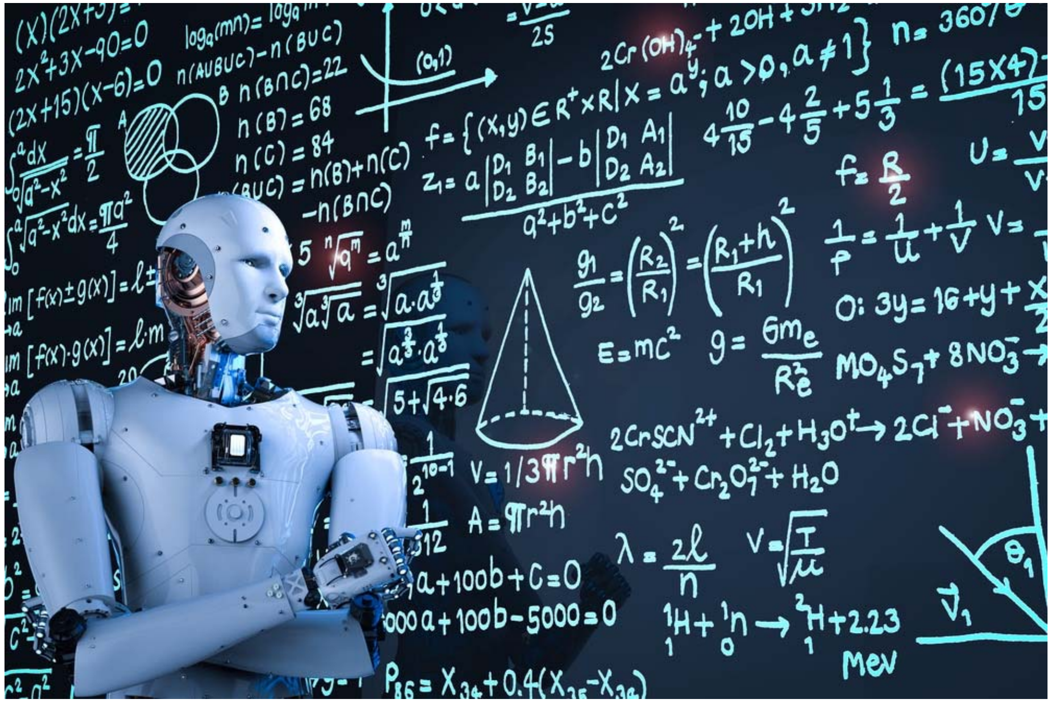
6. **Perception:** A machine gets the ability to use input from sensors for deducing aspects of the world and sensing the environment around the machine

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?

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/

Introduction: Artificial Intelligence

Johannes Betz / Prof. Dr. Markus Lienkamp / Prof. Dr. Boris Lohmann

(Johannes Betz, M. Sc.)

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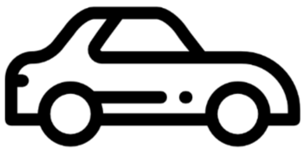
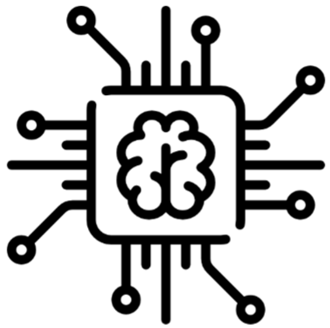
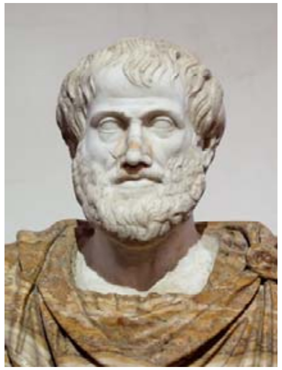




A brief History



300 BC: Aristoteles –
Described syllogism

1641: Hobbes –
Theory of cognition

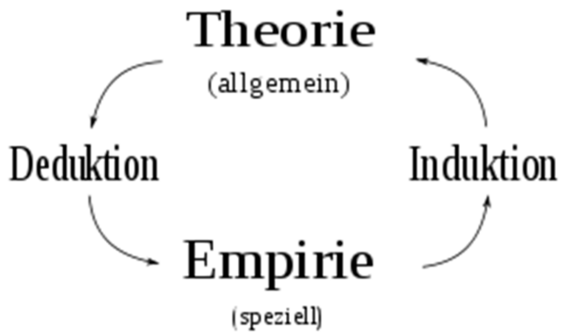
Induction

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

1913: Russel –
Formal Logic

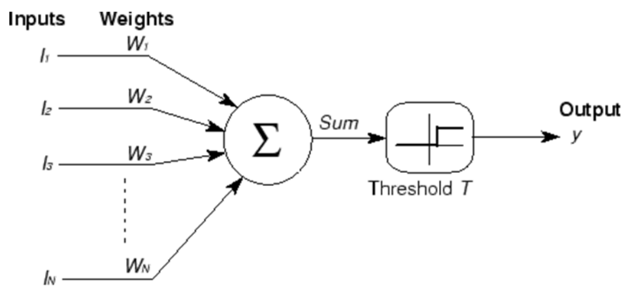


1930s: Carnap –
Logical Positivism

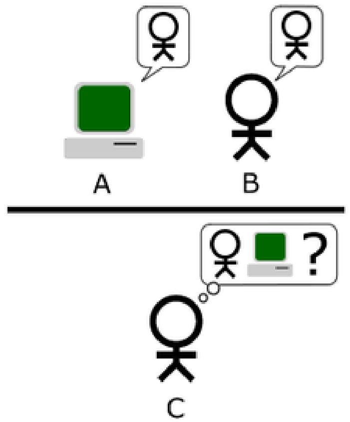
A brief History

Ax 1. $\bullet\ \forall x\{[\varphi(x) \rightarrow \psi(x)] \wedge P(\varphi)] \rightarrow P(\Psi)$
Ax 2. $P(\neg\varphi) \leftrightarrow \neg P(\varphi)$
Th 1. $P(\varphi) \rightarrow \Diamond\ \exists x\ [\varphi(x)]$
Df 1. $G(x) \leftrightarrow \forall\varphi[P(\varphi) \rightarrow \varphi(x)]$
Ax 3. $P(G)$
Th 2. $\Diamond\ \exists x\ G(x)$
Df 2. $\varphi \text{ ess } x \leftrightarrow \varphi(x) \wedge \forall\psi\{\psi(x) \rightarrow \bullet\ \forall x[\varphi(x) \rightarrow \psi(x)]$
Ax 4 $P(\varphi) \rightarrow \bullet\ P(\varphi)$
Th 3. $G(x) \rightarrow G \text{ ess } x$
Df 3. $E(x) \leftrightarrow \forall\varphi[\varphi \text{ ess } x \rightarrow \bullet \exists x\ \varphi(x)]$
Ax 5. $P(E)$
Th 4. $\bullet\ \exists x\ G(x)$

1931: Gödel – Untestable Logic



1943: McCulloch & Pitts – Foundations for artificial neuronal network

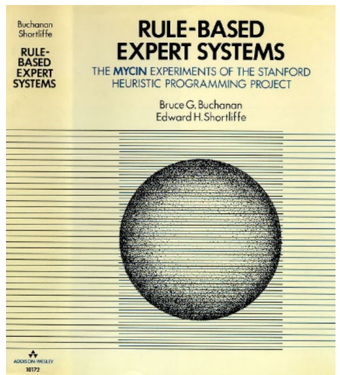


1951: Turing – Machine Intelligence

1956: McCarthy – Artificial Intelligence

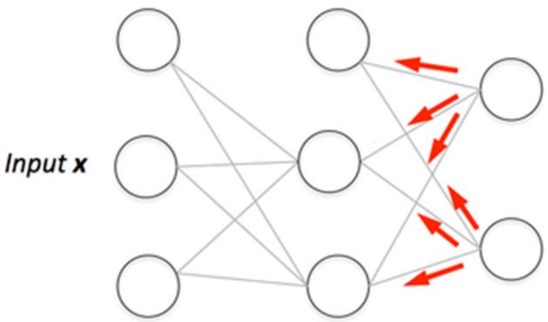
```
> Hello, I am Eliza.
* I am afraid.
> How long have you been afraid?
* Since midterms.
> Tell me more...
* I am afraid that I will fail
my course.
> Do you enjoy being afraid that
you will fail your course?
```

1966: Weizenbaum – NLP Eliza



1976: Buchanan – MYCIN

A brief History



1986: Hinton –
ANN Backpropagation

2005: AI Big Bang –
GPUs and Data

2009: Google – Self Driving Car

2011: IBM Watson –
Defeat Human in
Jeopardy Game

2016: Google AlphaGo –
Defeat Human in
Go Game

2018: Google Duplex –
Personal Assistant

Sources for the Pictures in „a brief history“:

Page 18:
https://en.wikipedia.org/wiki/Timeline_of_artificial_intelligence
https://de.wikipedia.org/wiki/Aristoteles
https://de.wikipedia.org/wiki/Leviathan_(Thomas_Hobbes)
https://www.google.de/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwiQkbKW1JncAhXQfFAKHXjiDhMQjRx6BAgBEAU&url=http%3A%2F%2Fwww.iep.utm.edu%2Fpeir-log%2F&psig=AOvVaw33e_esOy79elSRyBRKJHsR&ust=1531488172004537
https://www.tumblr.com/privacy/consent?redirect=https%3A%2F%2Fwww.tumblr.com%2Ftagged%2Fformal-logic-notation

Page 19:
https://blog.zeit.de/mathe/allgemein/gott-existenz-mathe/
http://wwwold.ece.utep.edu/research/webfuzzy/docs/kk-thesis/kk-thesis-html/node12.html
https://de.wikipedia.org/wiki/Turing-Test
http://history-computer.com/ModernComputer/Software/LISP.html
https://www.google.de/search?q=weizenbaum+eliza&rlz=1C1GGRV_enDE759DE759&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjDlI3QlcfdAhVKxoUKHRkRAXQQ_AUICigB&biw=2844&bih=1442#imgrc=DF_-oiN9jvRedM
http://people.dbmi.columbia.edu/~ehs7001/Buchanan-Shortliffe-1984/MYCIN%20Book.htm

Page 20:
https://sebastianraschka.com/faq/docs/visual-backpropagation.html
https://www.nvidia.de/object/geforce-gtx-970-de.html
http://www.computerbild.de/artikel/cb-News-Connected-Car-Google-Selbstfahrendes-Auto-faehrt-bald-auch-in-Virginia-11800592.html
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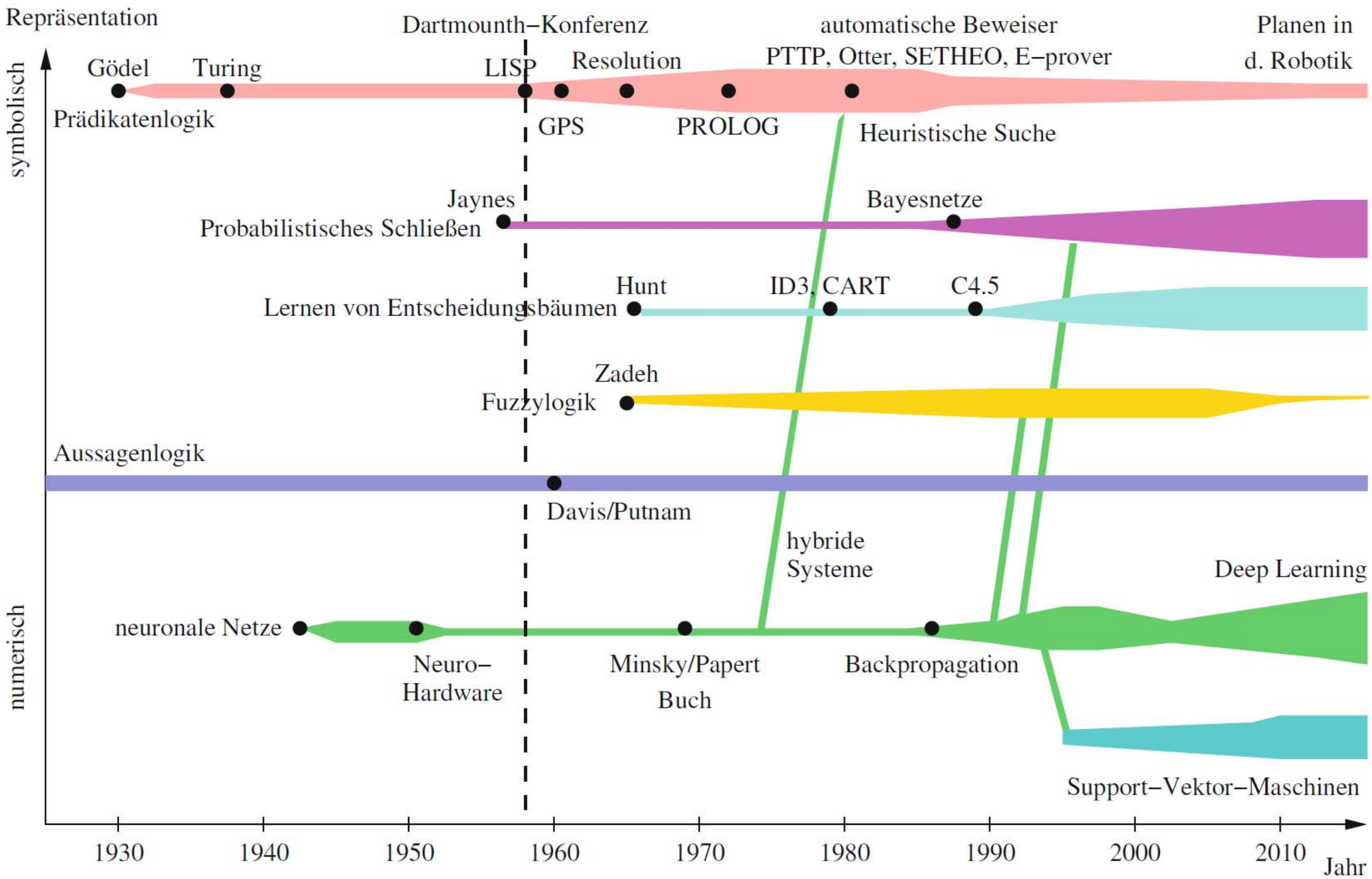
https://www.popsci.com/consent.php?redirect=https%3a%2f%2fwww.popsci.com%2fgoogle-deepminds-alphago-finishes-final-tournament-match-with-win
https://www.ideatovalue.com/curi/nickskillicorn/2018/05/google-duplex-a-i-envisions-a-future-where-you-are-fooled-into-speaking-with-robots/

