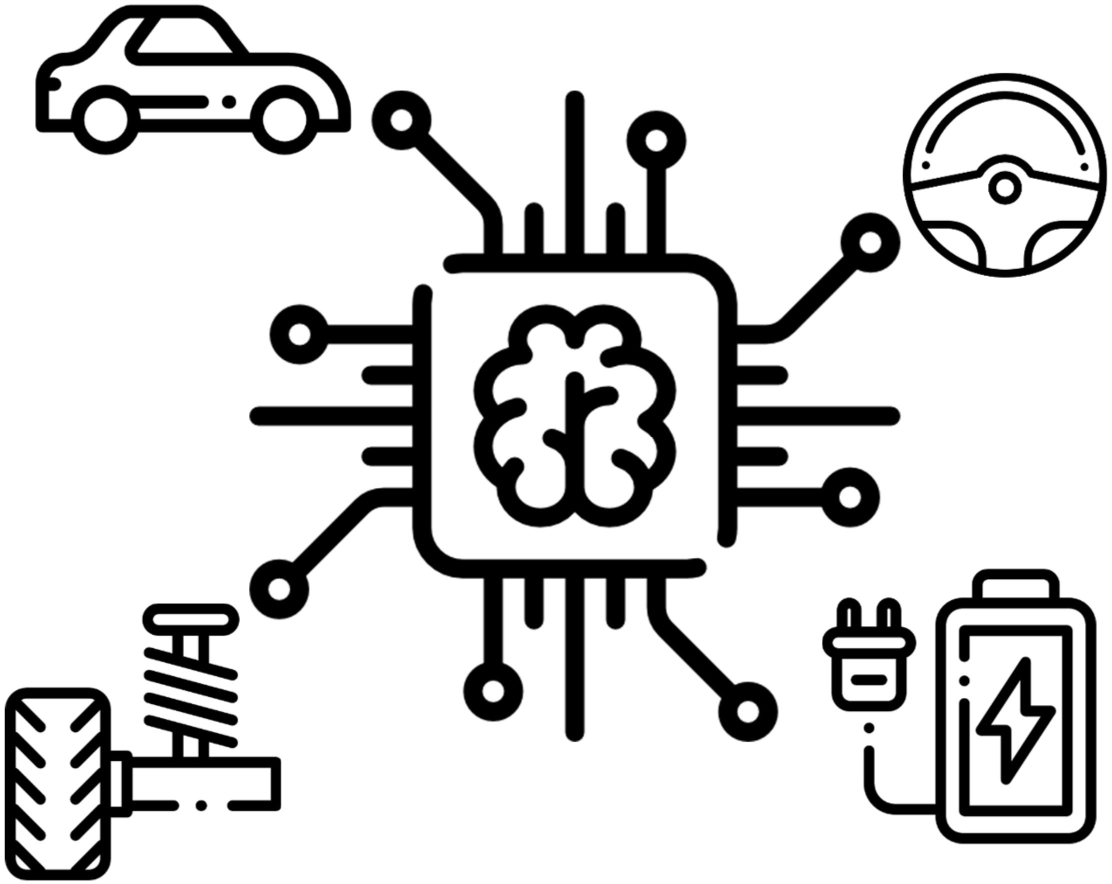
Institute of Automotive Technology
Faculty for Mechanical Engineering
Technical University of Munich

Artificial Intelligence in Automotive Technology

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



Lecture Overview

Lecture 16:15 – 17:45	Practice 17:45 – 18:30
1 Introduction: Artificial Intelligence 17.10.2019 – Johannes Betz	**Practice 1** 17.10.2019 – Johannes Betz
2 Perception 24.10.2019 – Johannes Betz	**Practice 2** 24.10.2019 – Johannes Betz
3 Supervised Learning: Regression 31.10.2019 – Alexander Wischnewski	**Practice 3** 31.10.2019 – Alexander Wischnewski
4 Supervised Learning: Classification 7.11.2019 – Jan Cedric Mertens	**Practice 4** 7.11.2019 – Jan Cedric Mertens
5 Unsupervised Learning: Clustering 14.11.2019 – Jan Cedric Mertens	**Practice 5** 14.11.2019 – Jan Cedric Mertens
6 Pathfinding: From British Museum to A* 21.11.2019 – Lennart Adenaw	**Practice 6** 21.11.2019 – Lennart Adenaw
7 Introduction: Artificial Neural Networks 28.11.2019 – Lennart Adenaw	**Practice 7** 28.11.2019 – Lennart Adenaw
8 Deep Neural Networks 5.12.2019 – Jean-Michael Georg	**Practice 8** 5.12.2019 – Jean-Michael Georg
9 Convolutional Neural Networks 12.12.2019 – Jean-Michael Georg	**Practice 9** 12.12.2019 – Jean-Michael Georg
10 Recurrent Neural Networks 19.12.2019 – Christian Dengler	**Practice 10** 19.12.2019 – Christian Dengler
11 Reinforcement Learning 09.01.2020 – Christian Dengler	**Practice 11** 09.01.2020 – Christian Dengler
12 AI-Development 16.01.2020 – Johannes Betz	**Practice 12** 16.01.2020 – Johannes Betz
13 Guest Lecture: VW Data:Lab 23.01.2020 –	

Objectives for Lecture 1: Introduction to AI

After the lecture you are able to…

… remember categories for classifying intelligence

… remember categories for classifying artificial intelligence

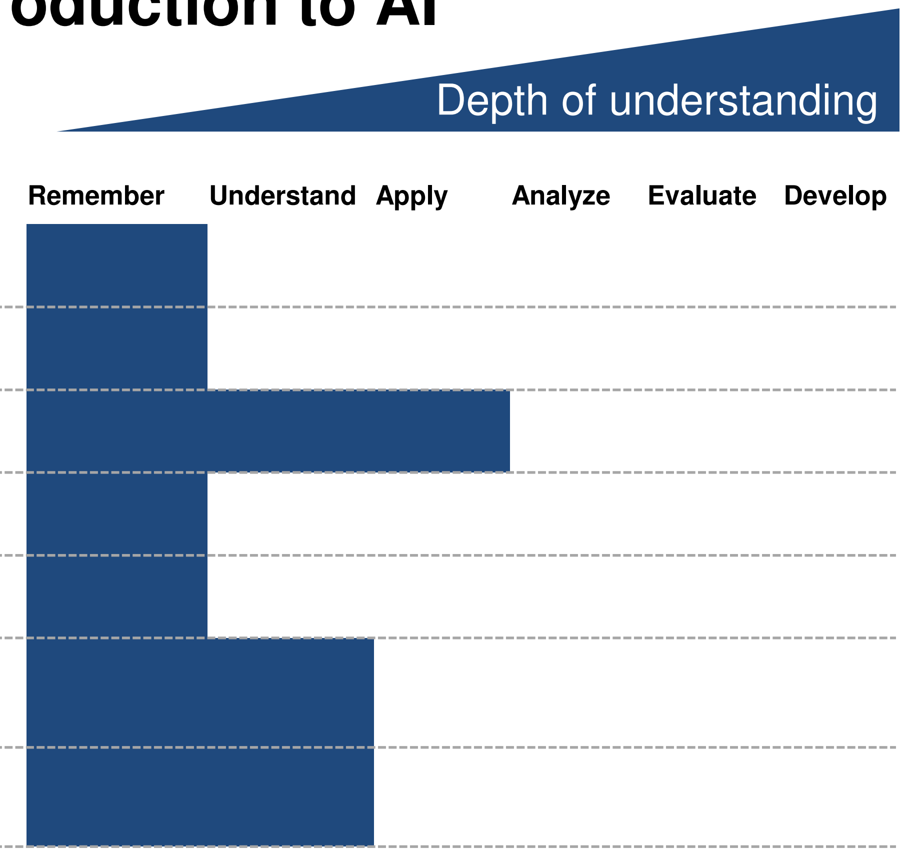
… classify artifical intelligence methods and tools in sub problems

… remember the problems of artifical intelligence algorithms

… remember AI applications

… understand why autonomous driving is an AI problem

… understand which AI algorithms is necessary to solve an autonomous driving task

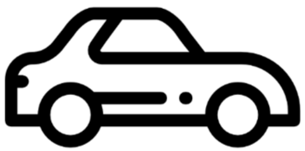


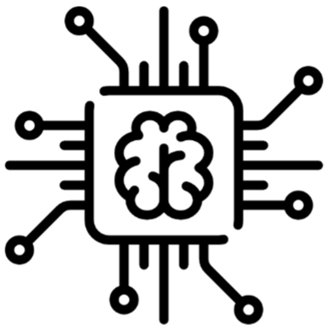
Introduction: Artificial Intelligence
Johannes Betz / Prof. Dr. Markus Lienkamp / Prof. Dr. Boris Lohmann

(Johannes Betz, M. Sc.)

Agenda

1. **Chapter: Artificial Intelligence in the Spotlight**
2. Chapter: 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



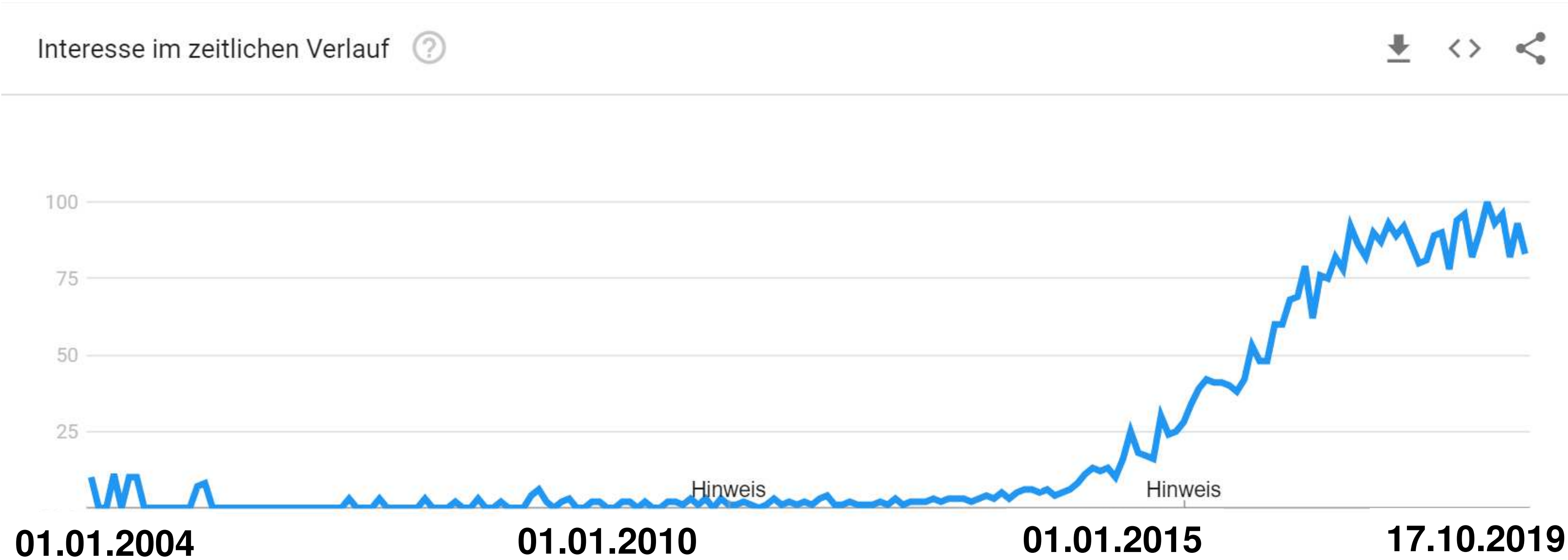


AI in the Spotlight

Nvidia GTC 2019 Conference Keynote (20.03.2019)

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

AI in the Spotlight



Google Trends „Deep Learning“

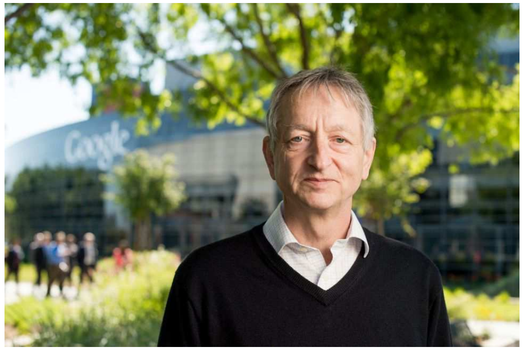
Source: Google Trends – Search „Deep Learning“

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.

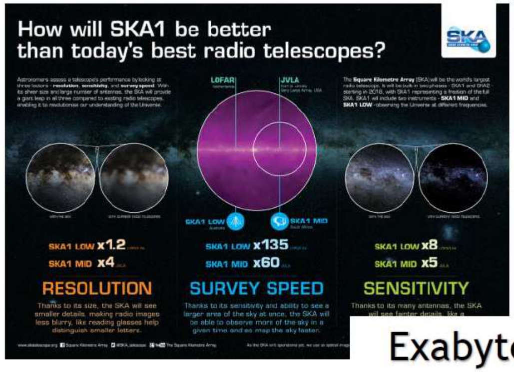
But he soldiered on: in 2004, with support from the Canadian Institute for Advanced Research, he launched a University of Toronto programme in neural computation and adaptive perception, where, with a group of researchers, he carried on investigating how to create computers that could behave like brains.

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 ?

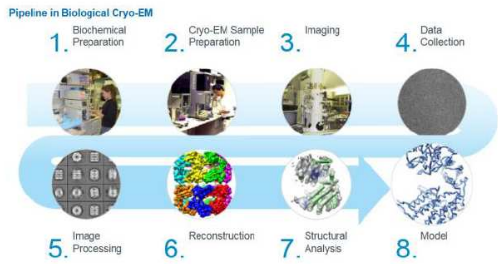
Source: https://www.wired.co.uk/article/wired-global-100

