



Source: <https://blenderartists.org/forum/showthread.php?316399-Industrial-Robots>

Robotics for Future Industrial Applications

Introduction to Industrial Robots & Challenges

Philipp Ennen, M.Sc.

Content

- I. Organizational
- II. Introduction
 - I. Rise of Robotics and AI
 - II. Smart Robots for the Manufacturing Industry
- III. Artificial Intelligence in Robotics
 - I. Definition
 - II. Approaches for AI in Robotics

Your Lecturers



Philipp Ennen, M.Sc.
PhD Candidate
„Robot Learning for Contact-Rich Assembly Tasks“



Haoming Zhang, M.Sc.
PhD Candidate
„Optimal Control, Machine Learning“

Organizational

Time	Sunday 13 th August	Monday 14 th August	Tuesday 15 th August	Wednesday 16 th August	Thursday 17 th August	Friday 18 th August	Saturday 19 th August
9:00-9:30							
9:30-10:00							
10:00-10:30		Introduction to Industrial Robots & Challenges	Fundamentals of Robot Learning and Control Theory				
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14:30-15:00	Free Time for Excursions, Sight-Seeing and Self-Study		Programming using Python				
15:00-15:30		Practical Unit: Introduction to Linux and Robot Operating System					
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18:00-18:30							
18:30-19:00							
19:00-19:30							
19:30-20:00							
20:00-20:30							
20:30-21:00							
21:00-21:30			OPTIONAL International Tuesday with the INCAS Student Organisation				
21:30-22:00						„Karaoke Night“ with the Summer School Team and your Buddies	

Organizational

Website and Wifi

- Website for this week: <https://goo.gl/X5twgi>

Home

Summerschool 2017: Intelligent Motion Planning

We (Haoming and Philipp) are glad to be organizing a seminar on intelligent motion planning for industrial robots. This seminar will be held in week two of the summer school "Robotics for Future Industrial Applications" at the Cybernetics Lab of the RWTH Aachen University (14. august - 18. august). This page will provide you with lecture materials and introductions for the practicals. If you have any further questions, feel free to contact us via email.

Contact details of Haoming and Philipp



Day 1: Introduction

Lecture: Introduction to Industrial Robots and Challenges

- Wifi-Access:
 - SSID: ariz
 - Password: ariz_ab12345!

Content

I. Organizational

II. Introduction

- I. Rise of Robotics and AI
- II. Smart Robots for the Manufacturing Industry

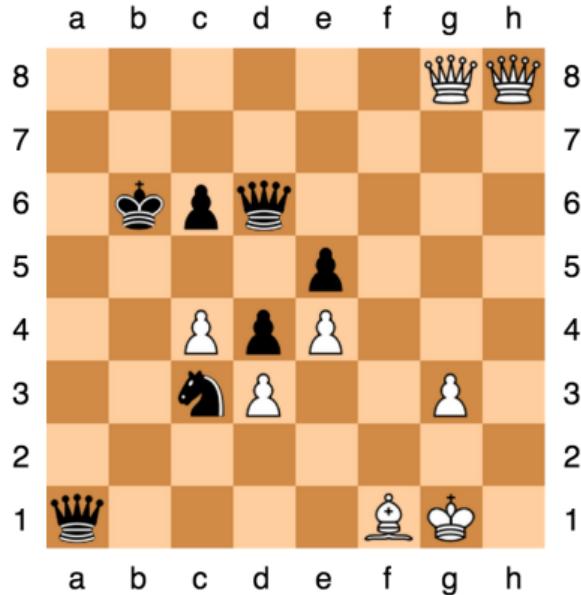
III. Artificial Intelligence in Robotics