Source: https://en.wikipedia.org/wiki/History_of_artificial_intelligence /

A brief History – General Overview



Source: Grundkurs Künstliche Intelligenz – Eine praxisorientierte Einführung

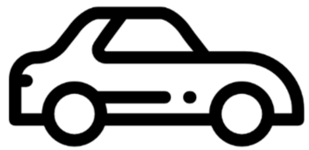
Introduction: Artificial Intelligence

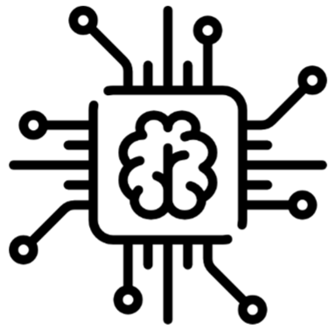
Johannes Betz / Prof. Dr. Markus Lienkamp /
Prof. Dr. Boris Lohmann

(Johannes Betz, M. Sc.)

Agenda

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





AI Methods

Breaking down the general problem of creating AI into 9 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 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
- Integrating uncertainty and probability

Methods & Tools:

- Searching: Intelligently searching through many possible solutions
  e.g. Tree Search, Dijkstra, Kruskal, Nearest Neighbour, A*-Search

- Optimization: Minimize/maximize a given problem with boundaries
  e. g. Lineare Programming, Quadratic Programming, Heuristics,…

- Evolutionary Computation: Optimization search based on evolutions
  e.g. Genetic Algorithms, Particle Swarm Optimization, Ant Colony Optimiziation

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

Methods & Tools:

- Logic: A set of sentences in logical form expressing facts and rules about a problem e.g. 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

Methods & Tools:

- Searching: intelligently searching through many possible solutions e.g. 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, e. g. Multi-Agents, Intelligent Agents

- Evolutionary Computation: Optimization search based on evolutions e.g. Genetic Algorithms, Particle Swarm, Ant Colony

- Uncertainty Reasoning: Operate with incomplete information e.g. 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 programm instructions

Methods & Tools:

1. **Supervised learning:** The computer is presented with example inputs and their desired outputs, given by a "teacher", and the goal is to learn a general rule that maps inputs to outputs.

2. **Unsupervised learning:** No labels are given to the learning algorithm, leaving it on its own to find structure in its input. Unsupervised learning can be a goal in itself (discovering hidden patterns in data) or a means towards an end

AI Methods – 4. Learning

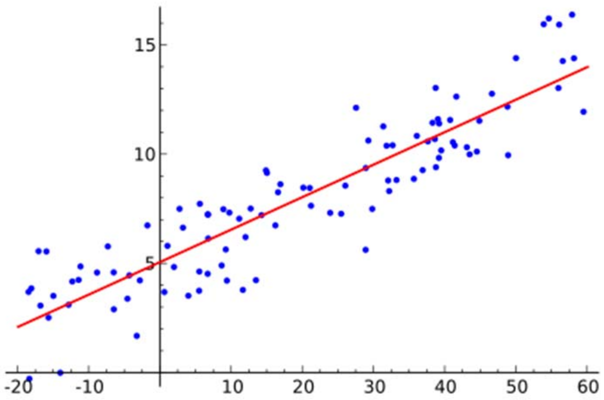
Supervised

Find a predictive model based on input and labeled output data

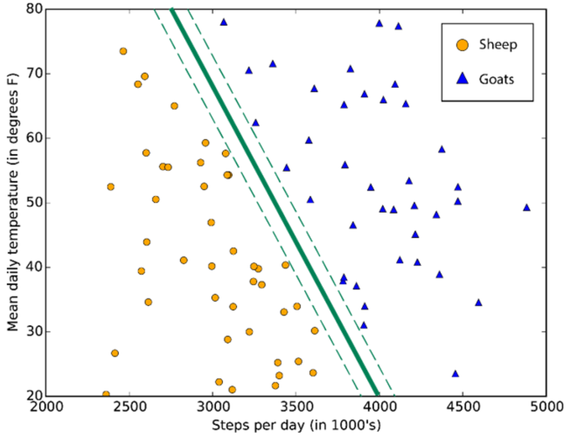
Unsupervised

Find similarities in input data and interprete them

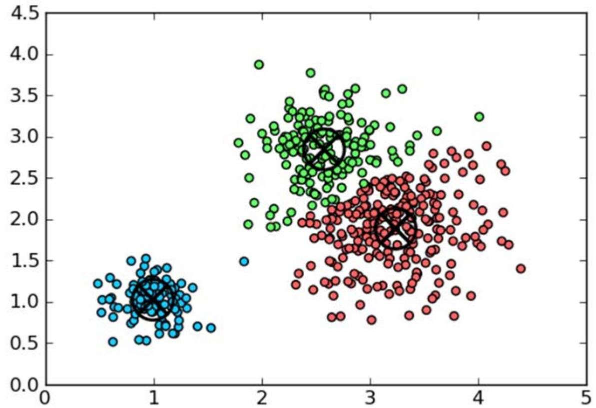
Regression



Classification



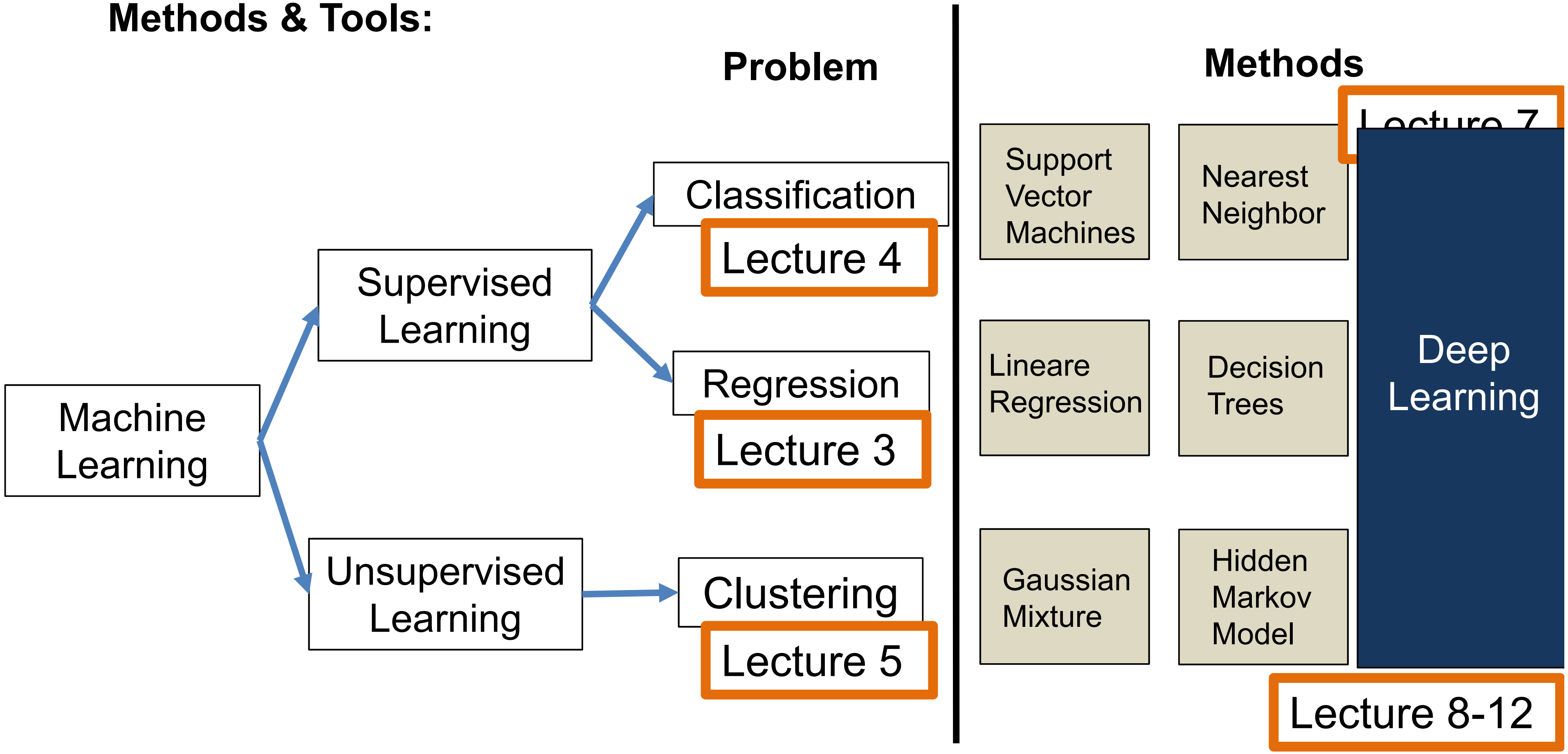
Clustering



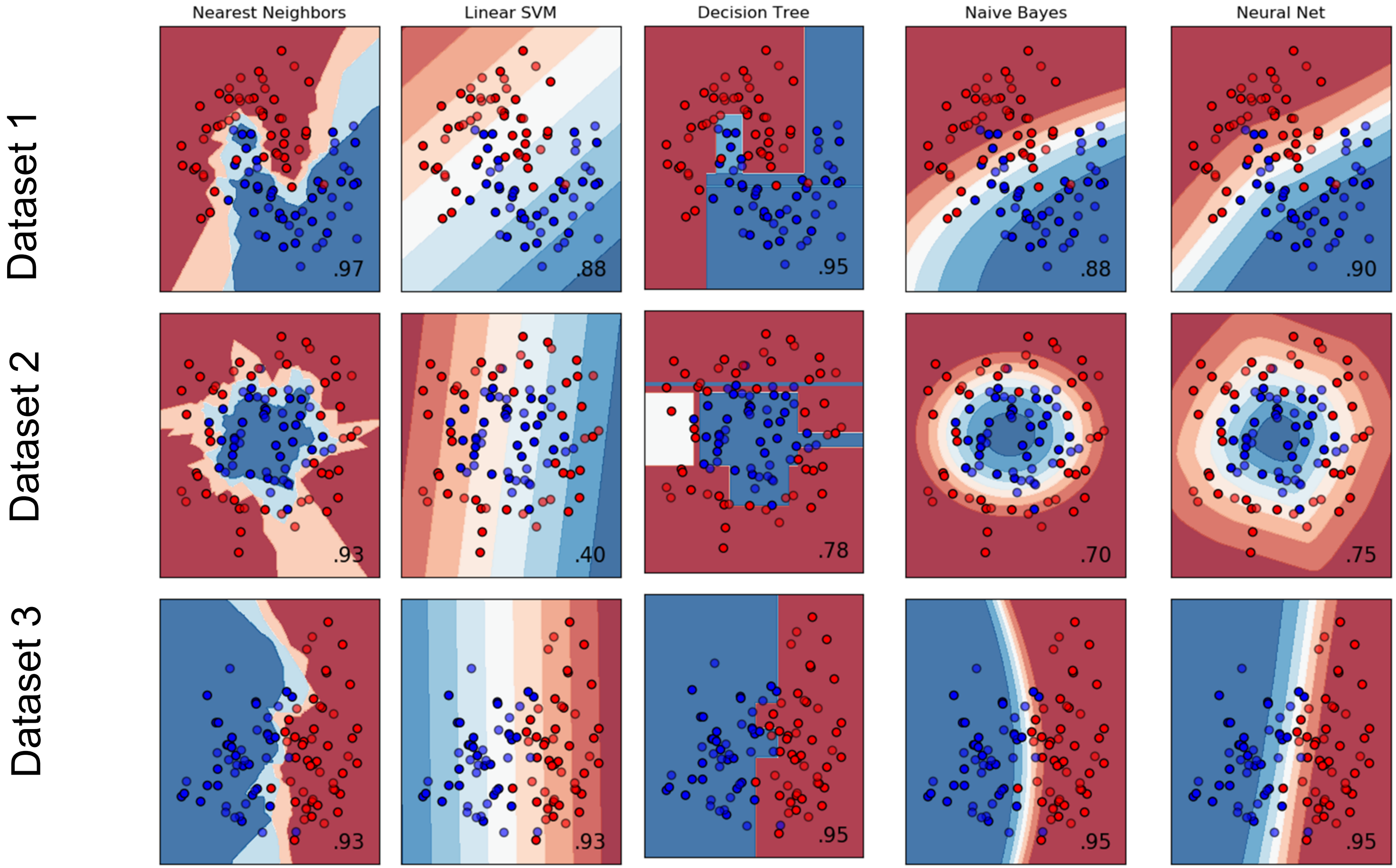
Source: https://upload.wikimedia.org/wikipedia/commons/thumb/3/3a/Linear_regression.svg/438px-Linear_regression.svg.png
https://docs.microsoft.com/en-us/azure/machine-learning/studio/media/algorithm-choice/image7.png
http://blog.mpacula.com/2011/04/27/k-means-clustering-example-python/