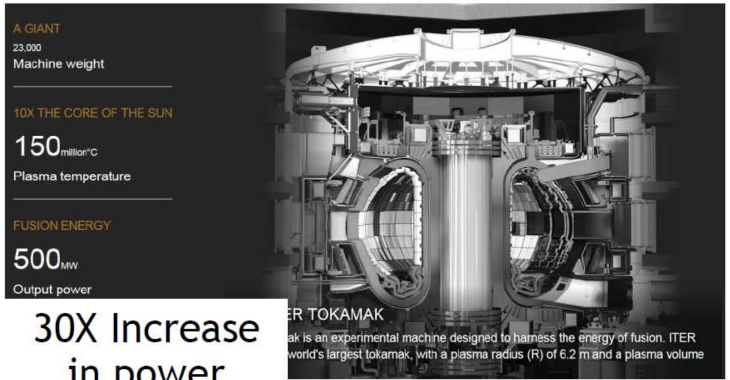
AI in the Spotlight



Exabyte/Day

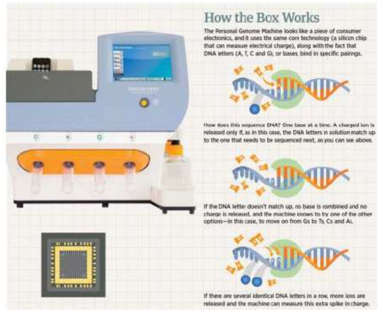
15 TB/Day





30X Increase in power

10X Increase in Data Volume

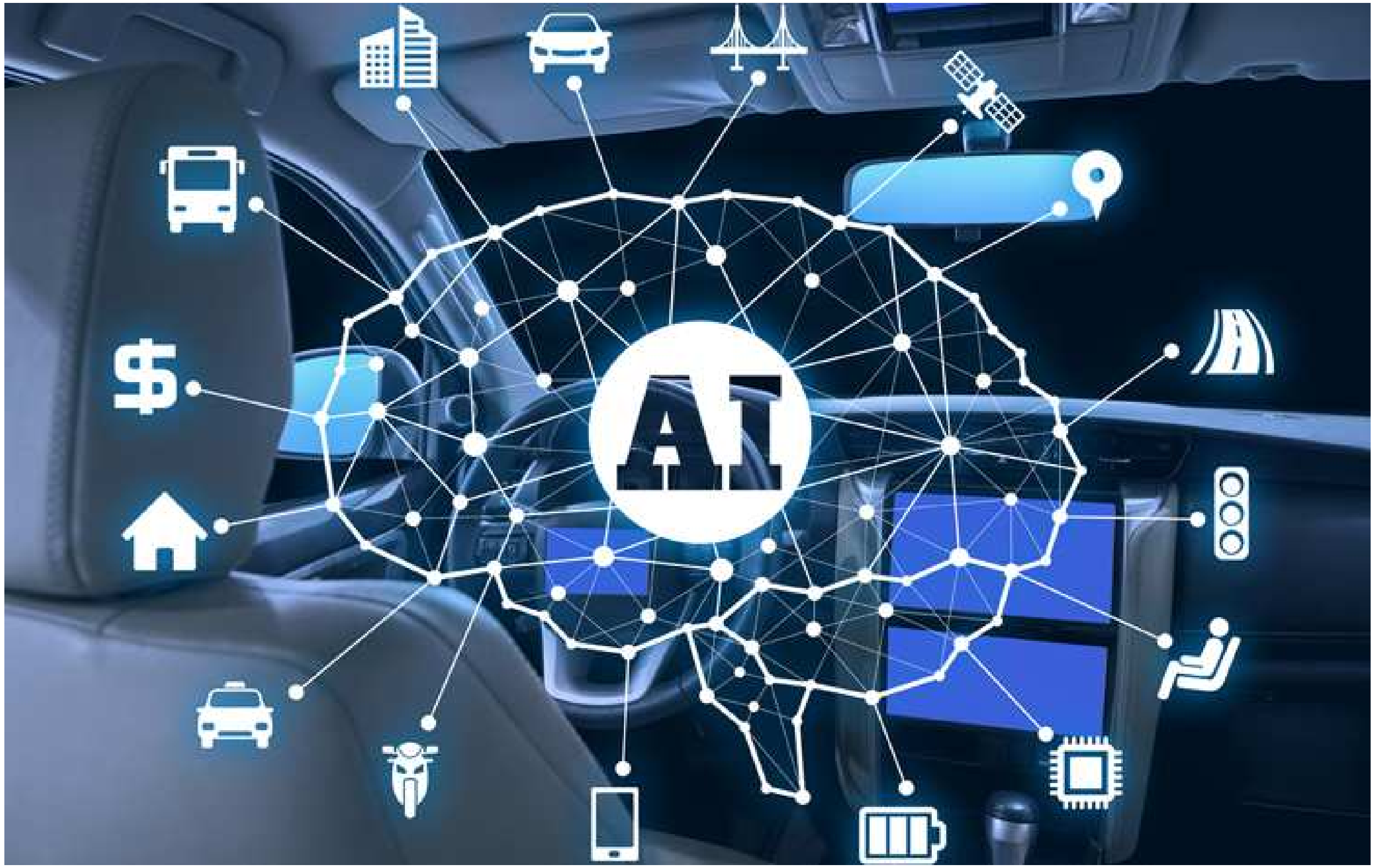


Personal Genomics

Experiments coming or upgrading in the next 10 years

Source: NVIDIA Accelerated Computing Workshop @LRZ

AI in the Spotlight



Automotive technology

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

Additional Slides

Artificial Intelligence 2019

- The term „artificial intelligence“ (AI) is widely used in media and tech discussions but is often mixed up with the following terms:
    - Machine learning (ML)
    - Deep learning
    - Reinforcement learning
    - Artificial neural networks
- Artificial intelligence is a multidisciplinary field of science whose goal is to create intelligent machines. In this lecture, we will learn how we can classify artificial intelligence in different subproblems and algorithms.
- We believe that AI will be a force multiplier on technological progress in our increasingly digital, data-driven world
    - AI continues to be popular among business executives, regardless of complications, concerns and confusion – 73% of senior executives see AI/ML and automation as areas they want to maintain or increase investment in
    - 71% of U.S. enterprises plan to leverage more AI/ML tools for security
    - 82% of IT and business decision makers agree that company-wide strategies to invest in AI-driven technologies would offer significant competitive advantages
    - Nearly 90% of IT leaders see their use of AI/ML increasing in the future and 41% look for technology that is powered by AI, a top factor in their purchasing decisions. Their top concerns: Data security (47%), implementing AI/ML (40%), driving innovation and implementing new tech (40%) (Adobe).

Source: https://www.forbes.com/sites/gilpress/2019/04/03/7-indicators-of-the-state-of-artificial-intelligence-ai-march-2019/#25602836435a

Introduction: Artificial Intelligence
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(Johannes Betz, M. Sc.)

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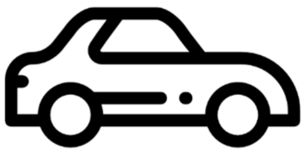
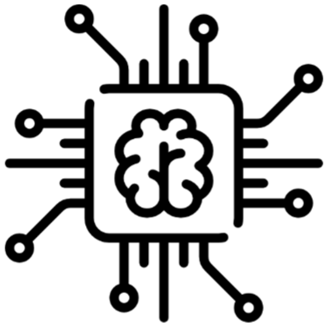
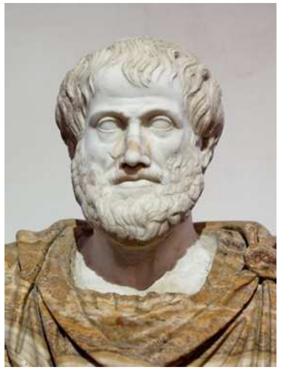




A brief History



300 BC: Aristoteles –
Described syllogism

1641: Hobbes –
Theory of cognition

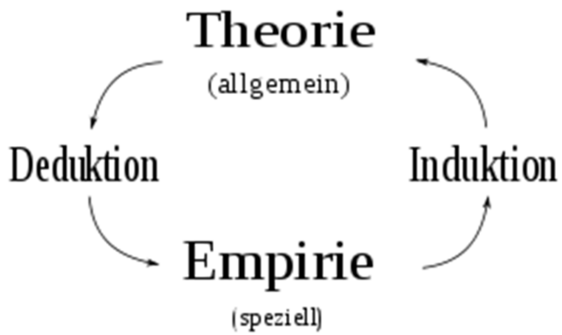
Induction

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

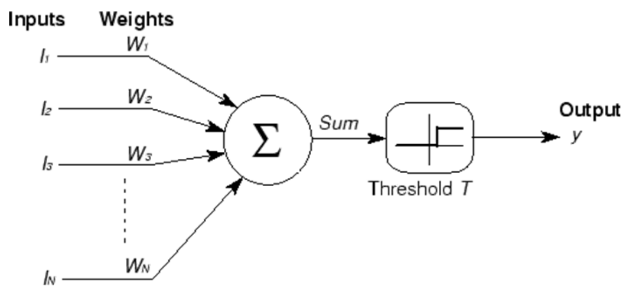


1930s: Carnap –
Logical Positivism

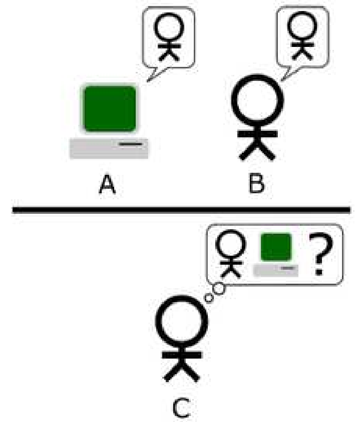
A brief History

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

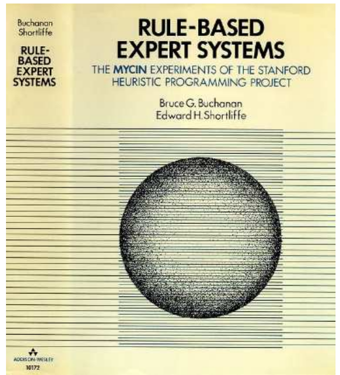


1951: Turing –
Machine Intelligence

1956: McCarthy –
Artificial Intelligence

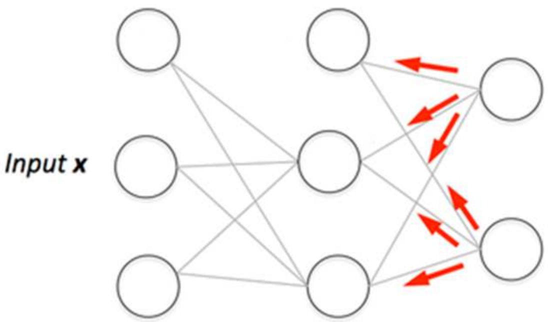
```
> Hello, I am Eliza.
* I am afraid.
> How long have you been afraid?
* Since midterms.
> Tell me more...
* I am afraid that I will fail
my course.
> Do you enjoy being afraid that
you will fail your course?
```

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 of 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
https://www.pcworld.com/article/2985897/data-center-cloud/ibm-watson-will-know-what-you-did-last-summer.html
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/

Introduction: Artificial Intelligence
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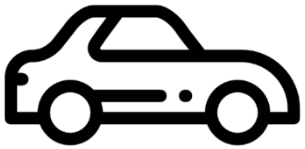
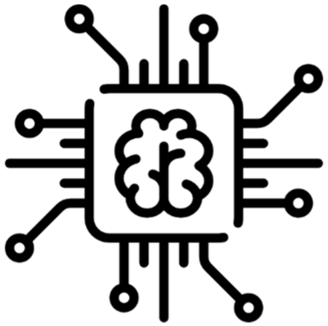
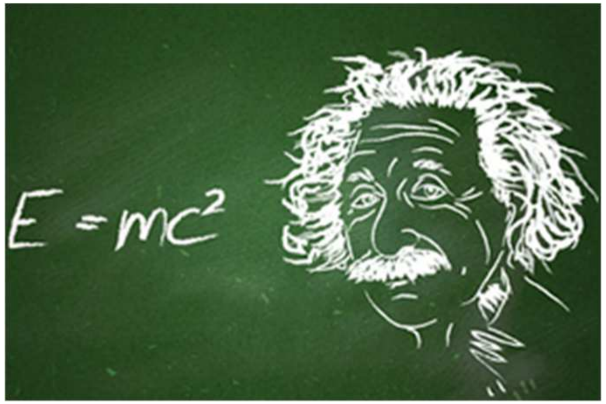
Agenda

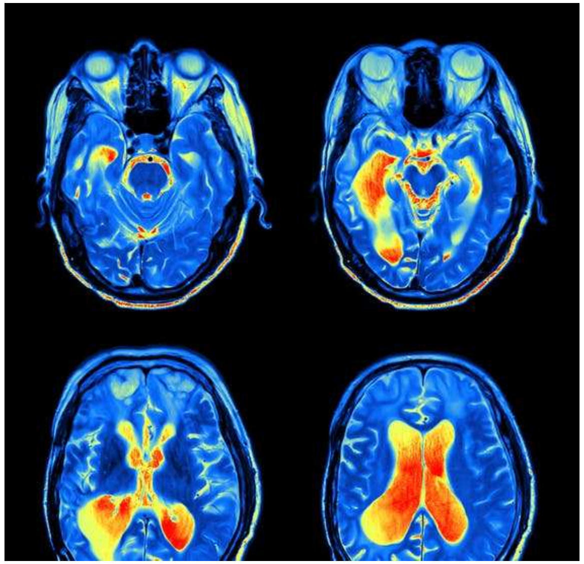




What is Intelligence?

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

- Structure
- System
- Discipline
- Precision
- Safety

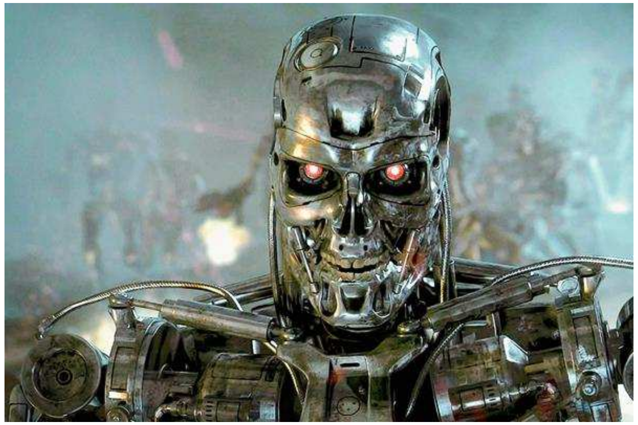
Methodical intelligence

- Critical analysis
- Strategic thinking
- Logic
- Objectivity

Analytical intelligence

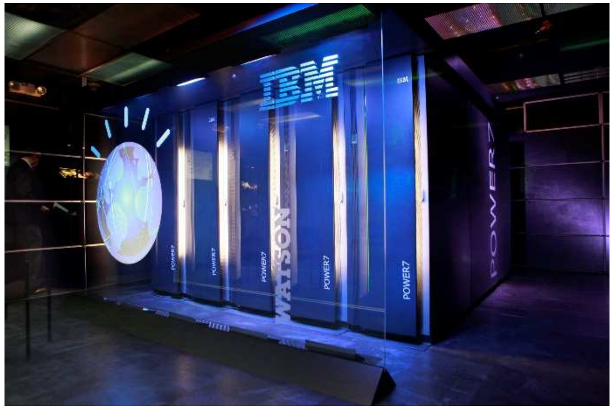
Source: https://koehlerkline.de/about/methode/die-vier-arten-der-intelligenz/ / https://en.wikipedia.org/wiki/Rules_of_chess#/media/File:ChessSet.jpg / http://www.brainfacts.org/thinking-sensing-and-behaving/thinking-and-awareness?page=3 / https://www.buerocheck24.de/leitz-tauenpapier-register-a-z-fuer-24-ordner-grau.html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

What is Artificial Intelligence?



Robots ?

Virtual assistant?

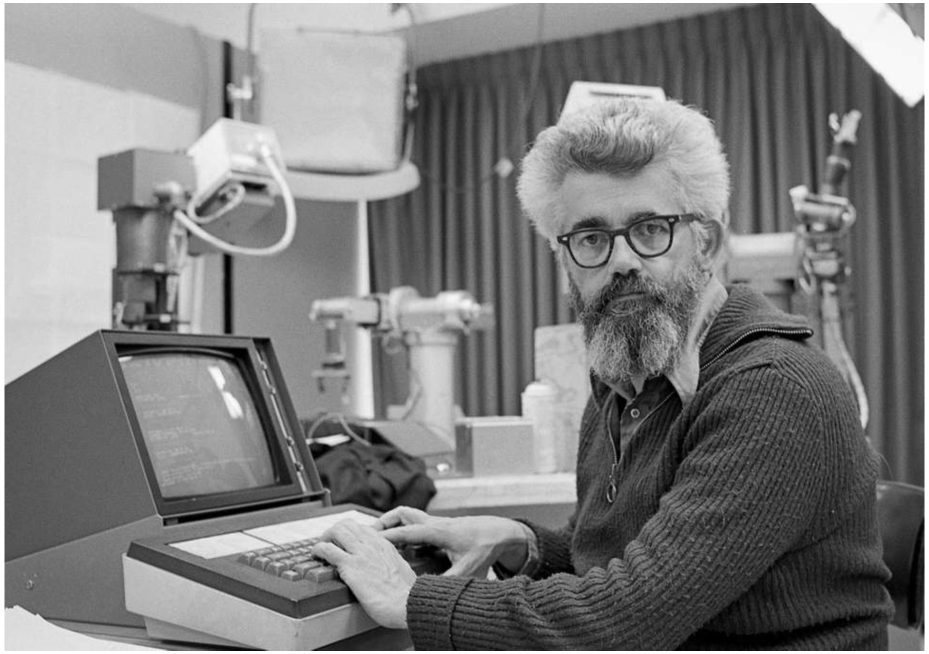


Supercomputers?

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

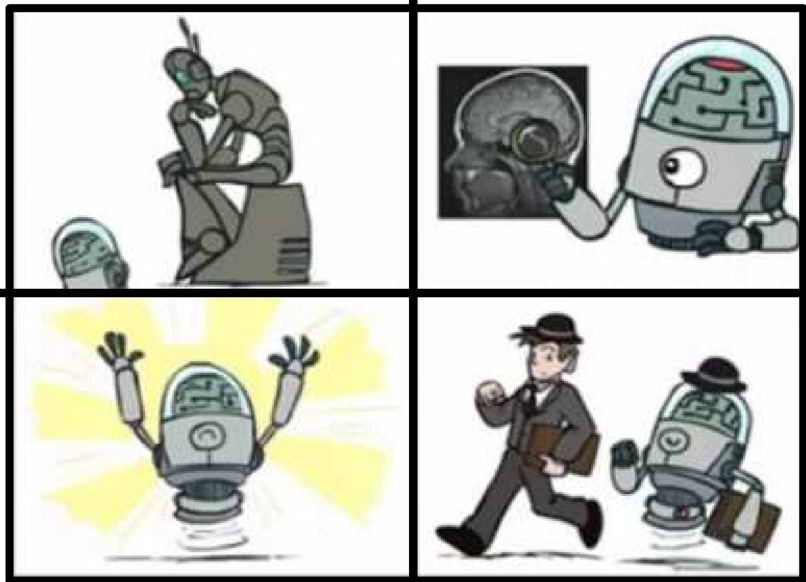
What is Artificial Intelligence? A Proposal for Categories

Thinking rationally

- Laws of thought
- Logic
- Correct reasoning

Thinking humanly

- Thought procedure
- Human performance
- Cognitive science



Acting rationally

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

Acting humanly

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

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

Additional Slides

What is Artificial Intelligence? A Proposal for Categories

- **Thinking rationally**: According to the school of thought (with roots from all the way back to Aristotle), we should be building agents that think rationally and have correct reasoning processes. There are some problems to this approach: It's not easy to state informal probabilistic knowledge in formal logical notation and any non-trivial problem we care about in AI is computationally intractable without guidance.

- **Thinking humanly**: According to this school of thought, we should be building agents that follow the thought procedures of humans. This is a field of science in itself (cognitive science), but it is not AI anymore.

- **Acting rationally**: The most accepted definition of AI today is the science of building agents that act rationally. *A rational agent is one that achieves the best possible outcome or when there is uncertainty, the best expected outcome.* Being rational means maximizing your expected utility. Rationality only concerns what decisions are made and not the thought processes behind them.

- **Acting humanly**: According to this school of thought, we should be building agents that act like humans. The Turing Test, proposed by Alan Turing, was designed to provide a satisfactory operational definition of intelligence. However, it turns out that this is also not a very useful definition because the focus turns on capturing the characteristics we do not value in humans in the first place (e.g., not spelling too correctly and not solving math problems too accurately).