AI Methods – 4. Learning

Methods & Tools:

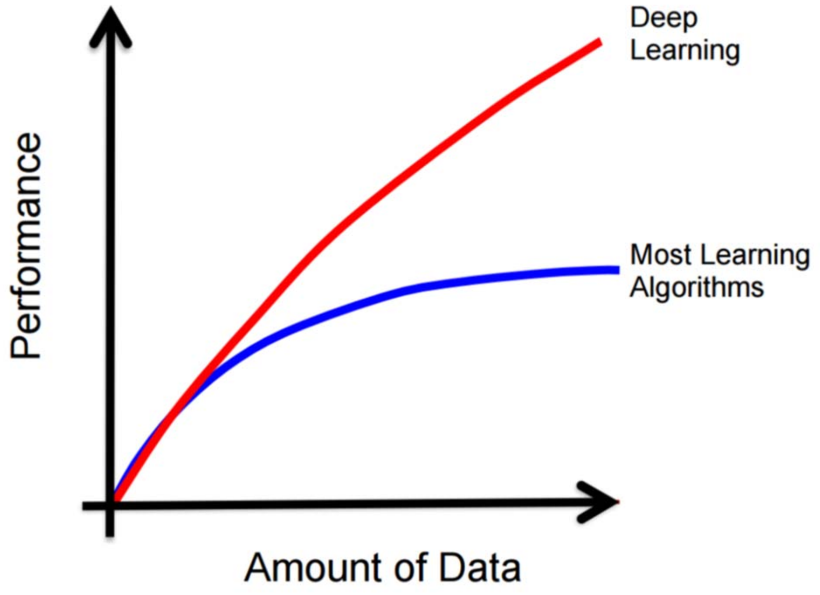


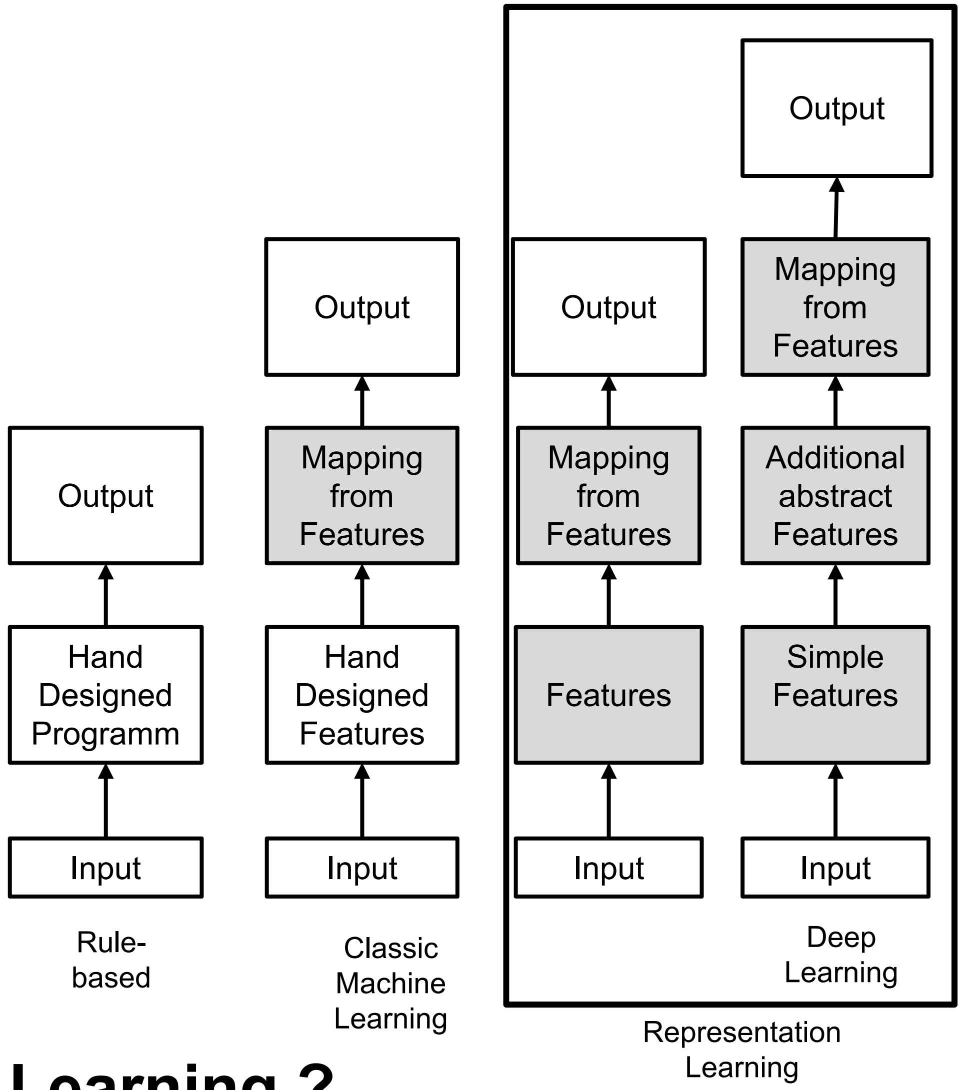
AI Methods – 4. Learning – Classification Example



Source: http://scikit-learn.org/stable/auto_examples/classification/plot_classifier_comparison.html

AI Methods – 4. Learning





Why Deep Learning ?

Quelle: MIT Lecture AI – Seite 33

AI Methods – 5. Natural Language Processing (NLP)

Problem Description:

- Language is highly complex because auf syntax (grammatics), 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 representet as an agent, NLP allows the interaction between the human and a computer

Methods & Tools:

- Logic: A set of sentences in logical form expressing facts and rules about a problem e.g. Propositional Logic, First order Logic, Knowledge-based
- Classic 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 an input: Camera, Lidar, Ultrasonic, Radar, Microphones, …
- **Machine Percpetion:** Capability to interpret data which is related to the environment world
- **Computer Vision:** The input from a camera (images/videos) is analyzed and information is extracted

Methods & Tools:

- Computer Vision **classic**: e.g. Color Extraction, Canny Edge, Hough lines,…
- Computer Vision **new**: e.g. Deep Neuronal Networks, Recurrent Neuronal Networks,…

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 & Tools:

- Behaviroal 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,…

AI Methods – 8. Social Intelligence

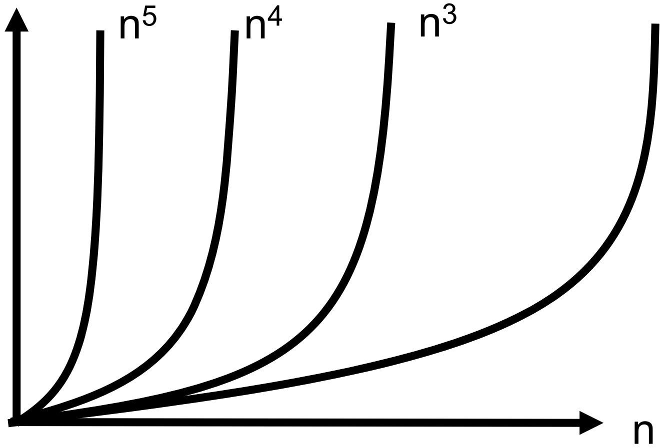
Problem Description:

- 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 speach detection, facial affect detection, body gesture detection and physical monitoring

Methods & Tools:

- Database   e.g. Logic Based (State-Machine), Knowledge-based
- Classification: What emotion could this be?   e.g. Support Vector Machines, k-Nearest Neighbour, Deep Learning,..
- Game Theory: mathematical interaction between intelligent rational decision-makers e.g. cooperative game, simultanous game, evolutionary game,…

AI Methods – Whats the problem?

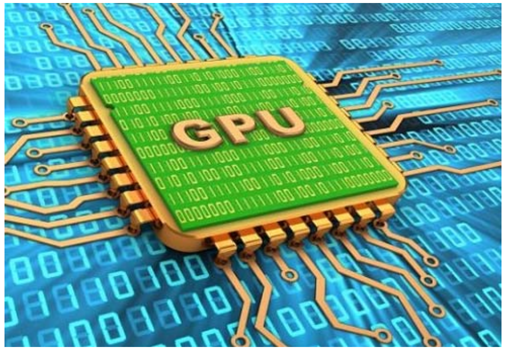


Computational Complexity:
- A lot of problems are NP-hard
- Exponential Explosion of time

Information Complexity:
- Information is limited
- Uncartainty is existent
- Knowledge Acquisiton acquired

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
Johannes Betz / Prof. Dr. Markus Lienkamp / Prof. Dr. Boris Lohmann

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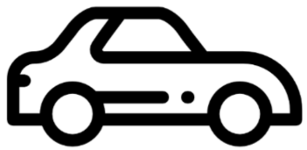
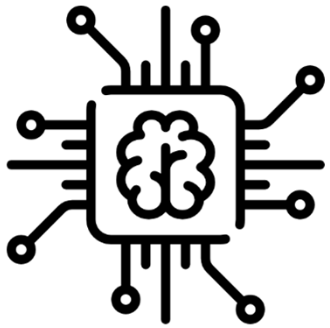
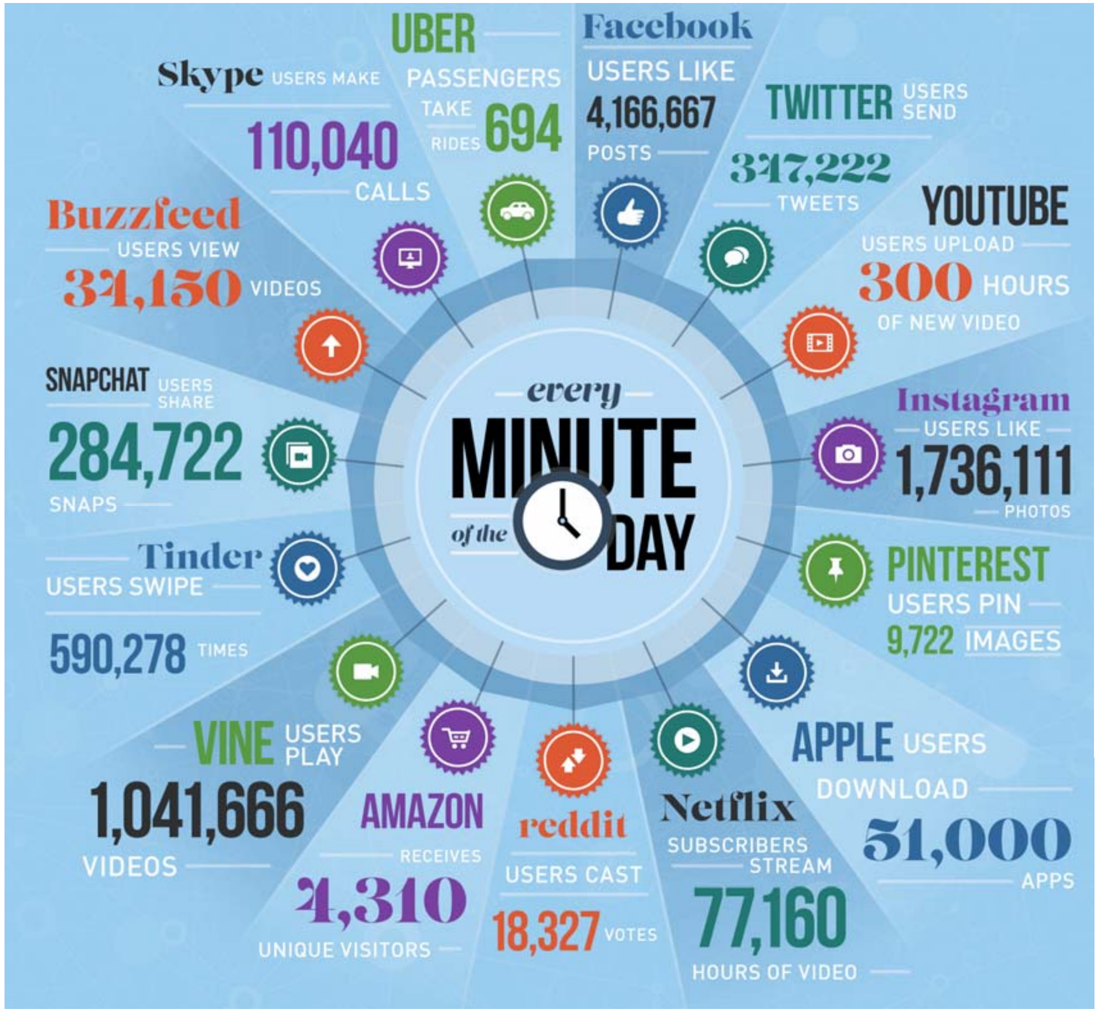