Source: https://kartikkukreja.wordpress.com/2015/05/17/what-is-ai-and-what-can-we-do-with-it-today/

Additional Slides

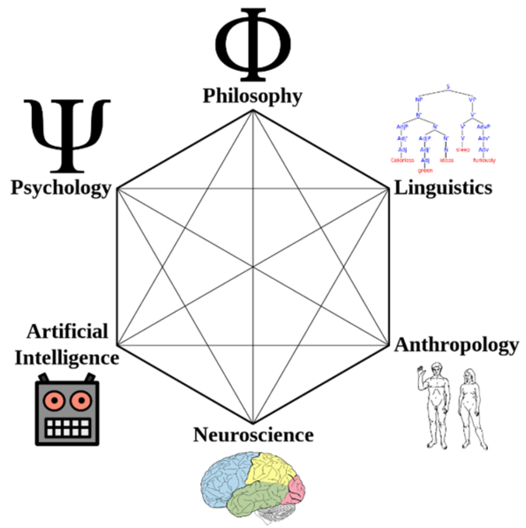
The Turing Test

- Can machines think? This is a question that has occupied philosophers since Decartes. But even the definitions 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 this 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 simplification but it is sufficient for our present purposes).
- Although the Turing test is not without flaws (e.g., failing 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

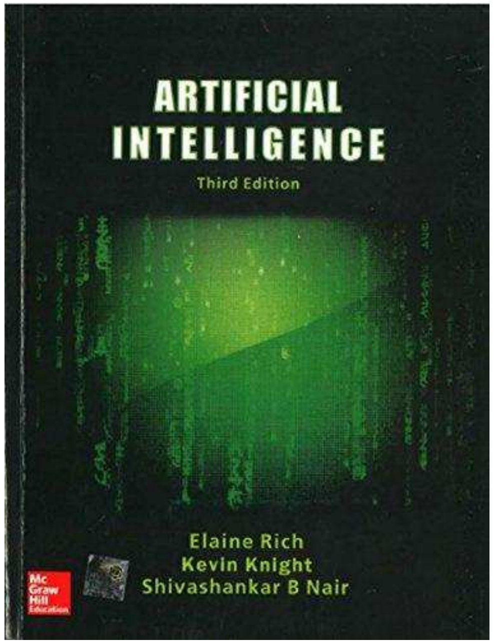
- Cognitive science is the interdisciplinary, scientific study of the mind and its processes. It examines the nature, the tasks, and the functions of cognition (in a broad sense). Cognitive scientists study intelligence and behavior, with a focus on how nervous systems represent, process, and transform 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 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*

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.

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 explicitly programmed **(machine learning (ML))**

Lecture 7-12

Weak AI

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

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

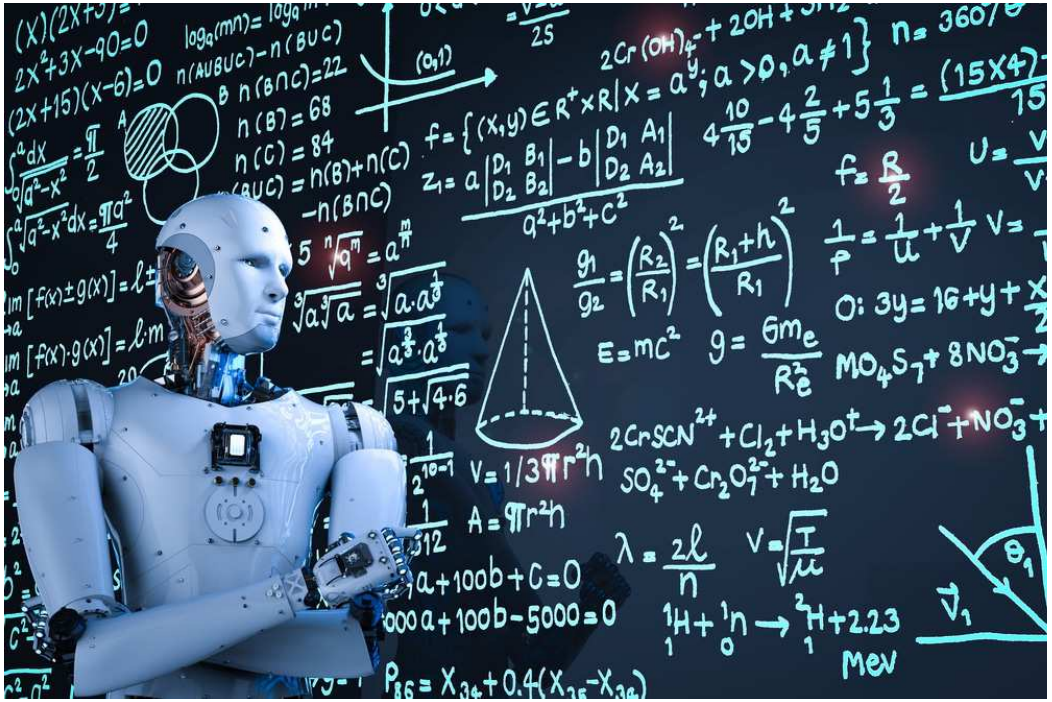
7. **Motion and manipulation:** A machine gets the ability to learn how to plan their motion and move efficiently

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

Weak AI

What is Artificial Intelligence? A Second Proposal for Categories

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



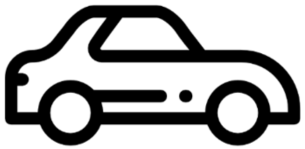
9. General intelligence: Achieving the full range of human cognitive abilities (= general AI or strong AI or full AI)

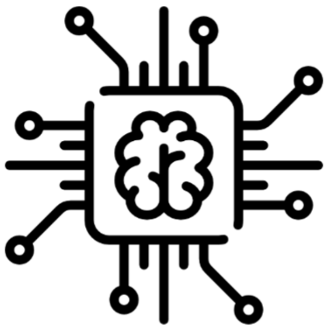
Introduction: Artificial Intelligence
Johannes Betz / Prof. Dr. Markus Lienkamp / Prof. Dr. Boris Lohmann

(Johannes Betz, M. Sc.)

Agenda

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





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?

Additional Slides

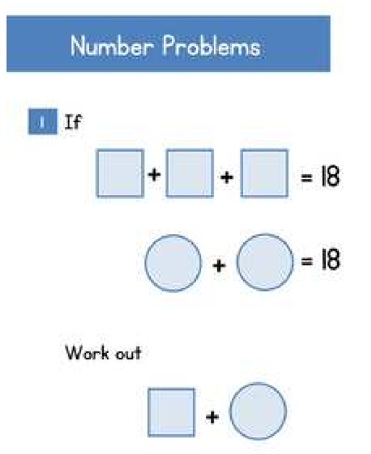
Definitions

- **Sub-problem:** We brake down the general problem of creating AI into different „sub-problems“. Each of the 8 categories gives us the ability to solve a specific „class of problems“. Therefore, we only distribute with the problem itself.
- **Method:** In this lecture, we define the term “method” as a generic term for a collection of algorithms. These methods can be used to solve our artificial intelligence sub-problems. Each sub-problem can be solved with different methods. The methods distinguish between computing effort, complexity of the method and quality of the output.
- **Algorithm:** In this lecture we define the term “algorithm” as an unambiguous specification of how to solve a particular sub-problem in the field of artificial intelligence. We always assign the algorithms to a certain method. We distinguish the algorithms regarding computing effort, complexity of the method and quality of the output.

AI Methods – 1. Reasoning & Problem Solving

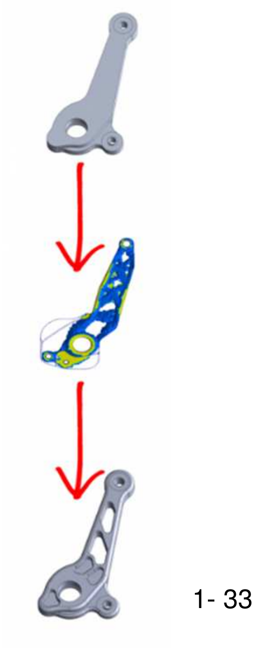
Problem description:

- 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 necessary



Methods & algorithms:

- 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 progamming, quadratic programming, heuristics, ...
- Evolutionary computation: Optimization search based on evolutions, e.g., genetic algorithms, particle swarm optimization, ant colony optimiziation

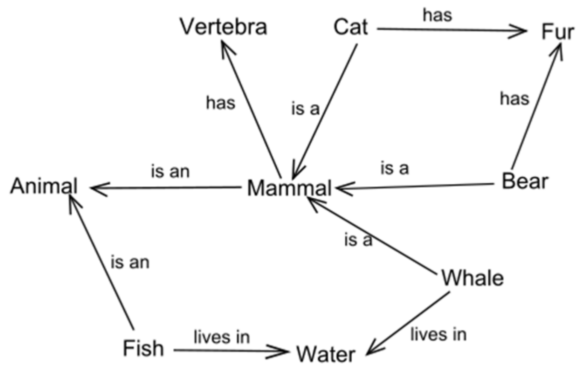


Source: https://www.pinterest.de/pin/161707442850537812/; https://www.coffee.de/solidworks-topologieoptimierung/

AI Methods – 2. Knowledge Representation:

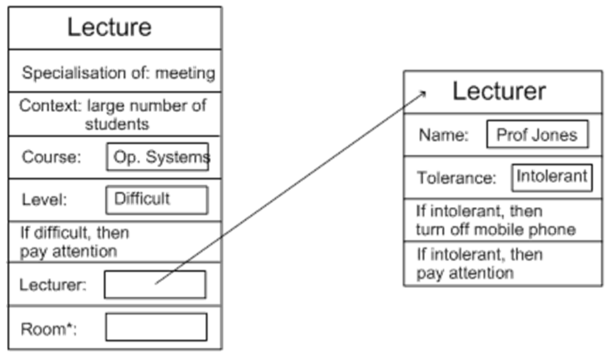
Problem description:

- 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 & algorithms:

- Logic: A set of sentences in logical form expressing facts and rules about a problem e.g. Propositional Logic, First order Logic, Fuzzy Logic,…

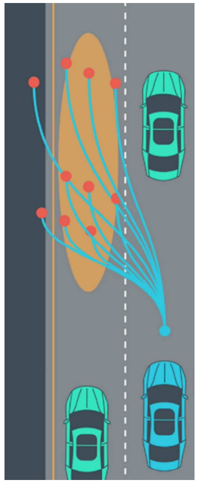


Source: http://ccg.doc.gold.ac.uk/ccg_old/teaching/artificial_intelligence/lecture4.html/ https://www.omicsbio.org/2017/12/03/biomedical-knowledge-representation-and-reasoning//

AI Methods – 3. Planning

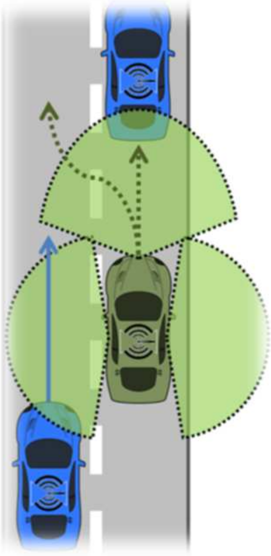
Problem description:

- 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 & algorithms:

- 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
- 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 program instructions

Methods & algorithms:

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

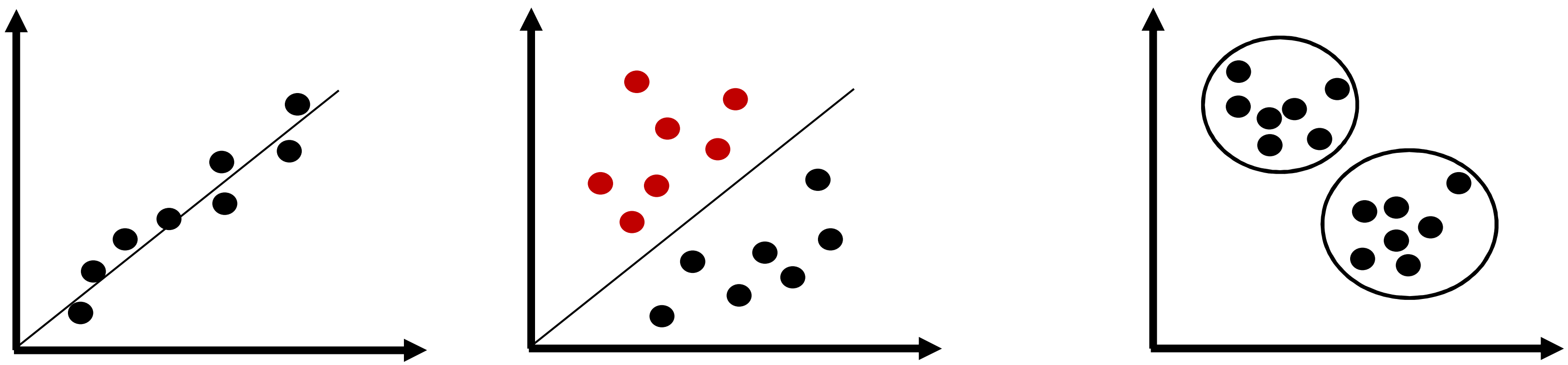
Supervised

Find a predictive model based on input and labeled output data

Unsupervised

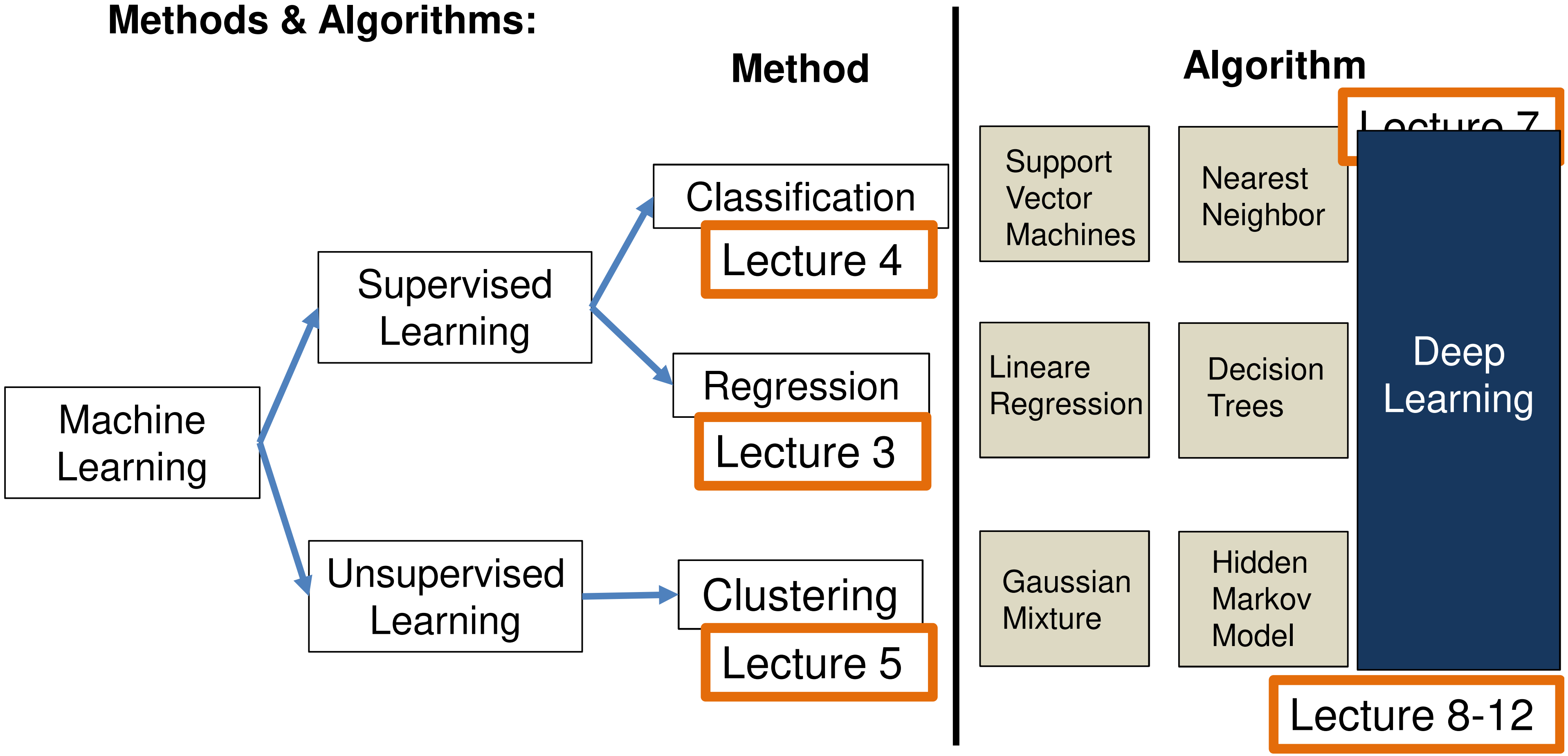
Find similarities in input data and interpret them

Regression **Classification** **Clustering**

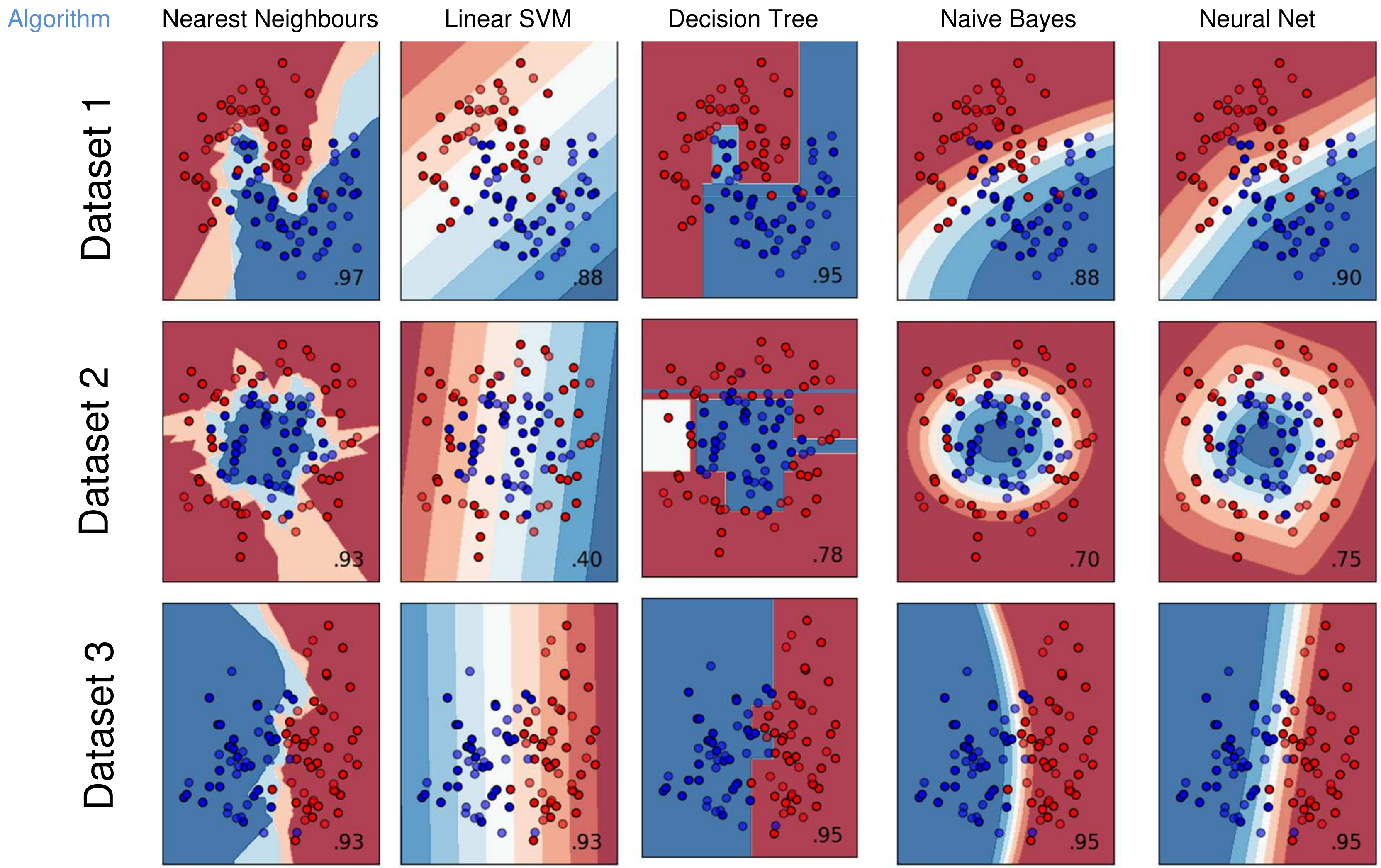


AI Methods – 4. Learning

Methods & Algorithms:

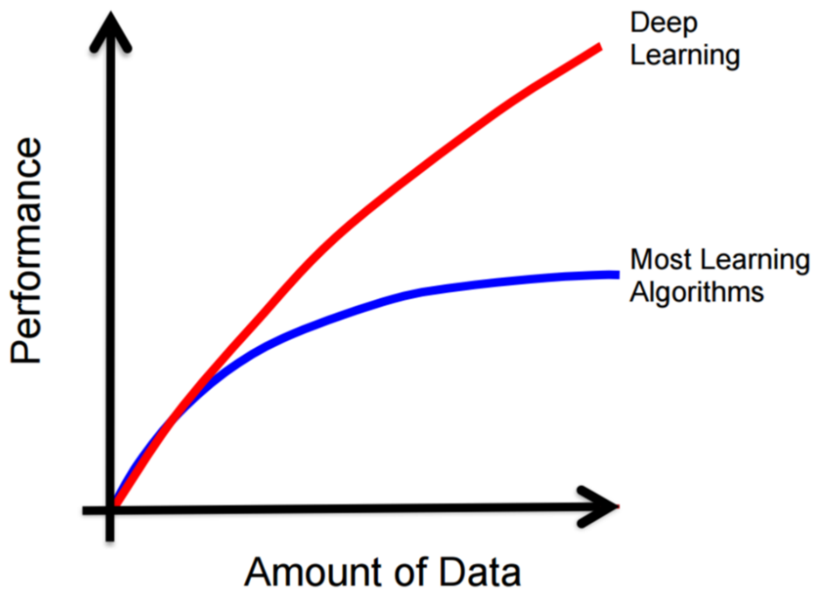


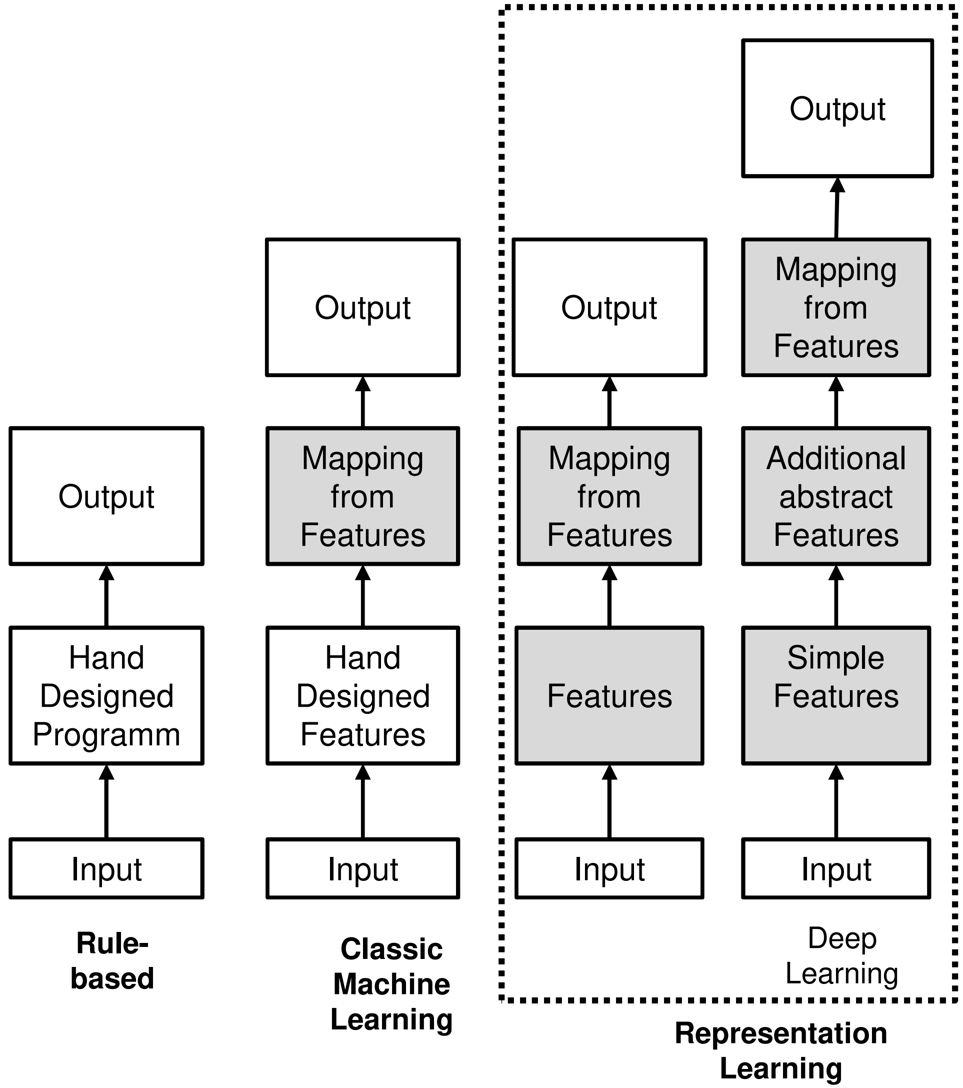
AI Methods – 4. Learning – Classification Example



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

AI Methods – 4. Learning





Why deep learning?

Source: MIT Lecture AI – p. 33

Additional Slides

- In machine learning, a **feature** is an individual measurable property or characteristic of a phenomenon being observed. Examples for features:
    - Computer vision: colors, edges, objects (Lecture 2)
    - Speech recognition: noise ratios, length of sounds, relative power, filter matches and many others
    - Spam detection: absence of certain email headers, email structure, language, frequency of specific terms and grammatical correctness of text.

- Choosing **informative, discriminating and independent features** is a crucial step for effective algorithms.

- In machine learning, the term **feature learning** or **representation learning** is a set of techniques that allows a system to **automatically discover** the representations needed for feature detection or classification from raw data. This replaces **manual feature engineering** and allows a machine to **both learn the features and use them to perform a specific task**.

- Feature learning is motivated by the fact that machine learning tasks such as classification often require input that is mathematically and computationally convenient to process. However, with real-world data such as images, videos, and sensor data, no attempts have been made to algorithmically define certain features. An alternative is to discover such features or representations through examination, without relying on explicit algorithms. Feature learning can be either supervised or unsupervised.

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

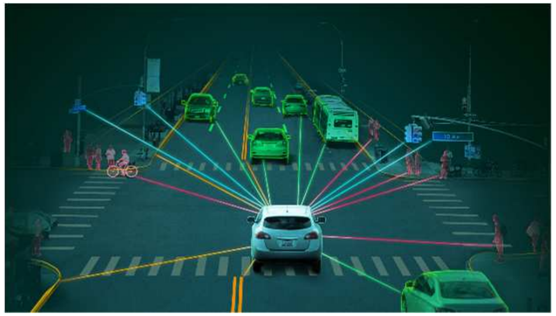
Methods & algorithms:

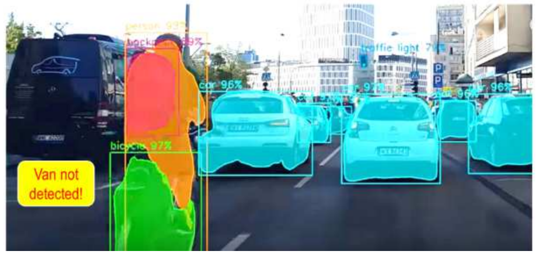
- Logic: A set of sentences in logical form expressing facts and rules about a problem, e.g., propositional logic, first-order logic, knowledge-based
- Classical machine learning, e.g., classification
- Deep learning, e.g., LSTM networks

AI Methods – 6. Perception

Problem description:

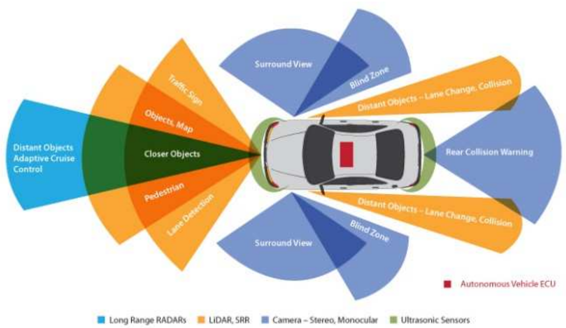
- A computer is represented as an agent
- This agent is getting the ability to perceive the environment
- The agent is using sensors as input: Camera, Lidar, ultrasonic, radar, microphones, …
- **Machine perception:** Capability to interpret data which is related to the environment world
- **Computer 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,…

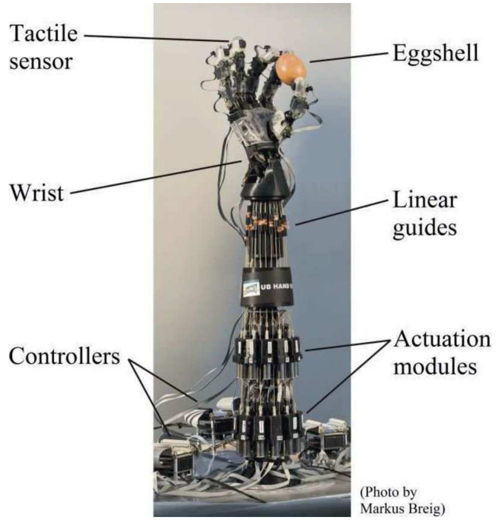


Source: http://www.thewhollysee.com / https://itrade.gov.il/uk/2018/10/19/vayavisions-autonomous-vehicle-perception-system-raised-8m/ https://www.tataelxsi.com/ip-solution/automotive/Autonomai.html

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/

Additional Slides

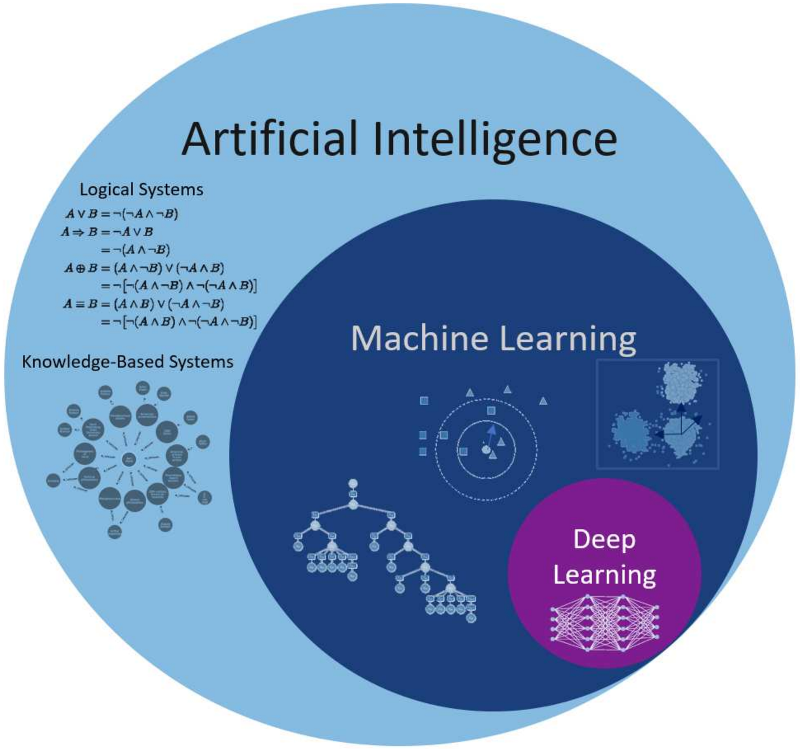
Summary: Definitions

Artificial intelligence (AI): A broad discipline with the goal of creating intelligent machines, as opposed to the natural intelligence that is demonstrated by humans and animals. It has become a somewhat catch all term that nonetheless captures the long term ambition of the field to build machines that emulate and then exceed the full range of human cognition.

Machine learning (ML): A subset of AI that often uses statistical techniques to give machines the ability to "learn" from data without being explicitly given the instructions for how to do so. This process is known as “training” a “model” using a learning “algorithm” that progressively improves model performance on a specific task.

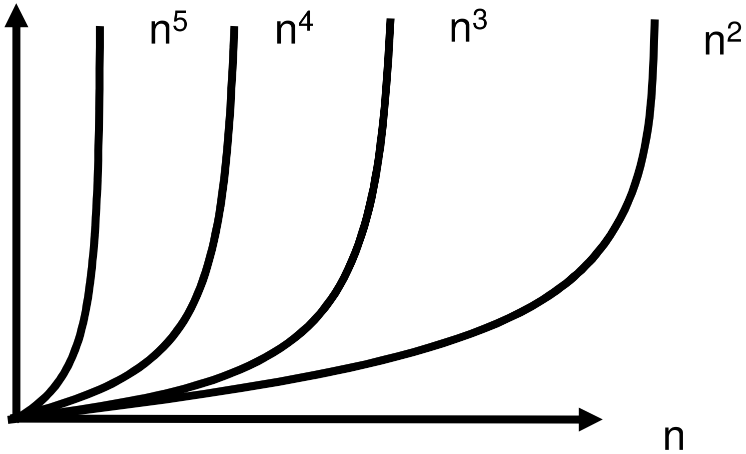
Deep learning (DL): An area of ML that attempts to mimic the activity in layers of neurons in the brain to learn how to recognize complex patterns in data. The “deep” in deep learning refers to the large number of layers of neurons in contemporary ML models that help to learn rich representations of data to achieve better performance gains.

Reinforcement learning (RL): An area of ML that has received lots of attention from researchers over the past decade. It is concerned with software agents that learn goal-oriented behavior by trial and error in an environment that provides rewards or penalties in response to the agent’s actions (called a “policy”) towards achieving that goal.