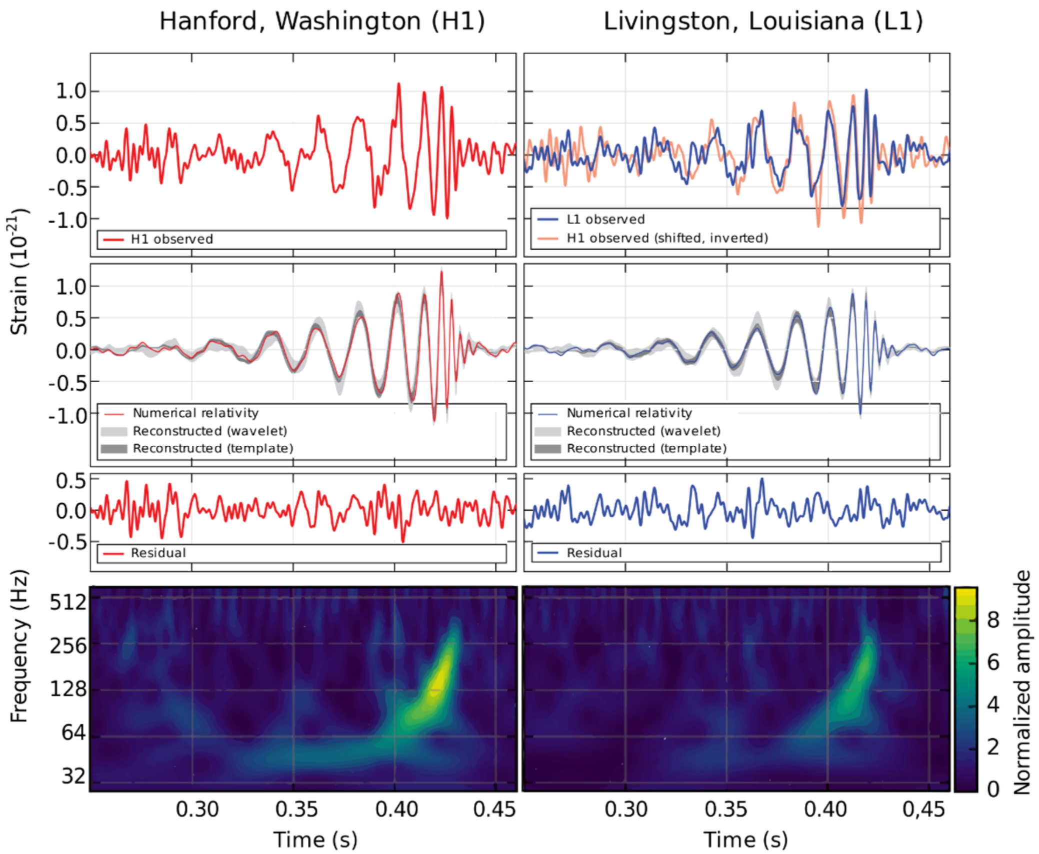
AI Applications – Big Data Analysis

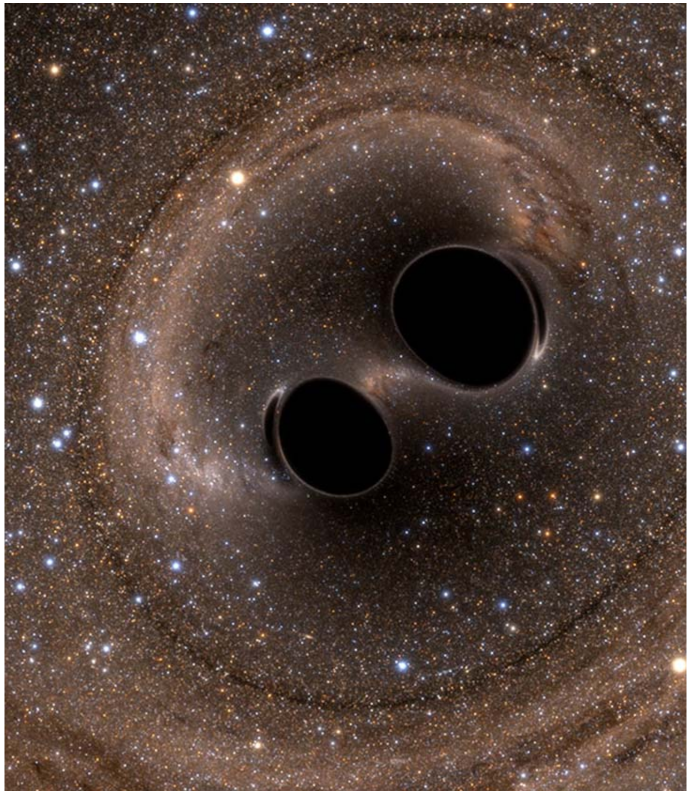


2018: Big Data is everywhere

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

AI Applications – Big Data Analysis

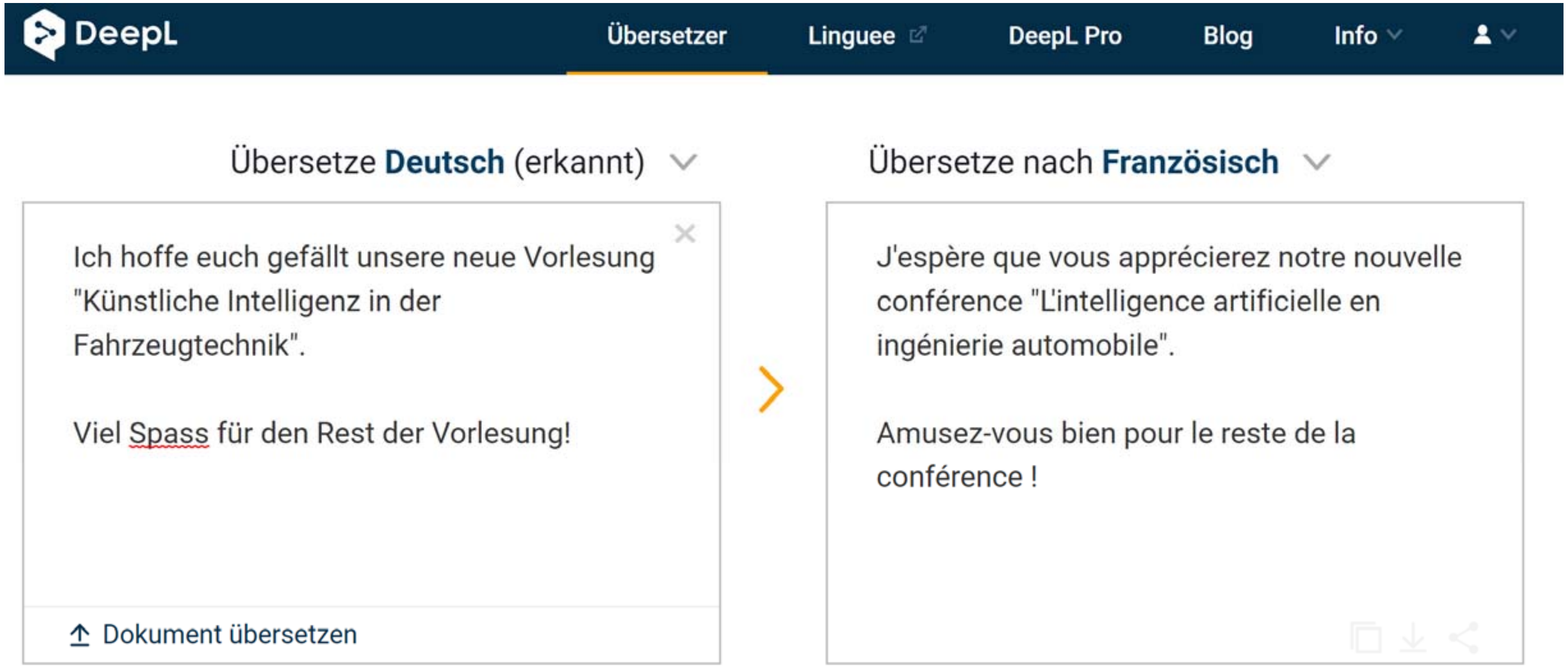




Astronomy, Astrophysics, Black Holes

Source: http://images.nvidia.com/content/pdf/ncsa-gravity-group-iter-success-story.pdf

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

Speach Recognition
Speach Segmentation
Text-to-Speach

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

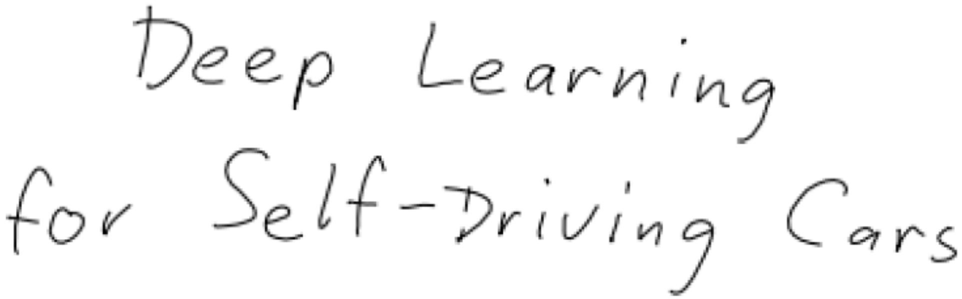
AI Applications – Natural Language Processing

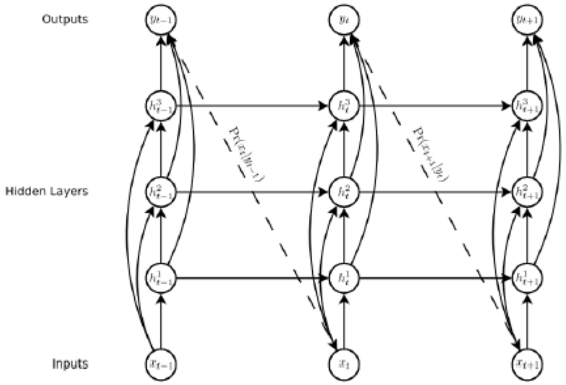
Input:

Text --- up to 100 characters, lower case letters work best

Deep Learning for Self Driving Cars

Output:





Alex Graves. **"Generating sequences with recurrent neural networks."** (2013).

Source: MIT Lecture „Self Driving Car“ Page 46

Additional Slides

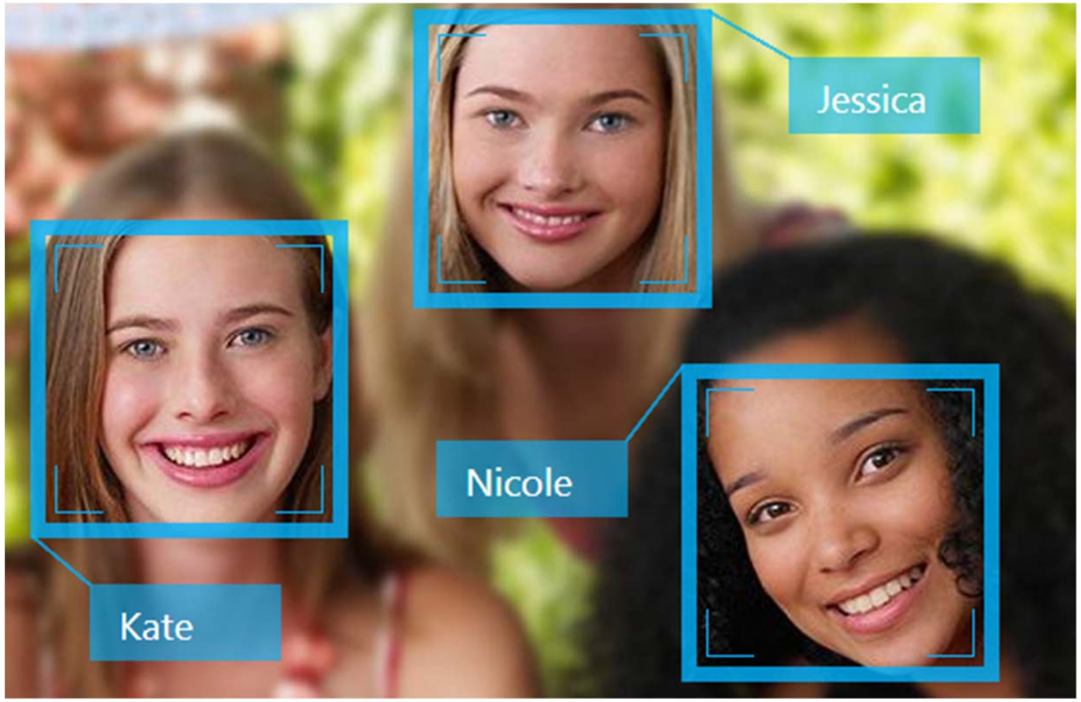
The field of study that focuses on the interactions between human language and computers is called Natural Language Processing, or NLP for short. It sits at the intersection of computer science, artificial intelligence, and computational linguistics

NLP is a way for computers to analyze, understand, and derive meaning from human language in a smart and useful way. By utilizing NLP, developers can organize and structure knowledge to perform tasks such as automatic summarization, translation, named entity recognition, relationship extraction, sentiment analysis, speech recognition, and topic segmentation.

NLP algorithms are typically based on machine learning algorithms. Instead of hand-coding large sets of rules, NLP can rely on machine learning to automatically learn these rules by analyzing a set of examples (i.e. a large corpus, like a book, down to a collection of sentences), and making a statical inference. In general, the more data analyzed, the more accurate the model will be.

- **Summarize blocks of text** using Summarizer to extract the most important and central ideas while ignoring irrelevant information.
- Create a **chat bot** using Parsey McParseface, a language parsing deep learning model made by Google that uses Point-of-Speech tagging.
- **Automatically generate keyword tags** from content using AutoTag, which leverages LDA, a technique that discovers topics contained within a body of text.
- **Identify the type of entity extracted**, such as it being a person, place, or organization using Named Entity Recognition.
- Use Sentiment Analysis to **identify the sentiment of a string of text**, from very negative to neutral to very positive.
- **Reduce words to their root**, or stem, using PorterStemmer, or **break up text into tokens** using Tokenizer.

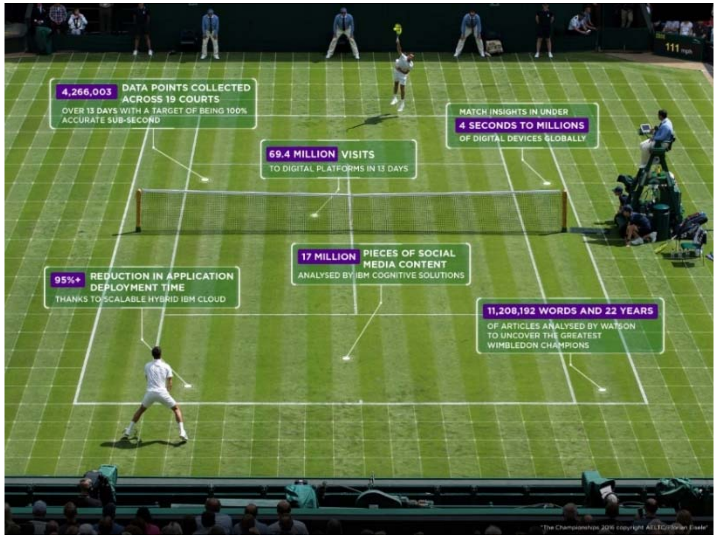
AI Applications – Security



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 – Sports Analysis

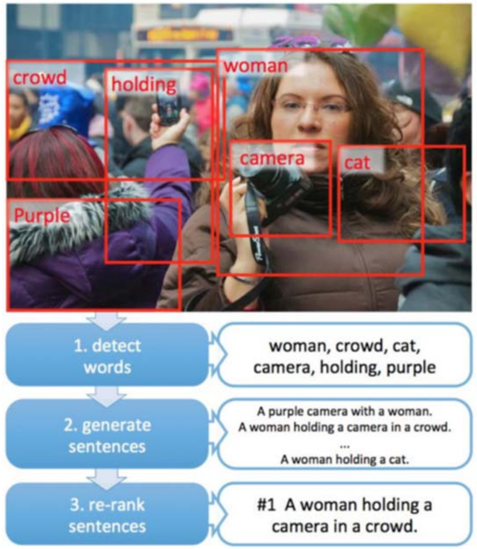


Tactical Analysis
Player Tracking
Sports content Analysis

Source: https://blogs.nvidia.com/blog/2017/06/05/hockey-analytics/

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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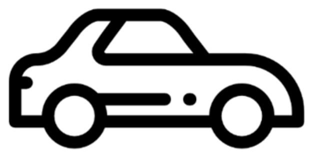
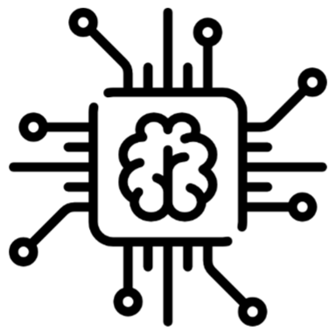
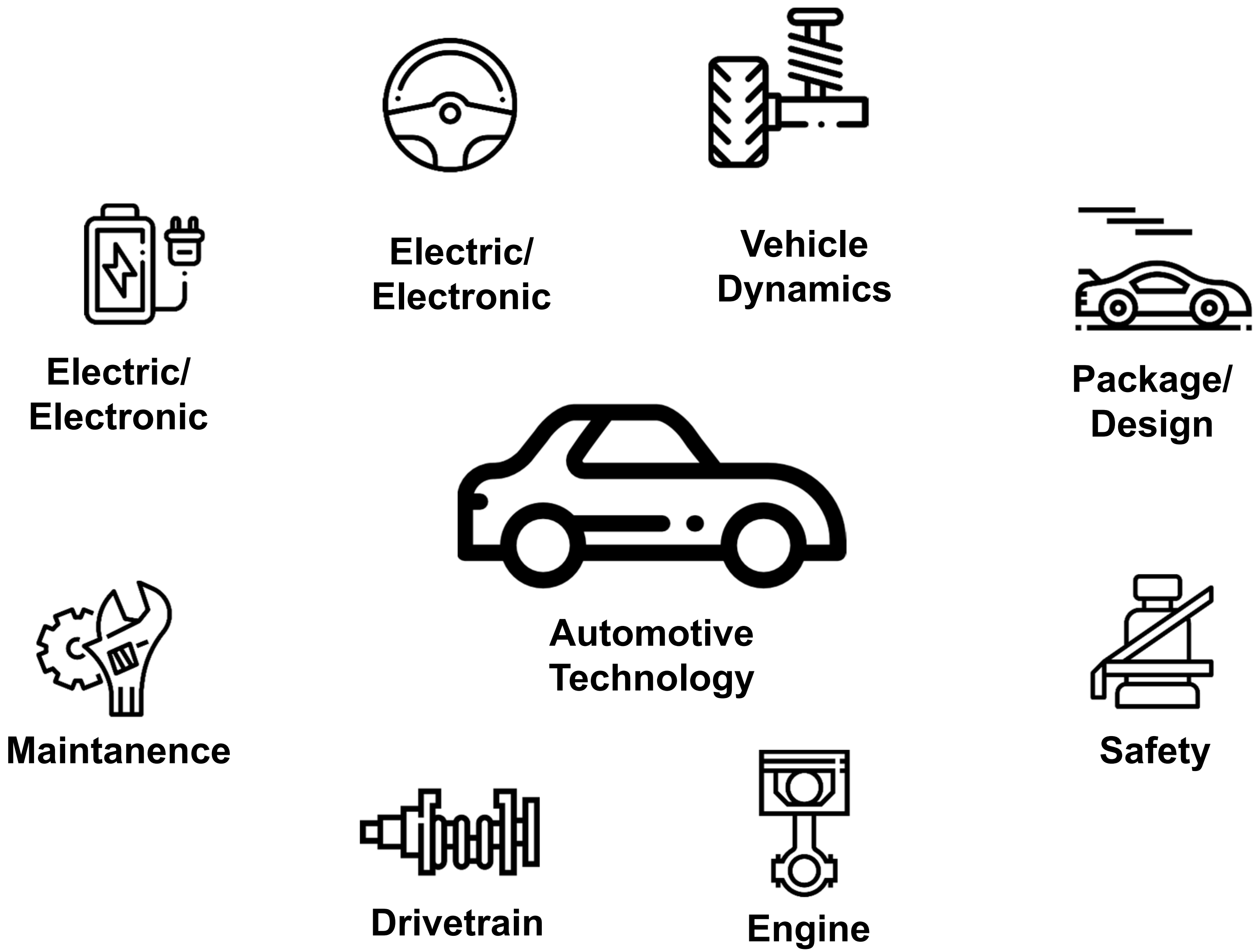




AI Applications – Automotive Technology



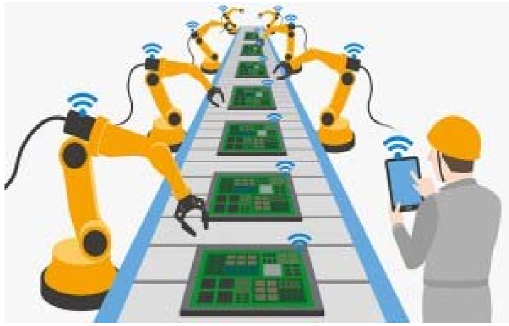
AI Applications – Automotive Technology

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

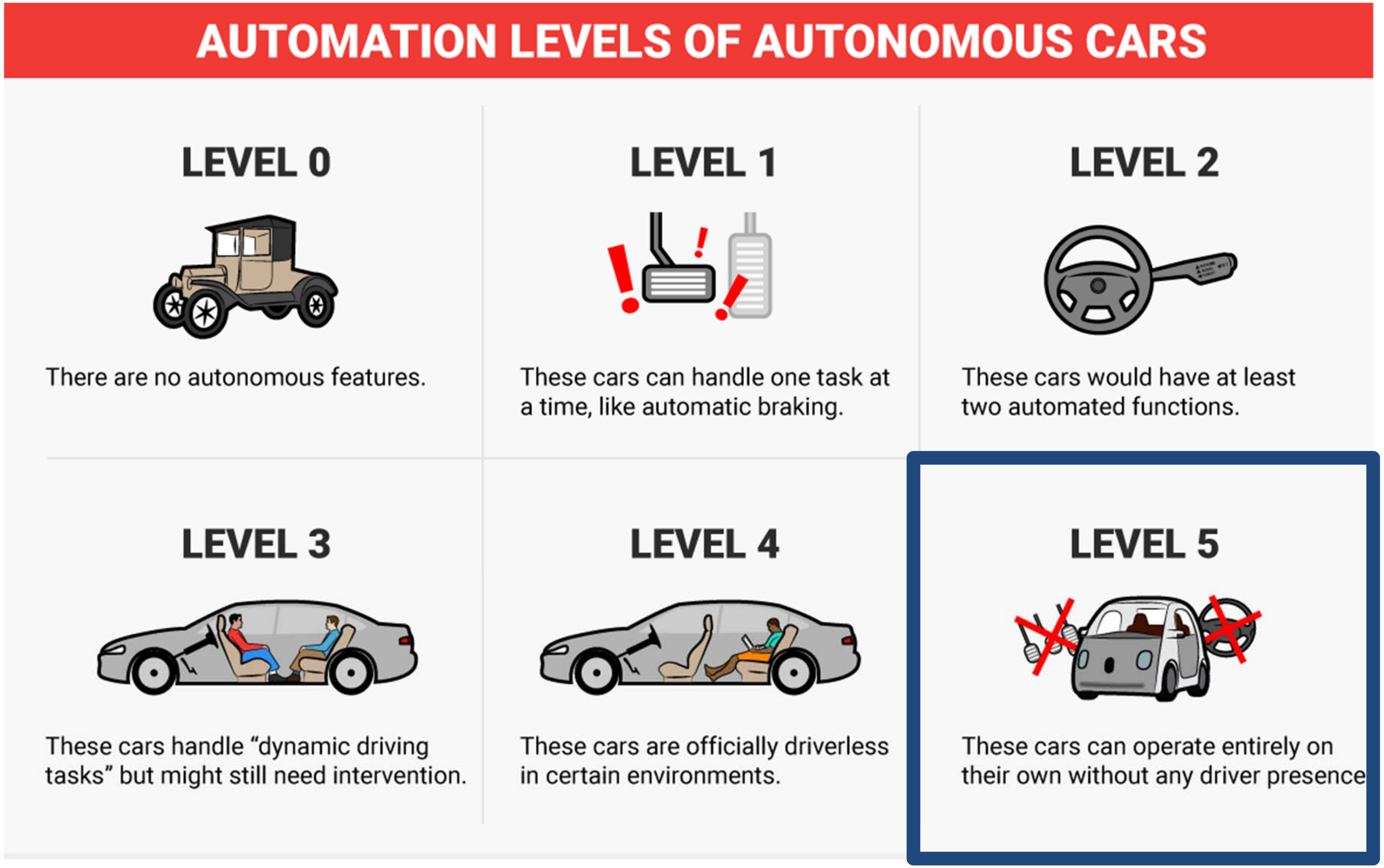
Source: https://www.springboard.com/learning-paths/data-analysis/ / https://medium.com/frontier-tech/the-next-seat-belt-60e980c3ea8b / https://hothardware.com/news/google-stops-publishing-waymo-self-driving-car-accident-reports http://www.bhs-business.com/the-production-process.html