Source: https://data-science-blog.com/blog/2018/05/14/machine-learning-vs-deep-learning-wo-liegt-der-unterschied/

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

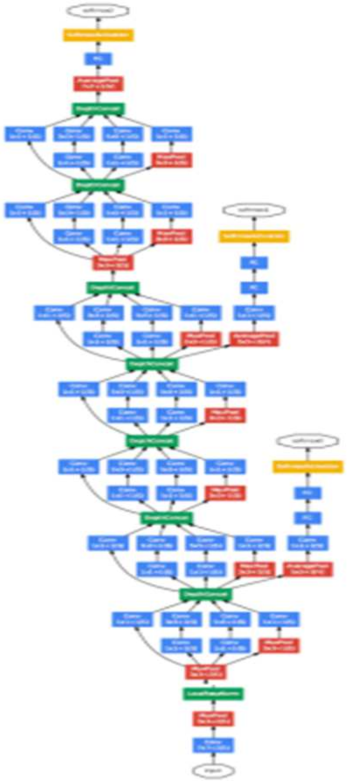
Additional Slides

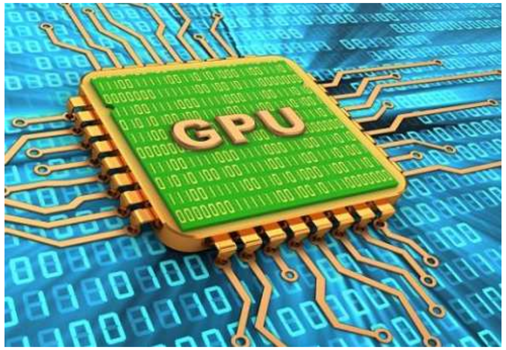
Complexity theory, a branch of theoretical computer science, deals with the classification of problems in terms of their complexity. An important problem class is the complexity class NP, the class of all decision problems for which a solution can be efficiently checked. NP stands for non-deterministic polynomial time. An NP difficult problem is at least as "difficult" as all problems in NP. This means that an algorithm that solves an NP severe problem can be used with a reduction to solve all problems in NP.

A common misconception is that the NP in "NP-hard" stands for "non-polynomial" when in fact it stands for "non-deterministic polynomial acceptable problems". It is suspected that there are no polynomial-time algorithms for NP-hard problems, but that has not been proven. Moreover, the class P, in which all problems can be solved in polynomial time, is contained in the NP class.

- **NP**: Class of computational decision problems for which a given yes-solution can be verified as a solution in polynomial time by a deterministic Turing machine (or solvable by a non-deterministic Turing machine in polynomial time).
- **NP-hard:** Class of problems which are at least as hard as the hardest problems in NP. Problems that are NP-hard do not have to be elements of NP; indeed, they may not even be decidable.
- **NP-complete**: Class of decision problems which contains the hardest problems in NP. Each NP-complete problem has to be in NP.
- **NP-easy**: At most as hard as NP, but not necessarily in NP.
- **NP-equivalent**: Decision problems that are both NP-hard and NP-easy, but not necessarily in NP.
- **NP-intermediate**: If P and NP are different, then there exist decision problems in the region of NP that fall between P and the NP-complete problems. (If P and NP are the same class, then NP-intermediate problems do not exist because in this case every NP-complete problem would fall in P, and by definition, every problem in NP can be reduced to an NP-complete problem.)

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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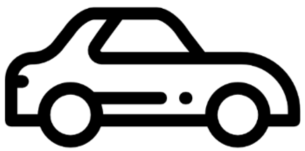
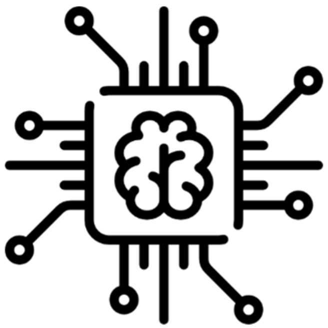
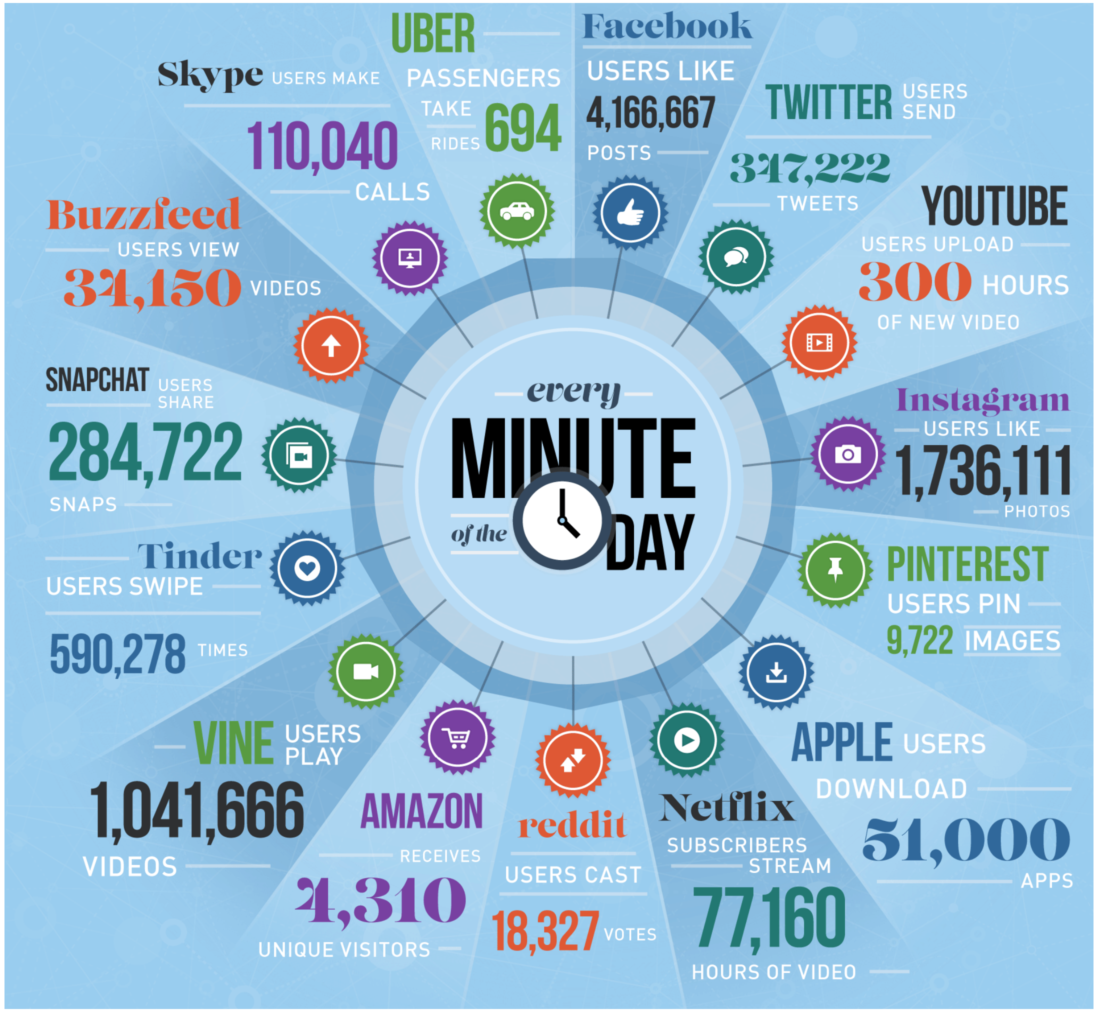




AI Applications – Big Data Analysis



2019: Big data is everywhere

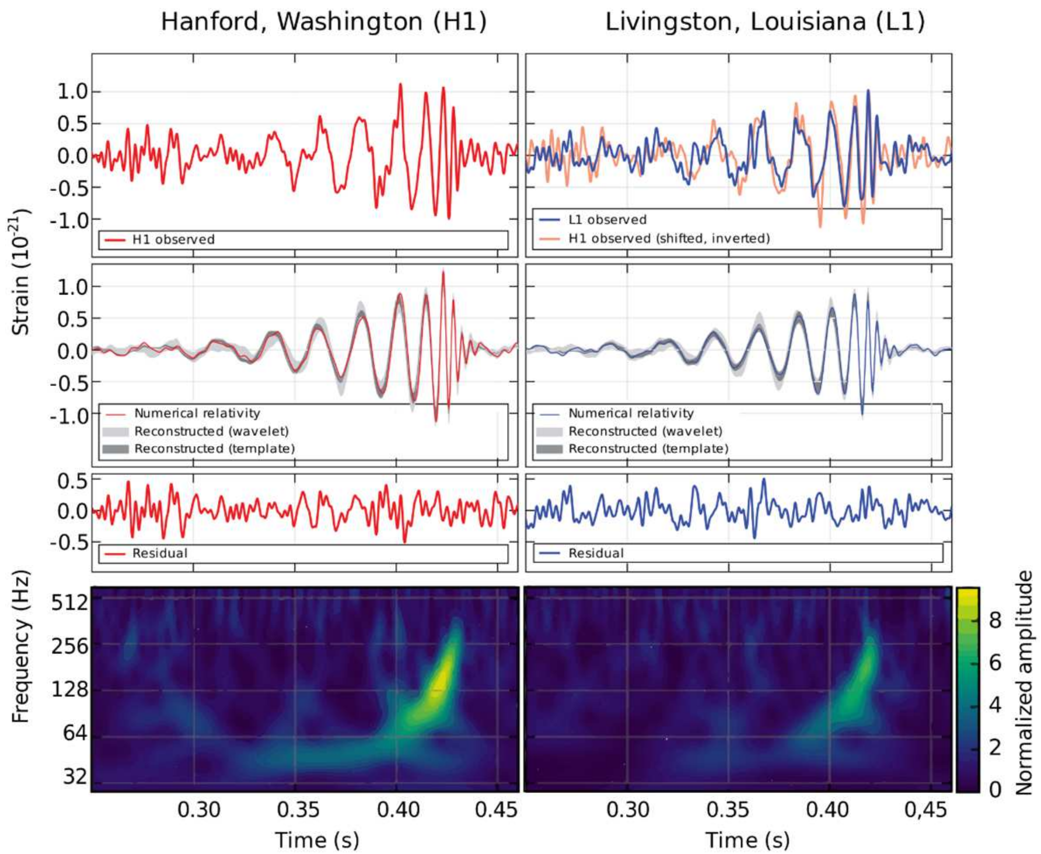
Source: https://blog.microfocus.com/how-much-data-is-created-on-the-internet-each-day/

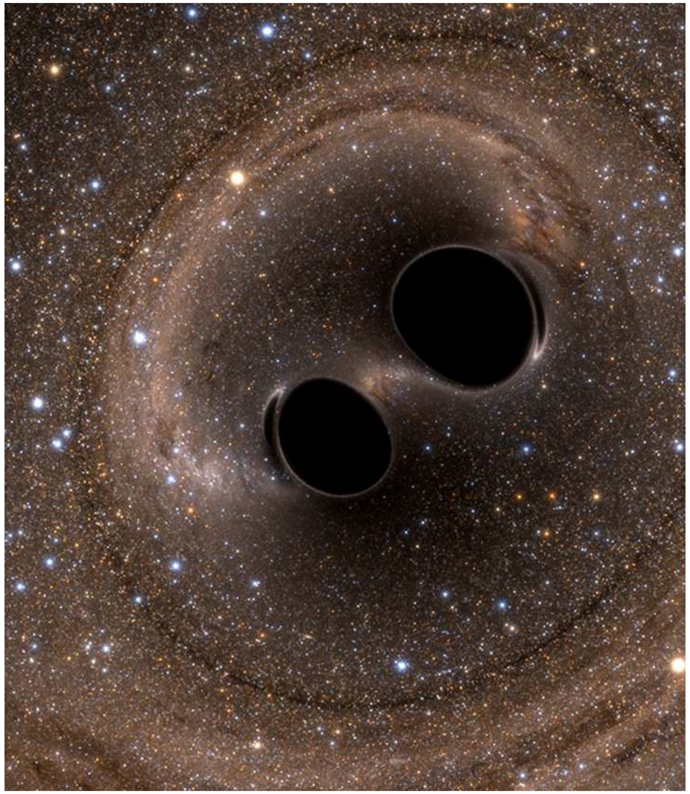
Additional Slides

Each minute of every day the following happens on the internet:

- Social media is HUGE – reports show almost 300 million new social media users each year. That is 550 new social media users each minute.
- Since 2013, the number of Tweets each minute has increased 58% to more than 474,000 tweets PER MINUTE in 2019!
- YouTube usage more than tripled from 2014-2016 with users uploading 400 hours of new video each minute of every day! Now, in 2019, users are watching 4,333,560 videos every minute.
- 300 hours of video are uploaded to YouTube every minute!
- Instagram users upload over 100 million photos and videos everyday. That is 69,444 million posts every minute!
- Users spend nearly one hour a day on Facebook, but Instagram and Snapchat are quickly catching up.
- Since 2013, the number of Facebook posts shared each minute has increased 22%, from 2.5 million to 3 million posts per minute in 2016. This number has increased more than 300%, from around 650,000 posts per minute in 2011!
- Every minute on Facebook: 510,000 comments are posted, 293,000 statuses are updated, and 136,000 photos are uploaded.
- There are over 38,000 status updates on Facebook every minute.
- Facebook users also click the like button on more than 4 million posts every minute, and the Facebook like button has been pressed 13 trillion times.
- Over 3.5 billion Google searches are conducted worldwide each minute of everyday. That is 2 trillion searches per year worldwide. That is over 40,000 search queries per second!
- Worldwide over 100 million messages are sent every minute via SMS and in-app messages!
- 26 billion texts were sent each day by 27 million people in the US. That is 94 texts per day per person in the US in 2017.

AI Applications – Big Data Analysis

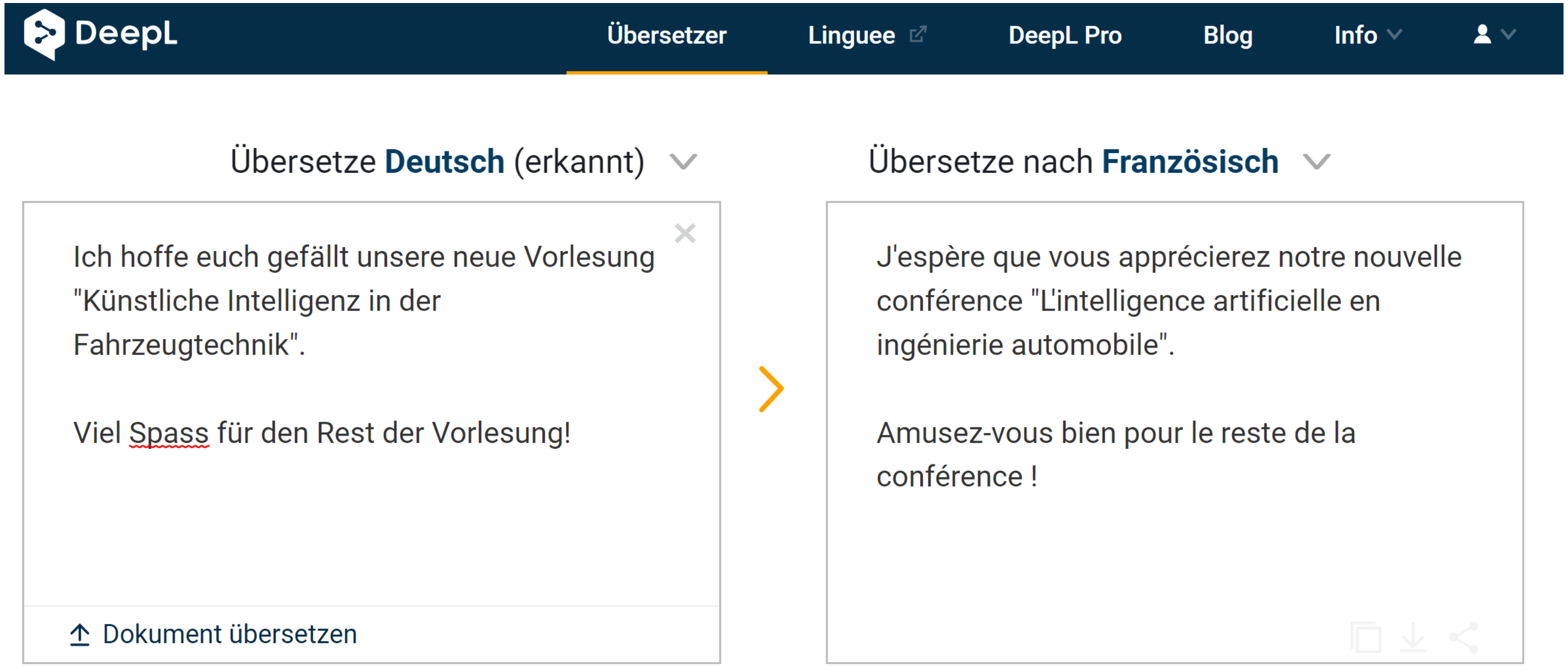




Astronomy, astrophysics, black holes, applied physic

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

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

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

Additional Slides

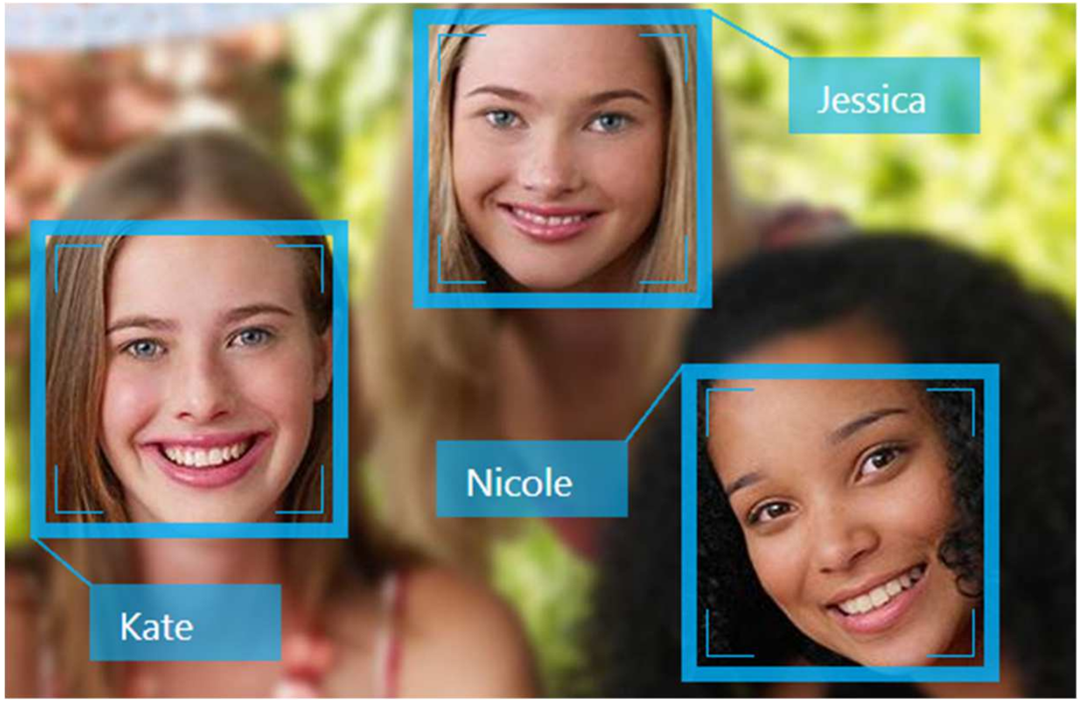
The field of study that focuses on the interactions between human language and computers is called natural language processing (NLP). It sits at the intersection of computer science, artificial intelligence, and computational linguistics.

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 statistical 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

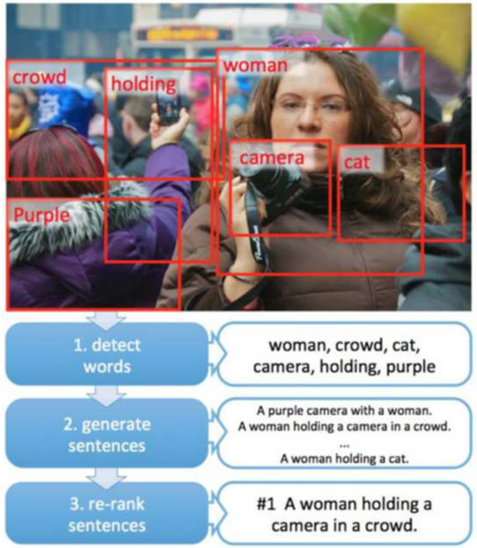


1. **Face detection: Spatial allocation**
2. **Feature extraction: Nose, mouth, eyes,…**
3. **Face recognition: Comparison with data base**

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

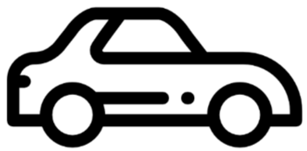
Introduction: Artificial Intelligence

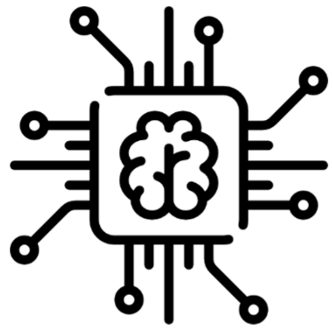
Johannes Betz / Prof. Dr. Markus Lienkamp / Prof. Dr. Boris Lohmann

(Johannes Betz, M. Sc.)

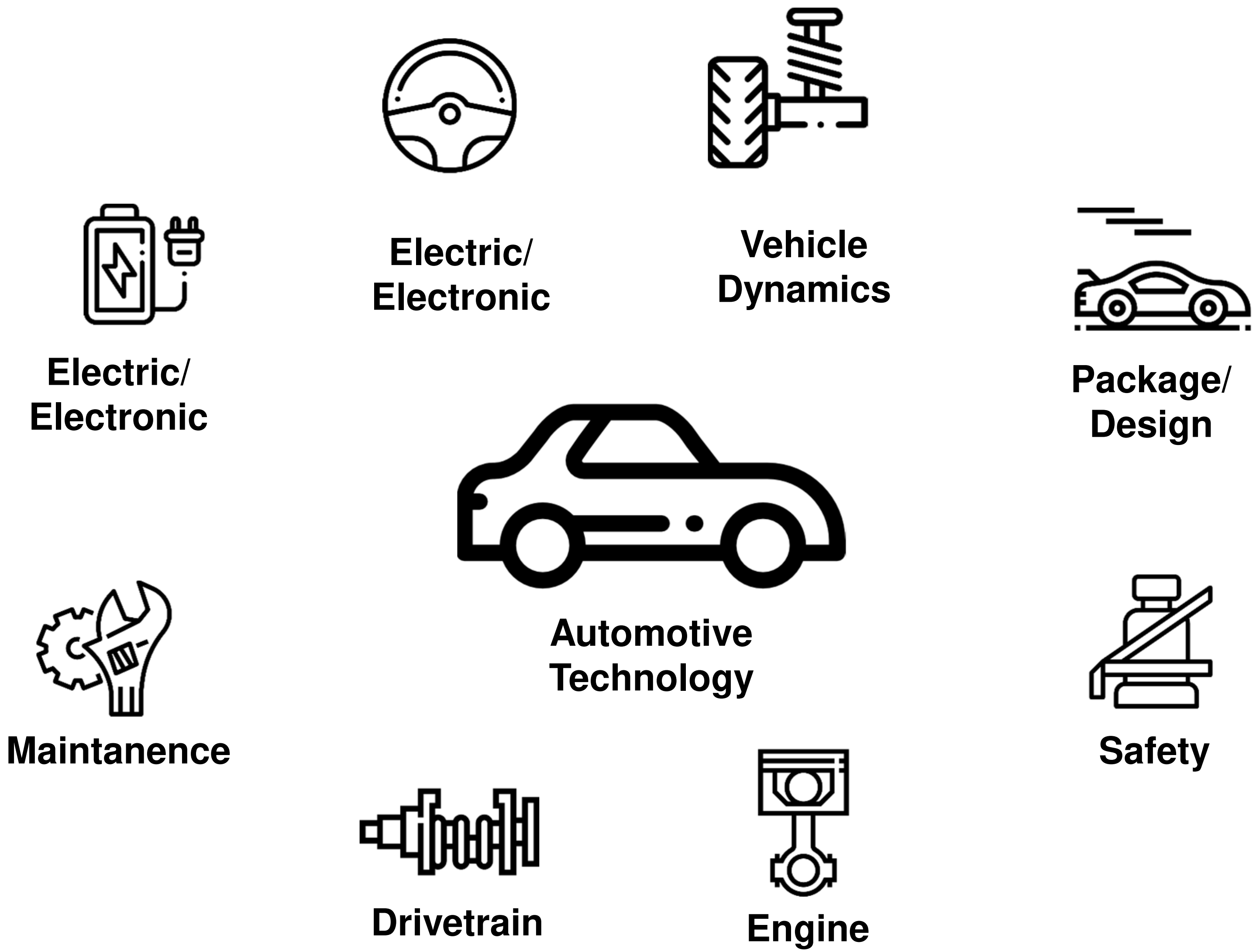
Agenda

1. Chapter: Artificial Intelligence in the Spotlight
2. Chapter: 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





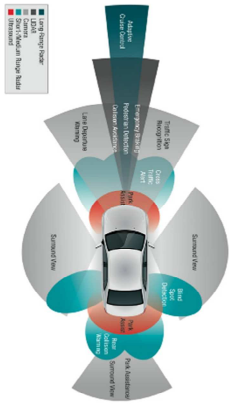
AI Applications – Automotive Technology



AI Applications – Automotive Technology

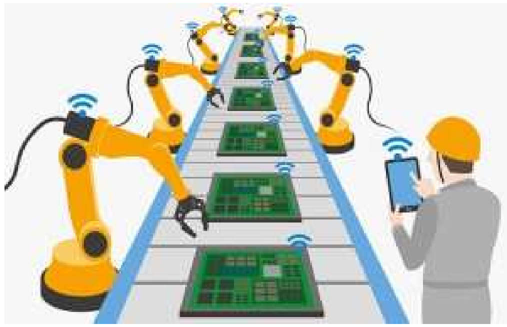
AI can be applied in different sectors regarding automotive technology

Automotive development: Data analysis tool



Vehicle functions: ADAS functions, predictive maintanence

Complete vehicles: Autonomous driving



Automotive production: Production improvement, automatic operations, monitoring

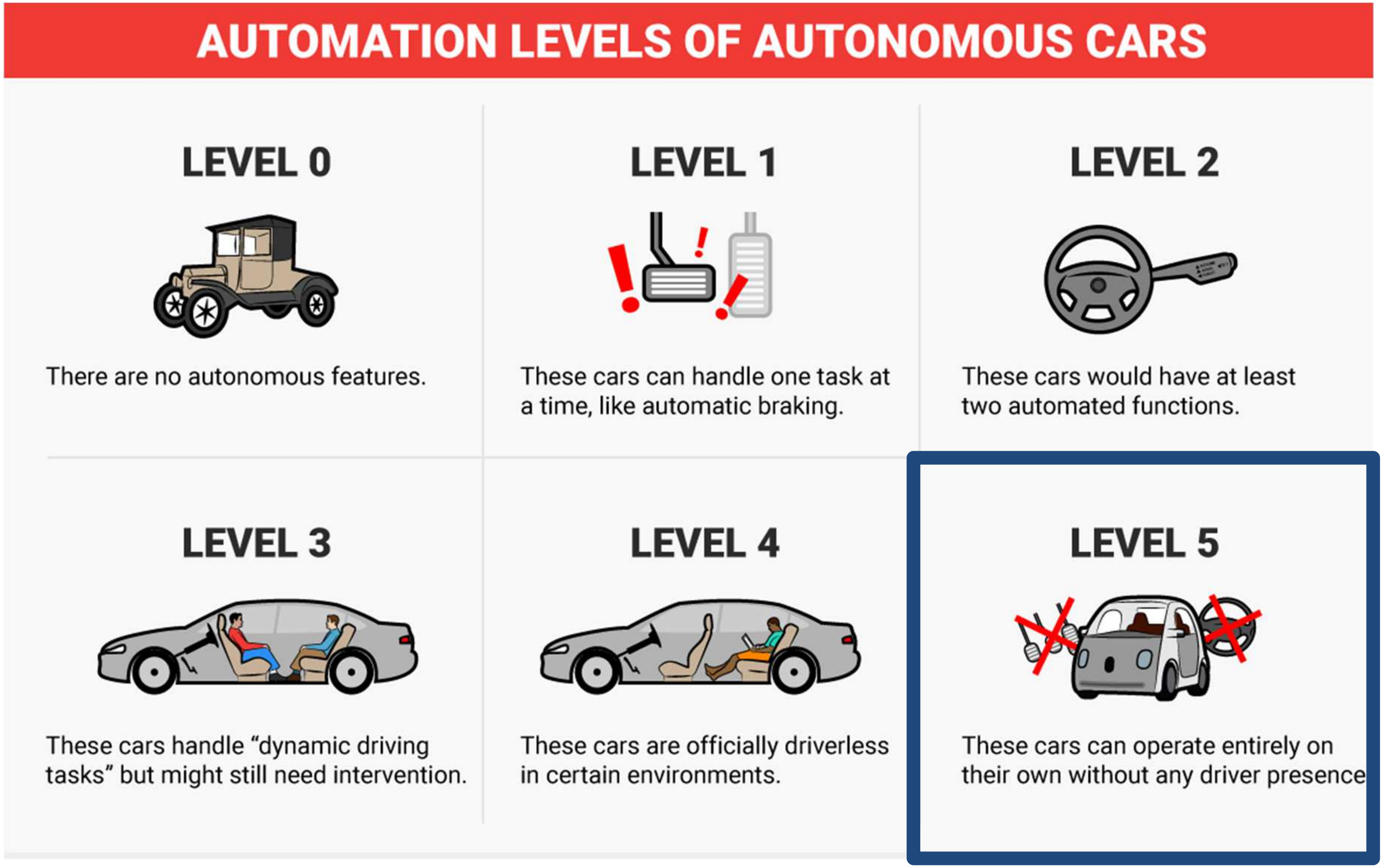
Source: https://www.springboard.com/learning-paths/data-analysis/ / https://medium.com/frontier-tech/the-next-seat-belt-60e980c3ea8b / https://hothardware.com/news/google-stops-publishing-waymo-self-driving-car-accident-reports http://www.bhs-business.com/the-production-process.html

AI Applications – Autonomous Cars

Motivation for autonomous driving:

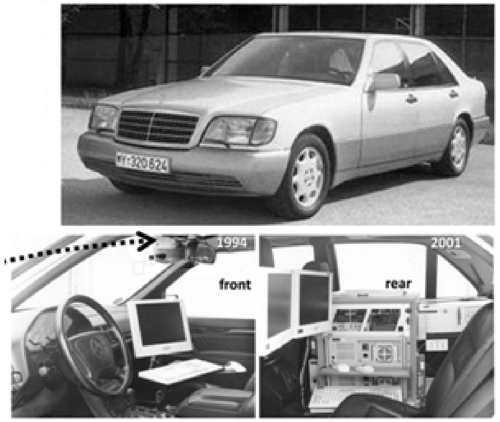
- **Safety improvement:** Over 90 % of all accidents can be attributed to human error
- **Comfort improvement:** People can sleep or work in the vehicle
- **Energy saving:** Perfect planned velocity and trajectory profiles
- **Traffic reduction:** Exchange of information between vehicles and adaptation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

AI Applications – Autonomous Cars



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

2019: Roborace
Autonomous Racing

Additional Slides

Autonomous Driving History

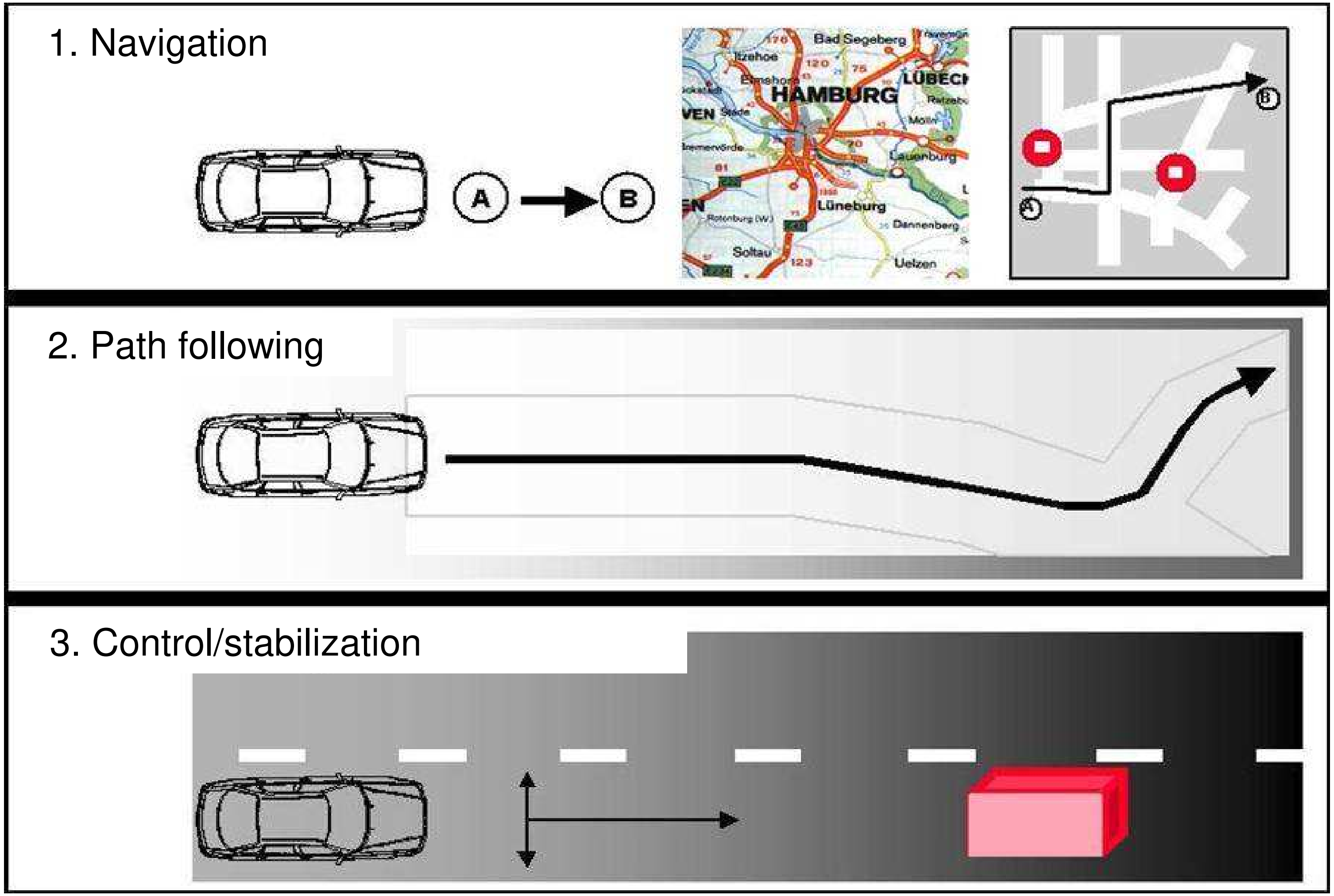
- The DARPA Grand Challenge was held in 2004, 2005 and 2007 as an autonomous driving competition with millions of dollars in prize money.
- The Google driverless car project maintains a test fleet of autonomous vehicles that had driven 300,000 miles (480,000 km) with no machine-caused accidents as of 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