AI Applications – Autonomous Cars

Motivation for autonomous driving:

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

AI Applications – Autonomous Cars



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

AI Applications – Autonomous Level 5 Cars

80s: Project Promotheus

2005: Darpa Grand Challenge

2007: Darpa Urban Challenge

AI Applications – Autonomous Level 5 Cars

2009: Google Research

2010: Audi TT autonomous Pikes Peak

2014: Tesla Model S Autopilot

2015: Audi RS7 Piloted Driving

2016: Nutonomy Self-Driving Taxi

2018: Roborace Autonomous Racing Series

Additional Slides

Autonomous Driving History

- The DARPA Grand Challenge was held in 2004, 2005 and 2007 as an autonomous driving competition with millions of dollars in prize money.
- The Google driverless car project maintains a test fleet of autonomous vehicles that had driven 300,000 miles (480,000 km) with no machine-caused accidents as of August 2012. By April 2014 700,000 autonomous miles (1,100,000 km) were logged. By December 2016, 2,000,000 miles (3,219,000 km) had been self driven.
- The €800 million EC EUREKA Prometheus Project conducted research on autonomous vehicles from 1987 to 1995. Among its culmination points were the twin robot vehicles VITA-2 and VaMP of Daimler-Benz and Ernst Dickmanns, driving long distances in heavy traffic.
- The 2010 VIAC Challenge saw four autonomous vehicles drive from Italy to China on a 100-day 9,900-mile (15,900 km) trip with only limited human intervention, such as in traffic jams and when passing toll stations. At the time, this was the longest-ever journey conducted by an unmanned vehicle.
- The ARGO vehicle (see History above) is the predecessor of the BRAiVE vehicle, both from the University of Parma's VisLab. Argo was developed in 1996 and demonstrated to the world in 1998; BRAiVE was developed in 2008 and demonstrated in 2009 at the IEEE IV conference in Xi'an, China.
- In 2012, Stanford's Dynamic Design Lab, in collaboration with the Volkswagen Electronics Research Lab, produced *Shelley*, an Audi TTS designed for high speed (greater than 100 miles per hour (160 km/h)) on a racetrack course.
- Oxford University's 2011 WildCat Project created a modified Bowler Wildcat which is capable of autonomous operation using a flexible and diverse sensor suite.

Additional Slides

Autonomous Driving History

- The Volkswagen Golf GTI 53+1 is a modified Volkswagen Golf GTI capable of autonomous driving.In his 2010 book, *Democracy and the Common Wealth*, Michael E. Arth claims that autonomous cars could become universally adopted if almost all private cars requiring drivers, which are not in use and parked 90% of the time, were traded for public self-driving taxis, which would be in near-constant use.
- AutoNOMOS – part of the Artificial Intelligence Group of the Freie Universität Berlin
- Toyota has developed prototype cars with autonomous capabilities for demonstration at the 2013 Consumer Electronics Show.
- In February 2013, Oxford University unveiled the RobotCar UK project, an inexpensive autonomous car capable of quickly switching from manual driving to autopilot on learned routes.[
- Israel has significant research efforts to develop a fully autonomous border-patrol vehicle. This originated with its success with Unmanned Combat Air Vehicles, and following the construction of the Israeli West Bank barrier. Two projects, by Elbit Systemsand Israel Aircraft Industries, are based on the locally produced Armored "Tomcar" and have the specific purpose of patrolling barrier fences against intrusions.
- The Oshkosh Corporation developed an autonomous military vehicle called TerraMax and is integrating its systems into some future vehicles.
- 2015, Apple electric car (iCar) project with autonomous driving is called Project Titan.
- In 2015 Uber announced a partnership with Carnegie Mellon to develop its own autonomous cars.
- nuTonomy,Aptiv, and Optimus Ride, have been testing autonomous cars in the Boston Marine Industrial Park; in June 2018, permission expanded to the entire city of Boston with a framework to expand to other cities in Eastern Massachusetts

Primary Task
Driving Task

- Navigation
- Path Following
- Control/Stabilization

Secondary Task
Machine Tasks

- Select the Gear
- Turn on Indicators
- Lights
- Horn
- Wiper
- Change Tires

Tertiary Task
Human = Transportation

- Safety
- Comfort
- Klima
- Acustic

Tertiary Task
Media, EDV-User

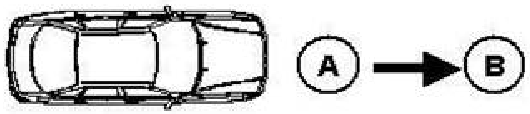
- Internet
- eMail
- Telephone

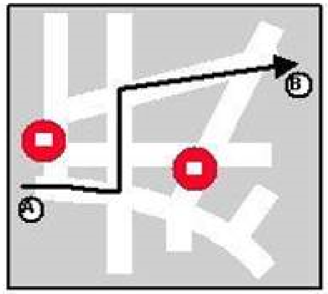
Hierarchy

AI Applications – The Primary Driving Task

Time

1. Navigation



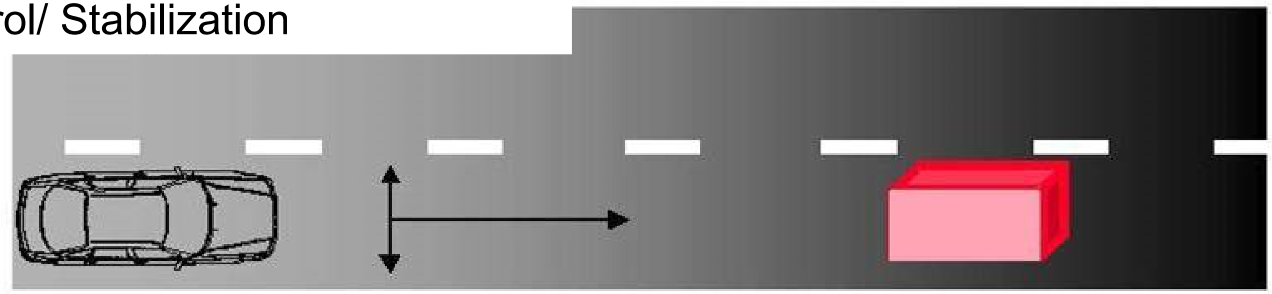


Hours to minutes

2. Path Following

Minutes to seconds

3. Control/ Stabilization



Seconds to miliseconds

AI Applications – The Primary Driving Task




The problem:

The world is a complex and dynamic place

Source: NVIDIA – LRZ Deep Learning Workshop

AI Applications – The Primary Driving Task

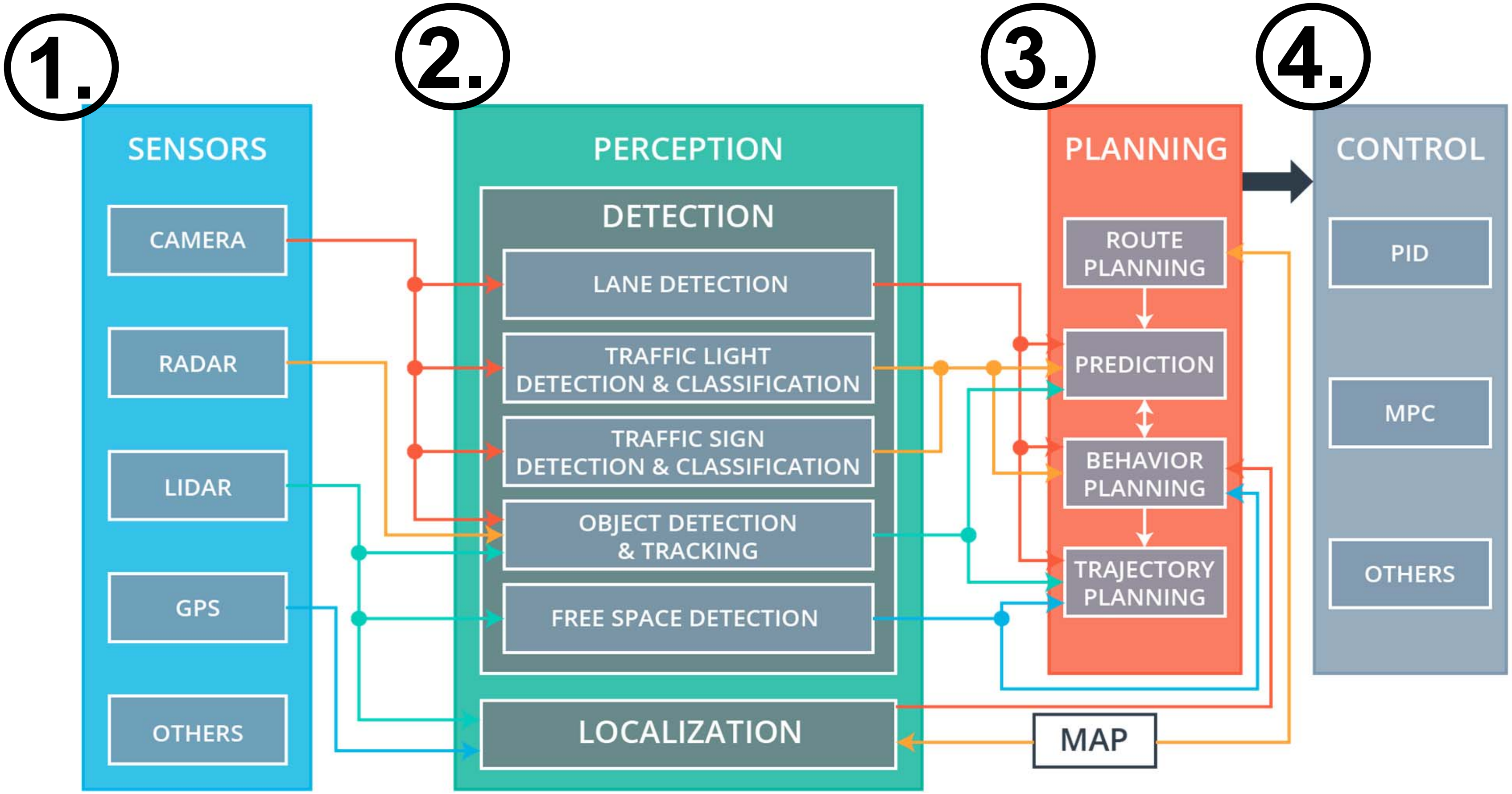
The solution:

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



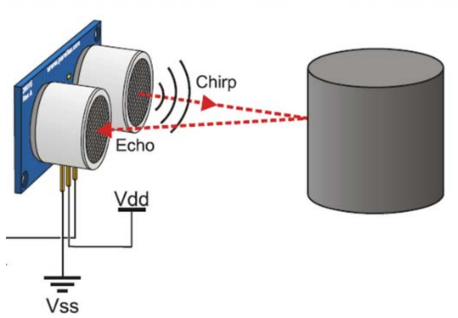
Autonomous Level 5 Car Pipeline

Source: Udacity – Self Driving Nanodegree Programm

AI Applications – Sensors

Radar

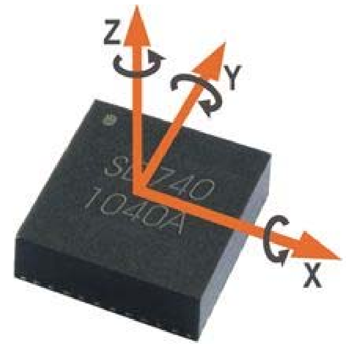
Lidar



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/

Additional Slides

Radar: Radio **D**etection **a**nd **R**anging - Automotive radar sensors are responsible for the detection of objects around the vehicle and the detection of hazardous situations (potential collisions). A positive detection can be used to warn/alert the driver or in higher level of vehicle automation to intervene with the braking and other controls of the vehicle in order to prevent an accident. Distance detection can be performed by measuring the round-trip duration of a radio signal. Based on the wave speed in the medium, it will take a certain time for the transmitted signal to travel, be reflected from the target, and travel back to the radar receiver. By measuring this time interval that the signal has travelled the distance can easily be calculated.