AI Applications – The Primary Driving Task



Time

Hours to minutes

Minutes to seconds

Seconds to miliseconds

Additional Slides

Primary task
Driving task

- Navigation
- Path following
- Control/ftabilization

Secondary task
Machine tasks

- Select gear
- Turn on indicators
- Lights
- Horn
- Wiper
- Change tires

Tertiary Task
Human = transportation

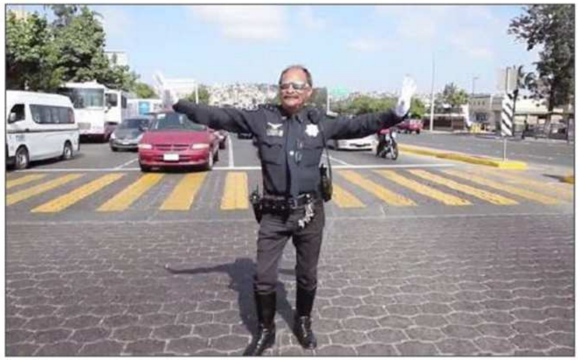
- Safety
- Comfort
- Klima
- Acustic

Tertiary task
Media, EDV user

- Internet
- eMail
- Telephone

Hierarchy

AI Applications – The Primary Driving Task



Problem:

The world is a complex and dynamic place

AI Applications – The Primary Driving Task

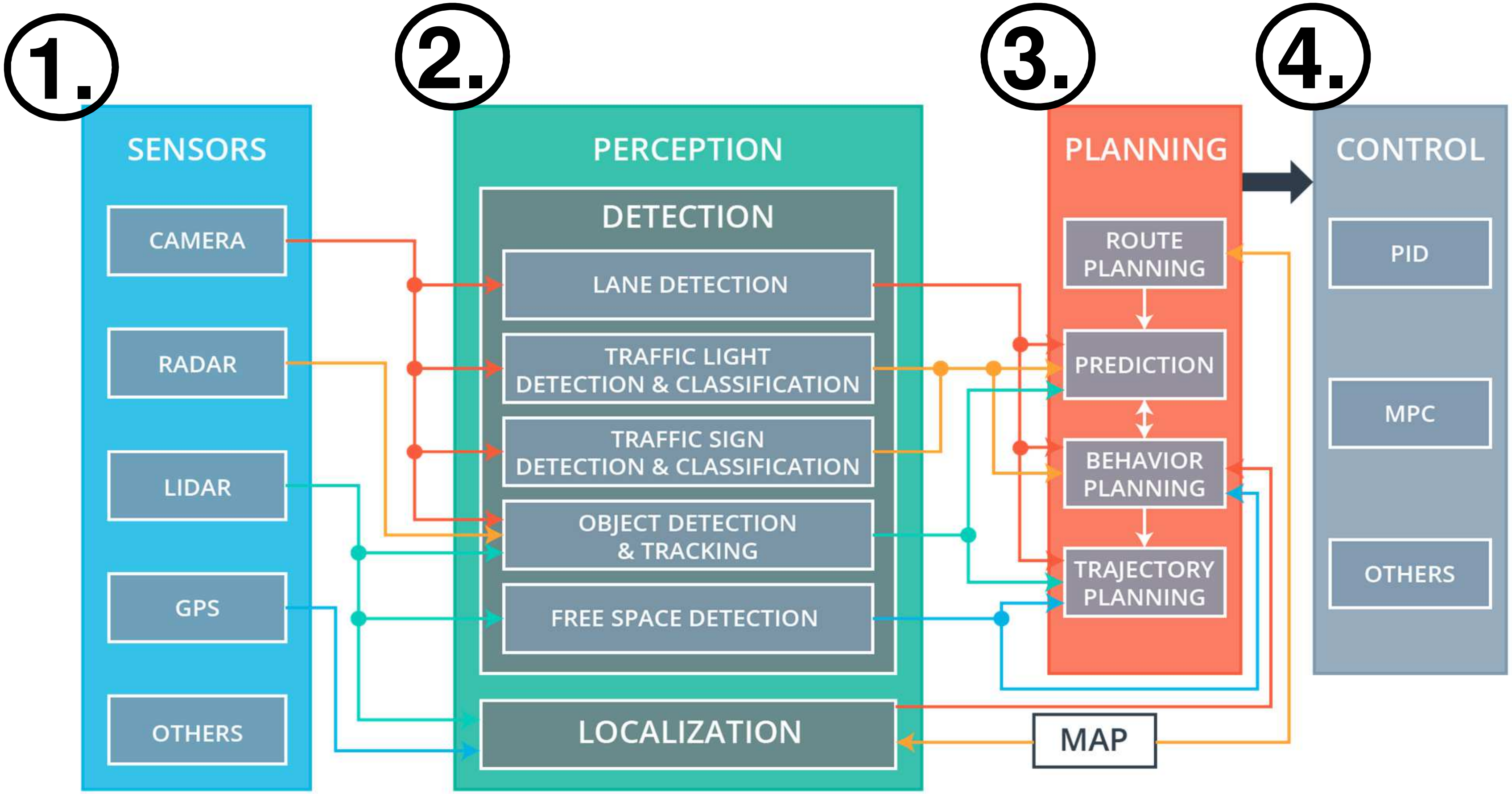
Solution:

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



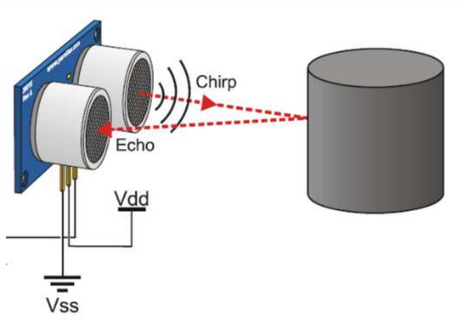
Autonomous level 5 car pipeline

Source: Udacity – Self Driving Nanodegree Programm

AI Applications – Sensors

Radar

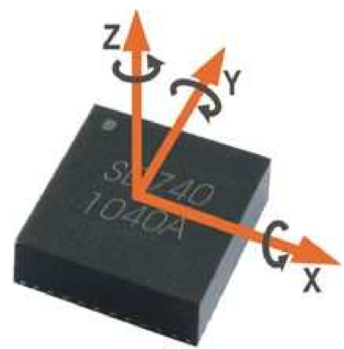
Lidar



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/

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

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

Additional Slides

Lidar: **LI**ght Detection **A**nd **R**anging. A 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.

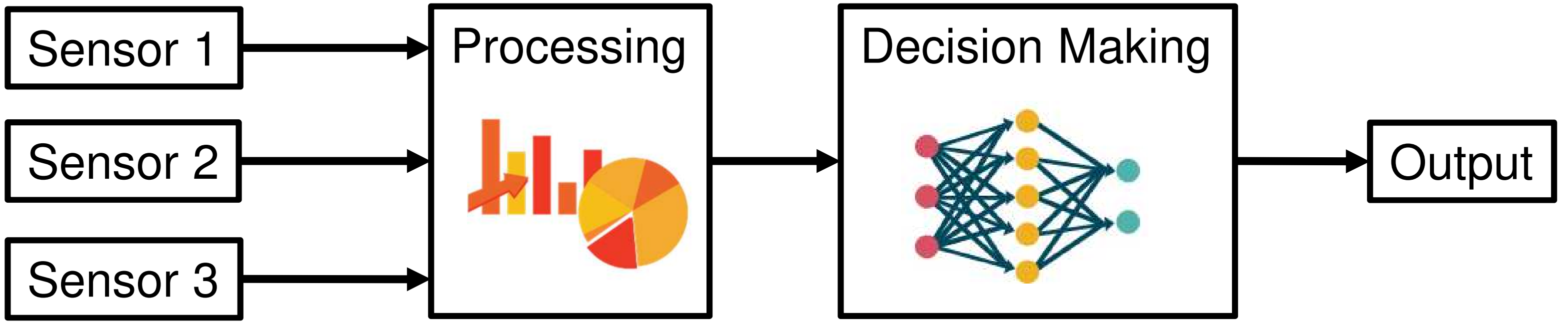
Camera: The recording capabilities of automotive video cameras are based on image sensors (imagers). This is the common name of those digital sensors that can convert an optical image into electronic signals. Currently used imager types are semiconductor based charge-coupled devices (CCD) or active pixel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

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

Additional Slides

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

Additional Slides

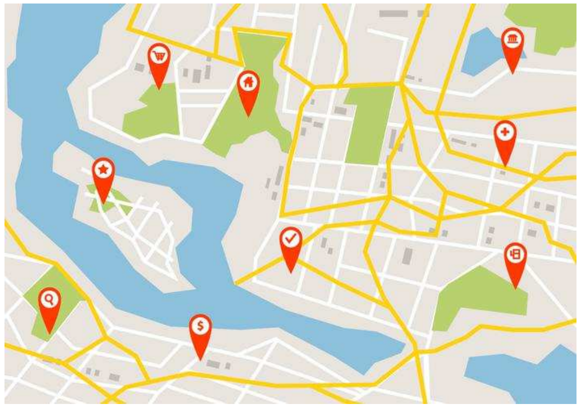
Different sensors have different strengths and weaknesses. Sensor fusion techniques are required to make full use of the advantages of each sensor. In the context of autonomous vehicle environment perception, LIDAR is able to produce 3D measurements and is not affected by the illumination of the environment, but it offers little information on objects' appearances; conversely, a camera is able to provide rich appearance data with much more details on the objects, but its performance is not consistent across different illumination conditions. Furthermore, a camera does not implicitly provide 3D information.

The techniques that have been applied to LIDAR and camera fusion can be roughly divided into two main categories based on their fusion process locations, including fusion at feature level (early stage, centralized fusion) and fusion at decision level (late stage, decentralized fusion). Based on the fusion mechanisms, they can be divided into the following categories: MRF/CRF based, probability based, and deep learning-based.

Source: Pendelton et al. https://www.mdpi.com/2075-1702/5/1/6

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

Additional Slides

Lane line marking detection is to identify the lane line markings on the road and estimate the vehicle pose with respect to the detected lines. This piece of information can serve as vehicle position feedback for vehicle control systems. A vast amount of research work has been done in this domain for several decades. However, it is yet to be completely solved and has remained as a challenging problem due to the wide range of uncertainties in real traffic road conditions and road singularities, which may include shadows from cars and trees, variation of lighting conditions, worn-out lane markings, and other markings such as directional arrows, warning text, and zebra crossings.

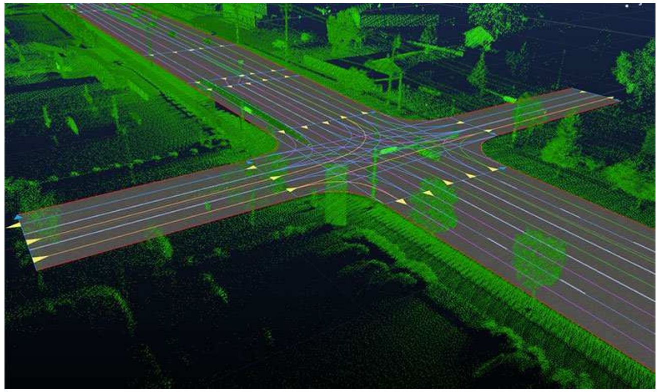
Most of the lane line detection algorithms share three common steps:

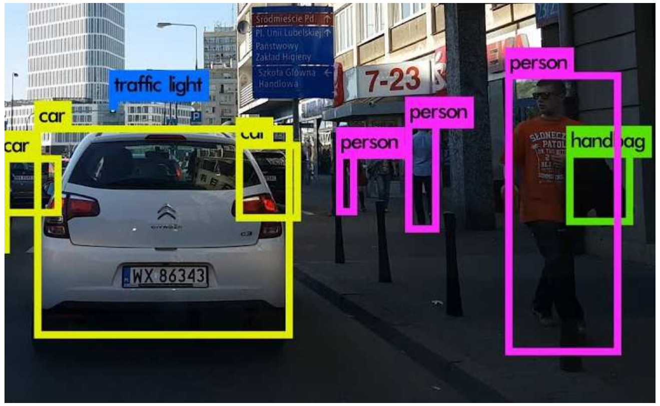
1. Lane line feature extraction, by edge detection and color by learning algorithms such as SVM
2. Fitting the pixels into different models, e.g., straight lines parabolas, hyperbolas and even zigzag line
3. Estimating the vehicle pose based on the fitted model. A fourth time integration step may exist before the vehicle pose estimation in order to impose temporal continuity, where the detection result in the current frame is used to guide the next search through filter mechanisms, such as Kalman filter and particle filter

Source: Pendelton et al. https://www.mdpi.com/2075-1702/5/1/6

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

Additional Slides

On-road object detection mainly concerns vehicle and pedestrian object classes. Due to the various types, appearances, shapes, and sizes of the objects, those methods reviewed in are not robust and not general enough for the application of autonomous vehicles. As listed in the KITTI database, for car, pedestrian, and cyclist detections, all of the leading entries and state of the art methods are based on deep learning schemes. Deep learning has shown its superior performance as compared to conventional learning or feature based approaches in the domain of obstacle detection. Therefore, in this section, we will only review the deep learning based approaches.

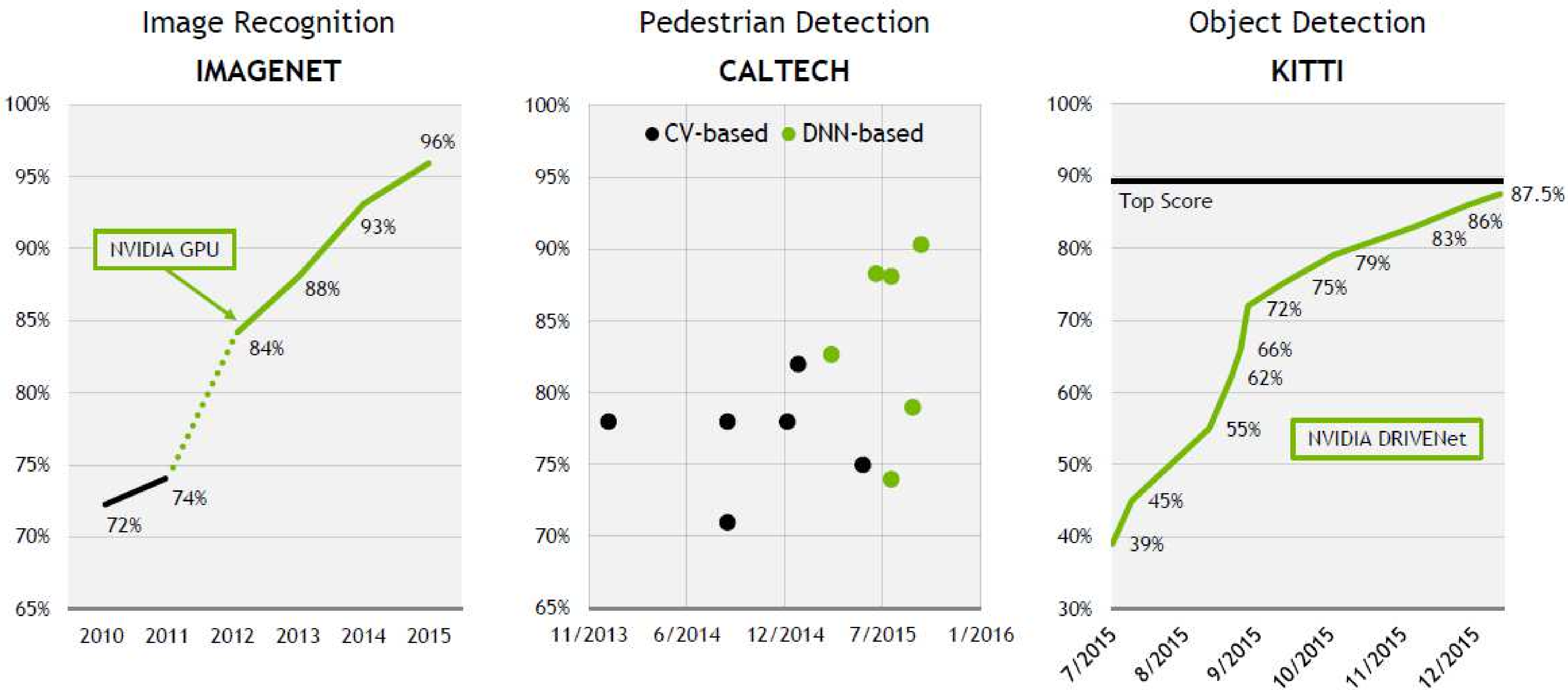
Normally, the general pipeline for deep learning approaches is that a set of proposal bounding boxes needs to be generated around the input image, then each proposal box will be sent through the CNN network to determine a classification (including background) and fine tune its bounding box locations as well. The common methods for bounding box proposal are Selective Search and EdgeBoxes, which both rely on inexpensive hand-crafted features and economical inference schemes.