Ultrasonic: Ultrasonic sensors are industrial control devices that use sound waves above 20 000 Hz, beyond the range of human hearing, to measure and calculate distance from the sensor to a specified target object. The sensor emits a packet of sonic pulses and converts the echo pulse into a voltage. The controller computes the distance from echo time and the velocity of sound. The velocity of sound in the atmosphere reaches 331.45 m/s when the temperature is 0°C

Quelle: http://www.mogi.bme.hu/TAMOP/jarmurendszerek_iranyitasa_angol/ch03.html

Additional Slides

Lidar: **LI**ght Detection **A**nd **R**anging. The Lidar is static which means it can measure in one direction (Traffipax). Instead of radio waves used by RADAR, LIDAR uses ultra violet, visible or infrared light pulses for detection. The light pulses are sent out of the sensor in many directions simultaneously and reflected by the surrounding objects. Object distance detection is based on precise time measurement of the pulse-echo reflection. Repeated measurement can result in speed detection of the measured object. The Laser Scanner is dynamic which means variable viewing angle. As the LIDAR measurements are taken many times with a rotating sensor in many directions, the result is a scanned planar slice. This type of measurement is called Laser Scanning. If the measurements are taken also in different angles or the sensor is moving (on top of vehicle) a complete 3D view of the surroundings can be created.

Camera: The recording capabilities of the automotive video cameras are based on image sensors (imagers). It is the common name of those digital sensors which can convert an optical image into electronic signals. Currently used imager types are semiconductor based charge-coupled devices (CCD) or active pixel sensors formed of complementary metal–oxide–semiconductor (CMOS) devices.

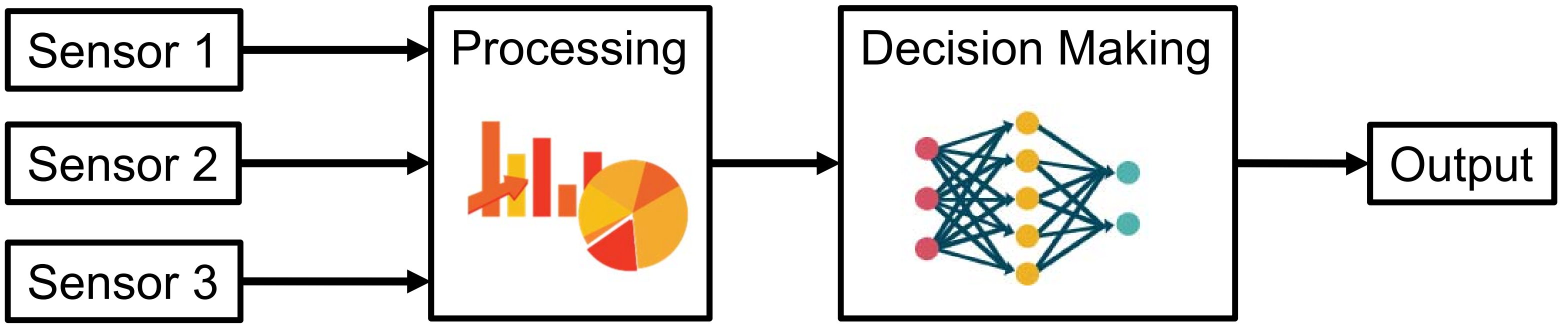
Quelle: http://www.mogi.bme.hu/TAMOP/jarmurendszerek_iranyitasa_angol/ch03.html

Additional Slides

Quelle: http://www.mogi.bme.hu/TAMOP/jarmurendszerek_iranyitasa_angol/ch03.html

AI Applications – AI Algorithm for sensor processing

- **Sensorfusion:**

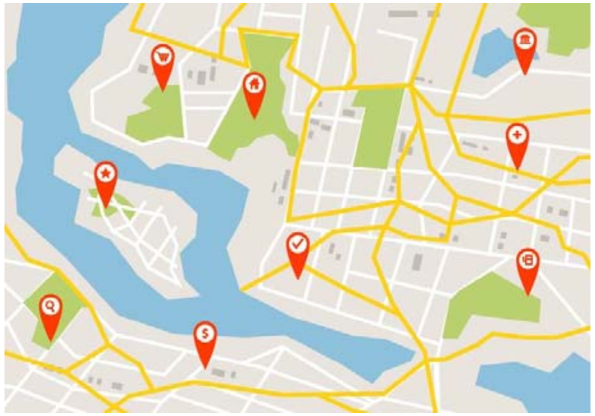


- **Faster Data Processing**

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

AI Applications – Perception

Scene Understanding: Where is the Road?



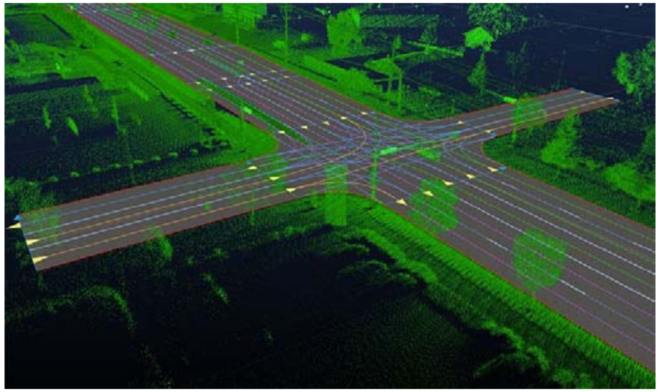
Input Information:
- Camera images
- HD maps
- GPS location

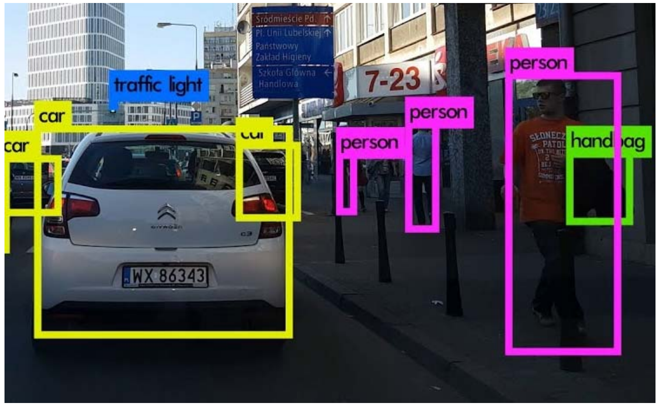
AI-Algorithm:
- Sensor fusion
- Computer Vision
- Faster map comparison

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 laserscans
- Radar scans
- Ultrasonic scans

AI-Algorithm:

- Sensor fusion
- Computer Vision
- Classification
- Uncertainity 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:

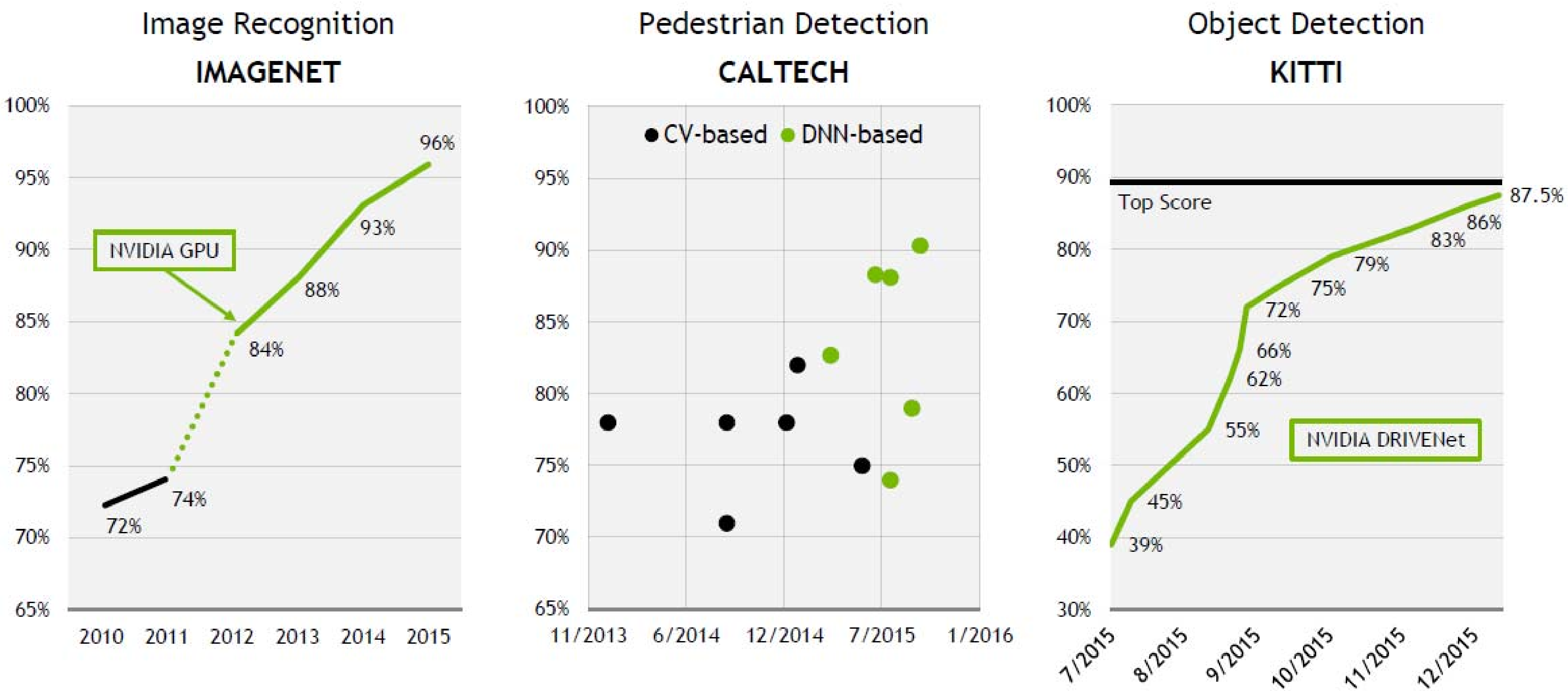
- Camera Images

AI-Algorithm:

- Computer Vision
- Classification

AI Applications – Perception

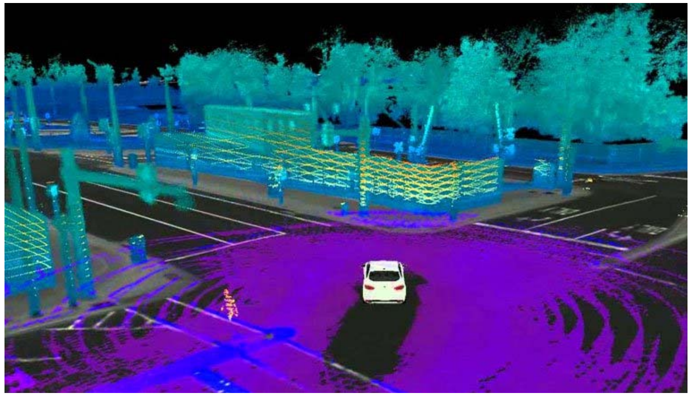
Scene Understanding:

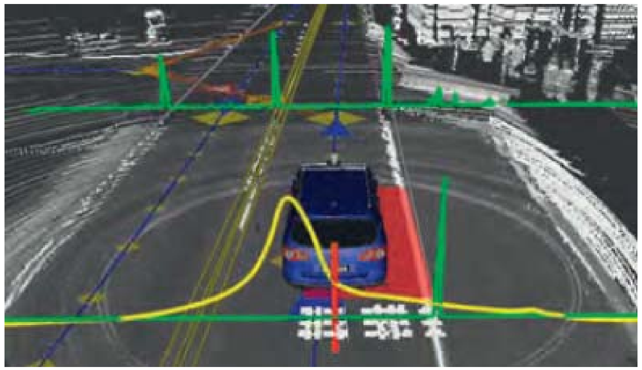


Source: NVIDIA Accelerated Computing Workshop @LRZ

AI Applications – Perception

Where am I? Have i seen that before?





Input Information:

- Camera Images
- HD-Maps
- Lidar laserscans
- GPS location

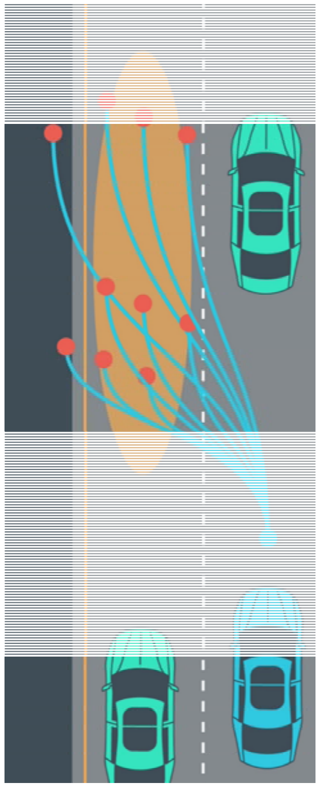
AI-Algorithm:

- 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



Input Information:

- Vehicle data: a_x/a_y, v_x/v_y,…
- GPS location
- Camera Images
- Lidar laserscans

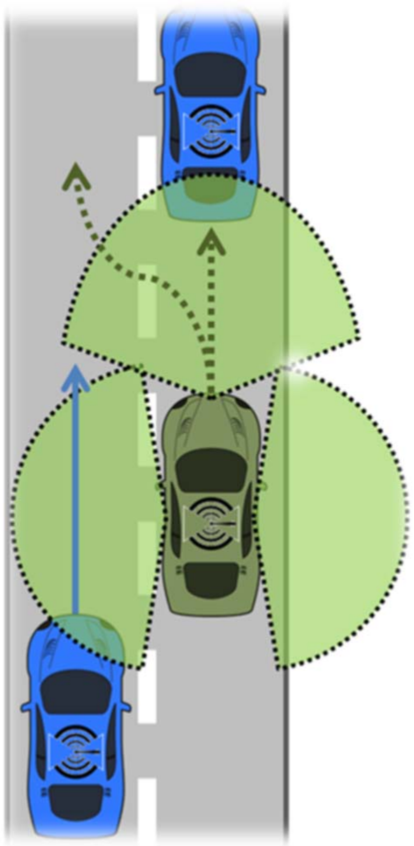
AI-Algorithm:

- Sensor Fusion
- Planning algorithms

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

AI Applications – Planning

Behavioral planning of own vehicle



Input Information:

- Vehicle data: a_x/a_y, v_x/v_y,…
- GPS location
- Camera Images
- Lidar laserscans

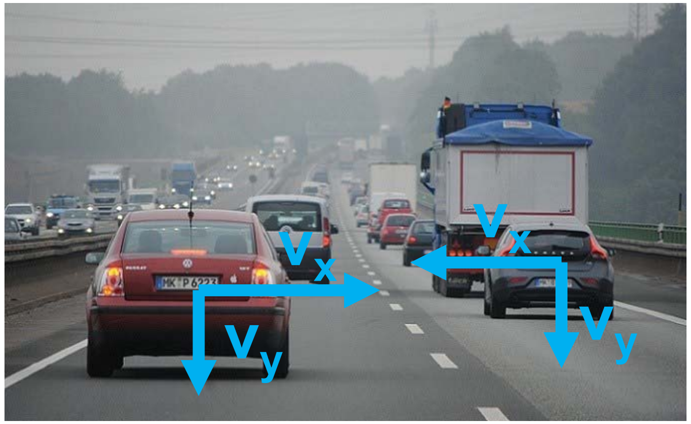
AI-Algorithm:

- Sensor fusion
- Computer Vision
- Uncertainty planning
- Regression
- Classification

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

Prediction of Behavior of objects around the car



Input Information:

- Camera Images
- Lidar laserscars
- Radar scans
- Ultrasonic scans

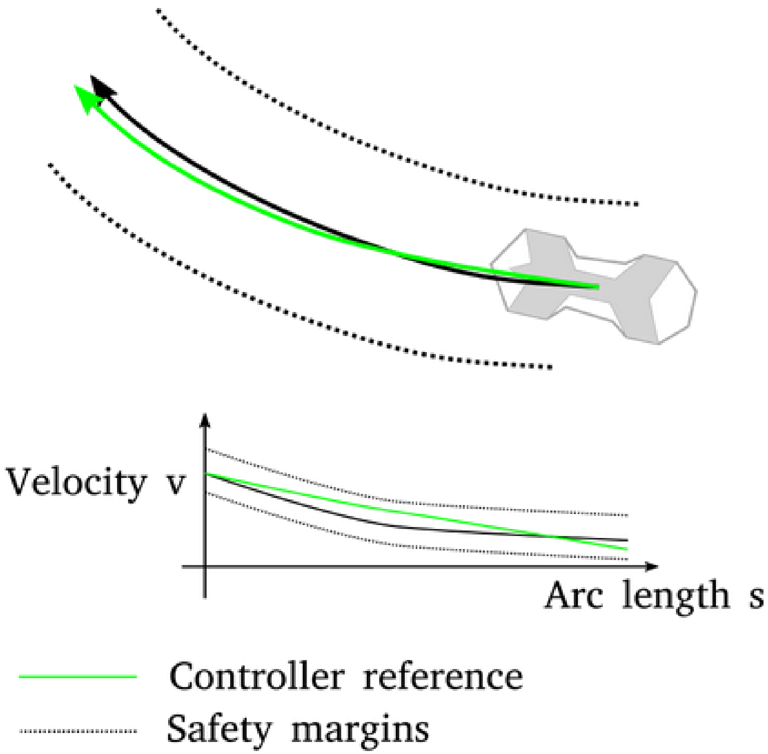
AI-Algorithm:

- Sensor Fusion
- Computer Vision
- Search
- Uncertainity Planning

Source https://www.studying-in-germany.org/driving-germany/
http://www.sfexaminer.com/uber-lyft-swarm-valencia-bike-lanes-supervisors-demand-barriers/

AI Applications – Control

Vehicle Control



Input Information:

- Vehicle data: a_x/a_y, v_x/v_y,…

AI-Algorithm:

- Sensor Fusion
- Uncertainity Planning
- Feed Forward
- Model Adaption
- Regression

AI Applications – Need for Improvements

Month	Number of disengagements	Autonomous miles on public roads
Dec 2016	11	57,614.8
Jan 2017	7	45,392.2
Feb 2017	4	35,459.7
Mar 2017	4	35,873.2
Apr 2017	10	27,238.7
May 2017	5	16,617.2
Jun 2017	6	13,917.2
Jul 2017	3	19,182.5
Aug 2017	3	20,456.7
Sep 2017	6	22,967.0
Oct 2017	3	27,308.7
Nov 2017	1	30,516.7
Total	**63**	**352,544.6**

Google Waymo Self – Driving car Disengagements

Human Performance:
1 mistake per 100,000,000 Miles

↓

Error Rate for AI to improve:
0.000001%

Source: https://www.dmv.ca.gov/portal/wcm/connect/42aff875-7ab1-4115-a72a-97f6f24b23cc/Waymofull.pdf?MOD=AJPERES&CVID=
http://www.eugenewei.com/blog/2014/10/13/moravecs-paradox-and-self-driving-cars

AI Applications – Predictive Maintanence

Problem / Motivation

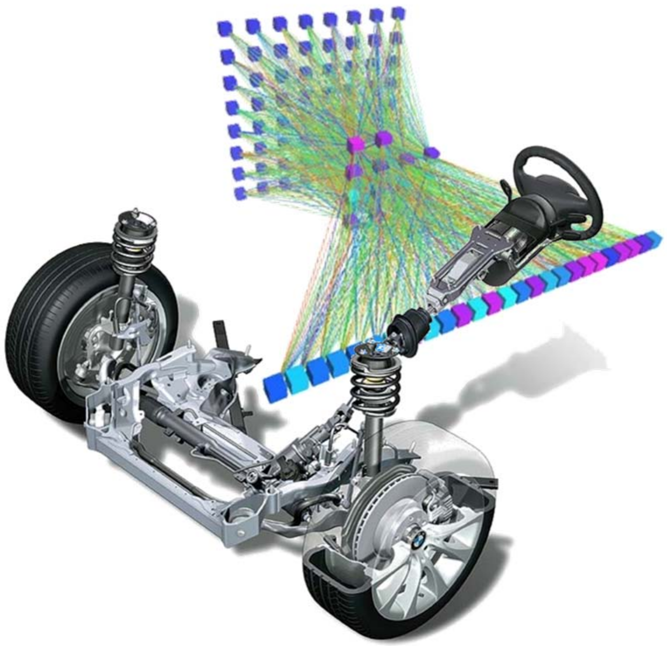
- Decreasing driver‘s perception for suspension wear and change of vehicle dynamics

Goals

- Development of an automated diagnosis system
- Detection of chassis system defects based on different sensors

Approach

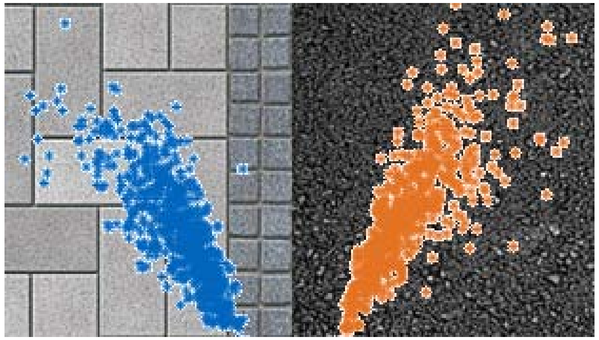
- Generation of measurement data with different component defects
- Classification of measurement data by machine learning algorithm
- Anomaly detection algorithms to use only healthy data for training



AI Applications – Road Surface Detection

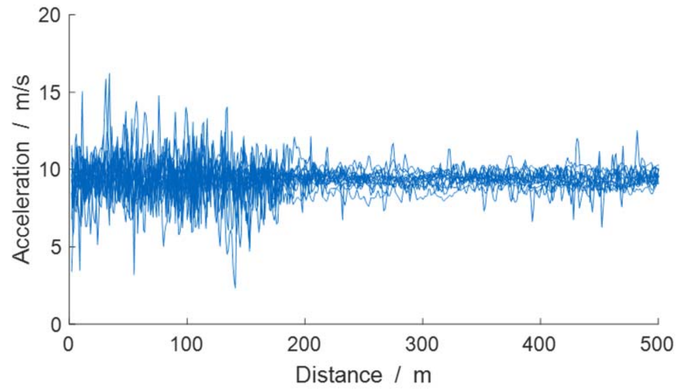
Problem / Motivation

- Time consuming detection of the road surface with special vehicles
- The current measurement method is very expensive, not comprehensive and not up-to-date



Goals

- Development of a method for classifying the road surface on the basis of smartphone sensor data to support the maintenance management
- Reduction of effort and costs to determine the surface quality



Approach

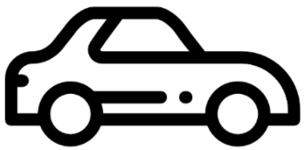
- Assignment and calibration of anonymized smartphone sensor data to road sections covered during numerous fleet tests
- Using Machine Learing algorithms

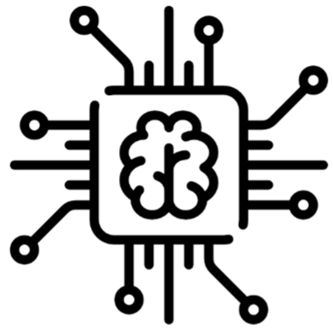
Introduction: Artificial Intelligence
Johannes Betz / Prof. Dr. Markus Lienkamp / Prof. Dr. Boris Lohmann

(Johannes Betz, M. Sc.)

Agenda

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





Summary – What did we learn today

- The industry attributes **artificial intelligence** the most potential for future methods and applications. The big problem with using artificial intelligence is that we **need a lot of data which is labeled** and we **need high computer performance**
- An overall definition for intelligence is complex so we **devide intelligence** into different styles of intelligence: **Emotional, Creative, Methodical, 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 **devide 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 sup-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 devide Machine Learning into three big problems: **Regression, Classification, Clustering**

Summary – What did we learn today

- One 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 devide autonomous driving into 4 sub-functions: **Sensor processing, Perception, Path & Behavioral Planning, Control**
- Each of those sub-functions can be accomplished with machine learning methods

Evaluation

Evaluation

- In this lecture we are doing in regularly evaluation
- We want **your** feedback for every **individual** session
- We evaluate the session each week
- We give feedback based on the evaluation the week after

Evaluation – Step by Step

1. Get out your smartphones
2. Open an app for QR-code reading
3. Read the following QR-code on the right side →
4. Open the website
5. Answer the questions
6. Send the evaluation

OR

1.Open the following website in your browser: https://evasys.zv.tum.de/evasys/online.php?p=AIAT-1

2.Answer the questions

3.Send the evaluation