Faster-RCNN was the first deep learning scheme that unify both the bounding box proposal and detection under the same network and achieved an end-to-end training process. The network consists of two major parts: proposal net and detection net, where these two nets share most of the CNN layers. The output from the proposal net are the proposed bounding boxes, which is used as the input to the detection net for recognition and bounding box fine tuning processes.

Source: Pendelton et al. https://www.mdpi.com/2075-1702/5/1/6

AI Applications – Perception

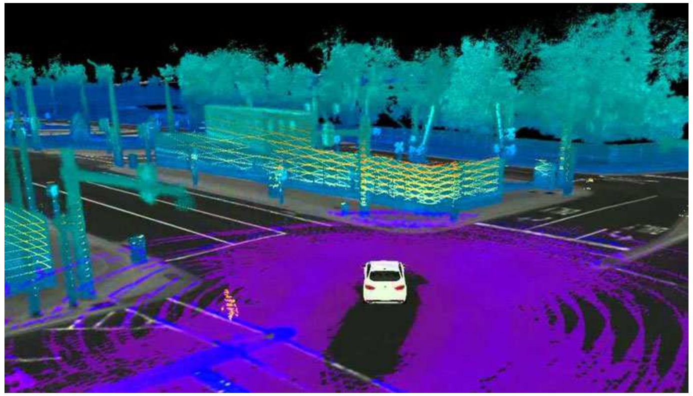
Scene understanding: **Improvement with AI**

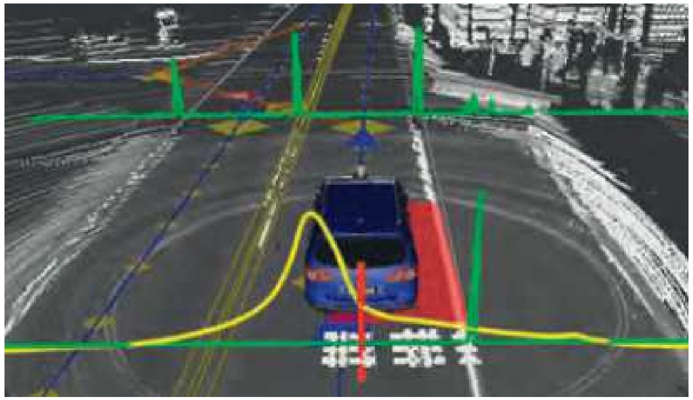


Source: NVIDIA Accelerated Computing Workshop @LRZ

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

Additional Slides

Localization is the problem of determining the pose of the ego vehicle and measuring its own motion. It is one of the fundamental capabilities that enables autonomous driving. However, it is often difficult and impractical to determine the exact pose (position and orientation) of the vehicle, and therefore the localization problem is often formulated as a pose estimation problem.

The problem of estimating the ego vehicle's pose can generally be divided into two sub-problems, namely the **pose fixing problem** and the **dead reckoning problem.** In the pose fixing problem, the measurement is related to the pose by an algebraic/transcendental equation. Pose fixing requires the capacity to predict a measurement given a pose, e.g., a map. In the dead reckoning problem, the state is related to the observation by a set of differential equations, and these equations have to be integrated in order to navigate. In this case, sensor measurements may not necessarily be inferable from a given pose. In this sense, pose fixing and dead reckoning complement each other.

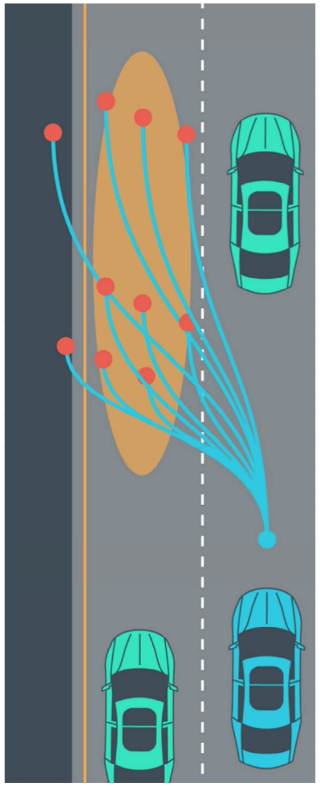
One of the most popular ways of localizing a vehicle is the **fusion of satellite-based navigation systems and inertial navigation systems.** Satellite navigation systems, such as GPS and GLONASS, can provide a regular fix on the global position of the vehicle. Their accuracy can vary from a few of tens of meters to a few millimeters depending on the signal strength, and the quality of the equipment used. Inertial navigation systems, which use accelerometer, gyroscope, and signal processing techniques to estimate the attitude of the vehicle, do not require external infrastructure. However, without the addition of other sensors, the initiation of inertial navigation system can be difficult, and the error grows in unbounded fashion over time.

Map aided localization algorithms use local features to achieve highly precise localization, and have seen tremendous development in recent years. In particular, **Simultaneous Localization and Mapping (SLAM)** has received much attention. The goal of SLAM is to build a map and use it concurrently as it is built. SLAM algorithms leverage old features that have been observed by the robot's sensors to estimate its position in the map and locate new features. Although it is not possible to determine the absolute position, SLAM uses statistical modelling that takes into account the odometry of the vehicle to remove most of the inconsistency between where the features are predicted to be and where it is based on the sensor readings. In general there are two approaches to SLAM problem: Bayesian filtering and smoothing

Source: Pendelton et al. https://www.mdpi.com/2075-1702/5/1/6

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

Additional Slides

Planning the path of a vehicle is part of the Motion planning. This is a very broad field of research, applied to mobile robots and manipulating arms for a wide variety of applications ranging from manufacturing, medical, emergency response, security/surveillance, agriculture and transportation. In the context of mobile robotics, motion planning refers to the process of deciding on a sequence of actions to reach a specified goal, typically while avoiding collisions with obstacles. Motion planners are commonly compared and evaluated based on their computational efficiency and completeness. Computational efficiency refers to the process run time and how this scales based on the dimensionality of the configuration space. The algorithm is considered complete if it terminates in finite time, always returns a solution when one exists, and indicates that no solution exists otherwise.

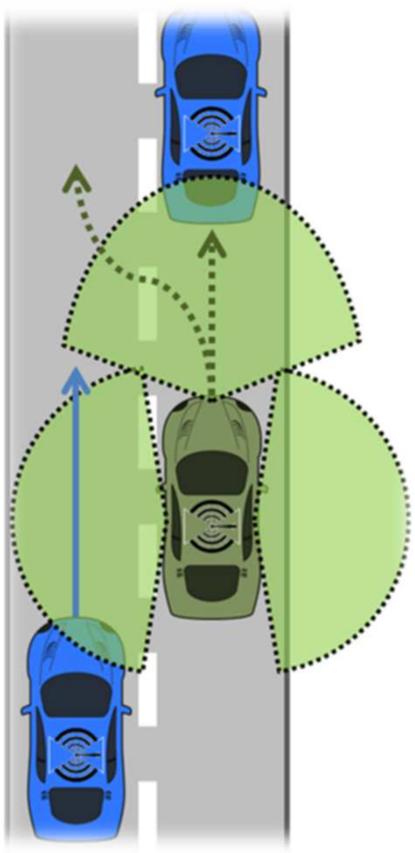
Many operating environments are not static, and are therefore not known a priori. In an urban environment, the traffic moves, road detours and closures occur for construction or accident cleanup, and views are frequently obstructed. The robot must constantly perceive new changes in the environment and be able to react while accounting for several uncertainties. Uncertainties arise from perception sensor accuracy, localization accuracy, environment changes, and control policy execution. However, in application, perhaps the largest source of uncertainty is the uncertainty in surrounding obstacles' movements.

To better account for obstacle movement, it is necessary to include time as a dimension in the configuration space, which increases the problem complexity. Furthermore, while instantaneous position and velocity of obstacles may be perceived, it is yet difficult to ascertain future obstacle trajectories. Prior approaches have aimed to use simple assumptions, such as constant velocity trajectory, in predicting obstacle movement, with errors accounted for by rapid iterative re-planning. Other more conservative approaches have aimed to account for variations in obstacle trajectory by bounding larger obstacle-occupied sub-spaces within the configuration space, within which samples are rejected by the planner. Rather than check for collisions directly in the robot's configuration space, another popular approach is to directly plan in the control space by prohibiting certain control actions which are predicted to lead to collision. For example, the velocity obstacles method assumes that obstacles will maintain their observed trajectories and forbids a robot from choosing relative velocities that would lead to collision with the obstacle's current trajectory. This was generally applied to circular, holonomic robots, but due to the ease of computation it has gained popularity in multi-robot planning, with proposed Reciprocal Velocity Obstacles. Recent extensions to the velocity obstacles method have further incorporated acceleration constraints, and adjustments for nonholonomic robots.

Source: Pendelton et al. https://www.mdpi.com/2075-1702/5/1/6

AI Applications – Planning

Behavioral planning of own vehicle: **What should i do?**



Input information:

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

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

Additional Slides

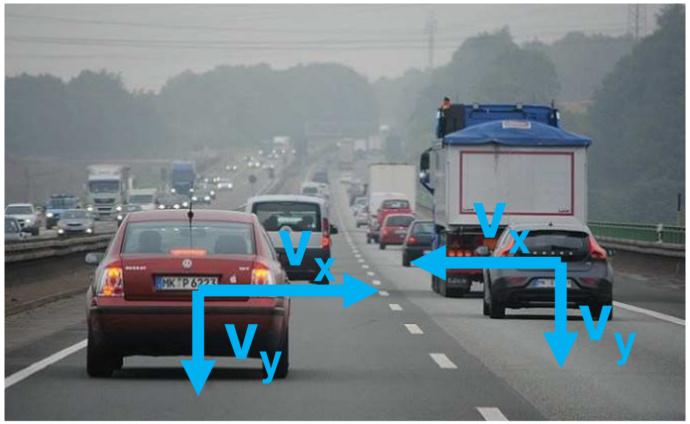
The **behavioral planner** is responsible for decision making to ensure the vehicle follows any stipulated road rules and interacts with other agents in a conventional, safe manner while making incremental progress along the mission planner's prescribed route. This may be realized through a combination of local goal setting, virtual obstacle placement, adjustment of drivable region bounds, and/or regional heuristic cost adjustment. Decisions were made onboard most DUC vehicles through Finite State Machines (FSMs) of varying complexity to dictate actions in response to specific perceived driving contexts. The terms precedence observer and clearance observer were coined to categorize functions which checked certain logical conditions required for state transitions, where precedence observers were to check whether the rules pertaining to the vehicle's current location would allow for it to progress, and clearance observers would check "time to collision"—the shortest time by which a detected obstacle would enter a designated region of interest—to ensure safe clearance to other traffic participants. For example, when approaching a stop sign, the SDV would have to both ensure precedence by coming to a complete stop at the stop line and wait for any other stationary vehicles at the intersection with priority to move off, and ensure clearance by measuring time to collision along its intended path (where oncoming traffic may not have to stop at the intersection).

Finite state machines of this nature are limited in that they are manually designed for a set number of specific situations. The vehicle may then perform unexpectedly in a situation that was not explicitly accounted for in the FSM structure, perhaps finding itself in a livelock, or even a deadlock state if there aren't sufficient deadlock protections. Recent research works have sought to improve organization in large decision making structures to thus manage larger rules sets. Other works have sought provable assurances in the decision making structure to guarantee adherence to rules sets. In road rules enforcement was checked using Linear-Temporal Logic (LTL) considerations, with successful real-world overtaking experiments.

Source: Pendelton et al. https://www.mdpi.com/2075-1702/5/1/6

AI Applications – Planning

Prediction of behavior of objects around the car: **What are the objects around me going to do?**



Input information:

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

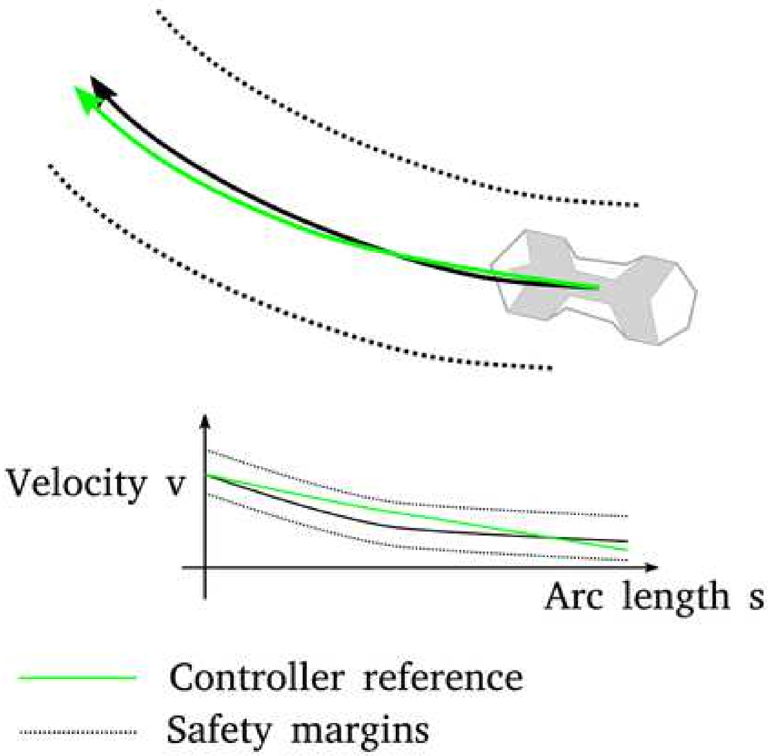
AI method:

- Sensor fusion
- Computer vision
- Search
- Uncertainty 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: **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

Additional Slides

The execution competency of an autonomous system, also often referred to as **motion control**, is the process of converting intentions into actions; its main purpose is to **execute the planned intentions** by providing necessary inputs to the hardware level that will generate the desired motions. Controllers map the interaction in the real world in terms of forces, and energy, while the cognitive navigation and planning algorithms in an autonomous system are usually concerned with the velocity and position of the vehicle with respect to its environment. Measurements inside the control system can be used to determine how well the system is behaving, and therefore the controller can **react to reject disturbances and alter the dynamics of the system to the desired state**. Models of the system can be used to describe the desired motion in greater detail, which is essential for satisfactory motion execution.

Classic Control:

Feedback control is the most common controller structure found in many applications. Feedback control uses the measured system response and actively compensates for any deviations from the desired behavior. Feedback control can reduce the negative effects of parameter changes, modelling errors, as well as unwanted disturbances. Feedback control can also modify the transient behavior of a system, as well as the effects of measurement noise. The most common form of classical feedback control is the proportional-integral-derivative (PID) controller. The PID controller is the most widely used controller in the process control industry. The concept of PID control is relatively simple. It requires no system model, and the control law is based on the error signal.

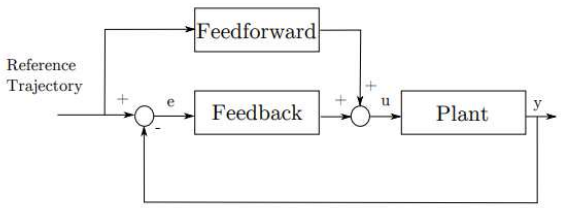


Figure 5. Two Degree of Freedom Controller.

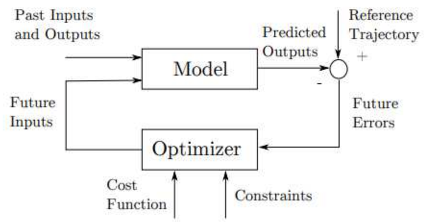


Figure 6. Basic Structure of Model Predictive Control.

Model Predictive Control:

Autonomous systems need motion models for planning and prediction purposes. Models can also be used in control execution. A control approach which uses system modelling to optimize over a forward time horizon is commonly referred to in the literature as model predictive control (MPC). The basic structure of MPC is shown in Figure 6. Model predictive control has been developed to integrate the performance of optimal control and the robustness of robust control. Typically the prediction is performed for a short time horizon called the prediction horizon, where the goal of the model predictive controller is to compute the optimal solution over this prediction horizon. The model, and thus the controller can be changed online to adapt to different conditions

Source: Pendelton et al. https://www.mdpi.com/2075-1702/5/1/6

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%

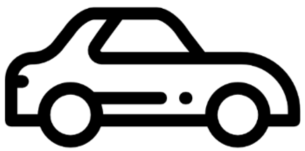
Source: https://www.dmv.ca.gov/portal/wcm/connect/42aff875-7ab1-4115-a72a-97f6f24b23cc/Waymofull.pdf?MOD=AJPERES&CVID=
http://www.eugenewei.com/blog/2014/10/13/moravecs-paradox-and-self-driving-cars

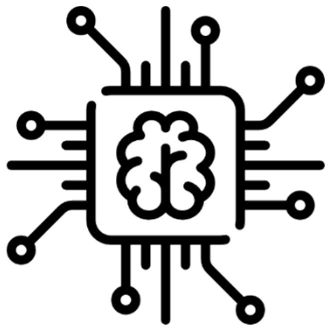
Introduction: Artificial Intelligence
Johannes Betz / Prof. Dr. Markus Lienkamp / Prof. Dr. Boris Lohmann

(Johannes Betz, M. Sc.)

Agenda

1. Chapter: Artificial Intelligence in the Spotlight
2. Chapter: 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.