- I. Definition
- II. Approaches for AI in Robotics

Introduction

„In robotics, the easy problems are hard and the hard problems are easy“

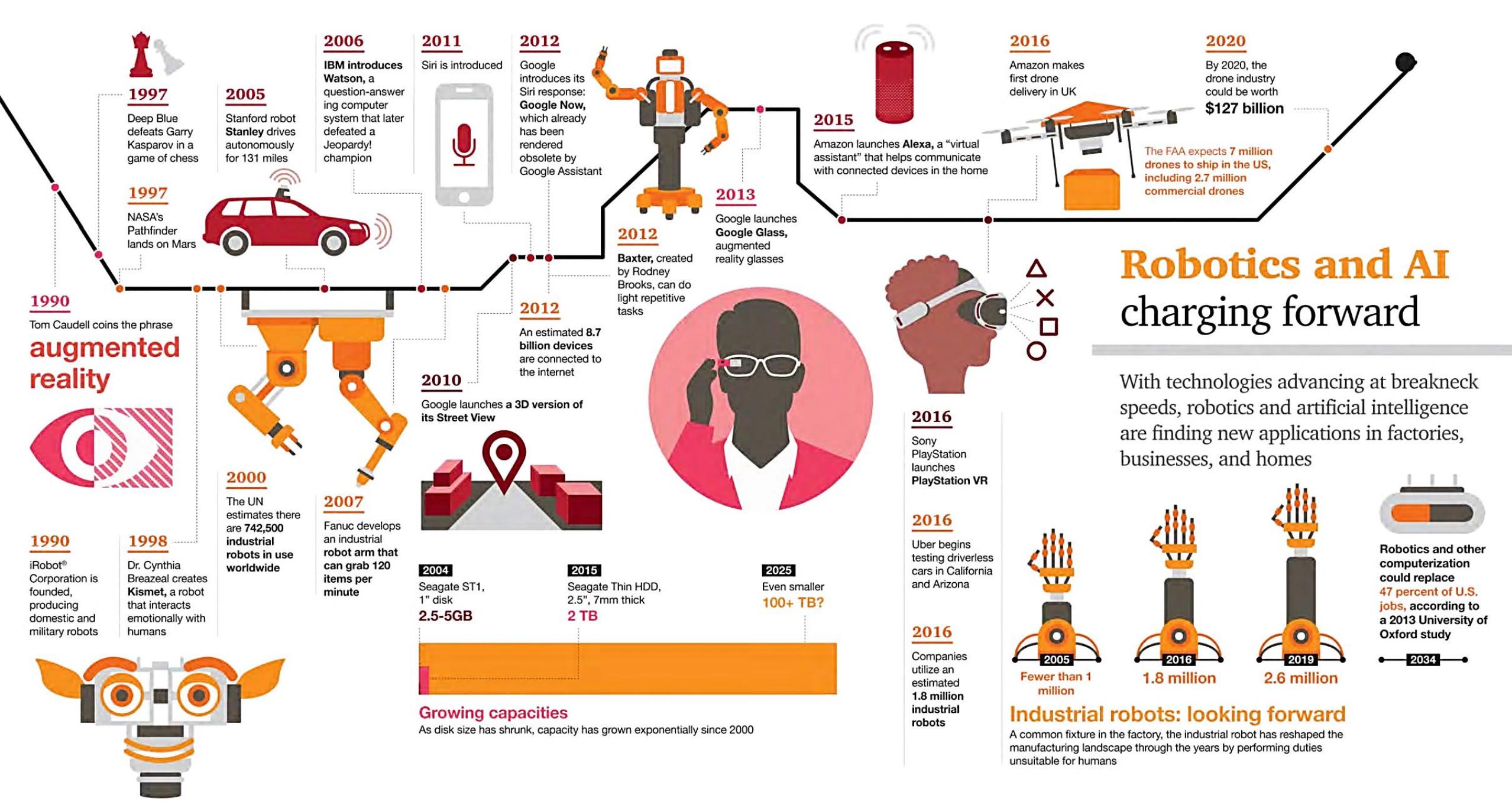
S. Pinker. The Language Instinct. New York: Harper Perennial Modern Classics, 1994

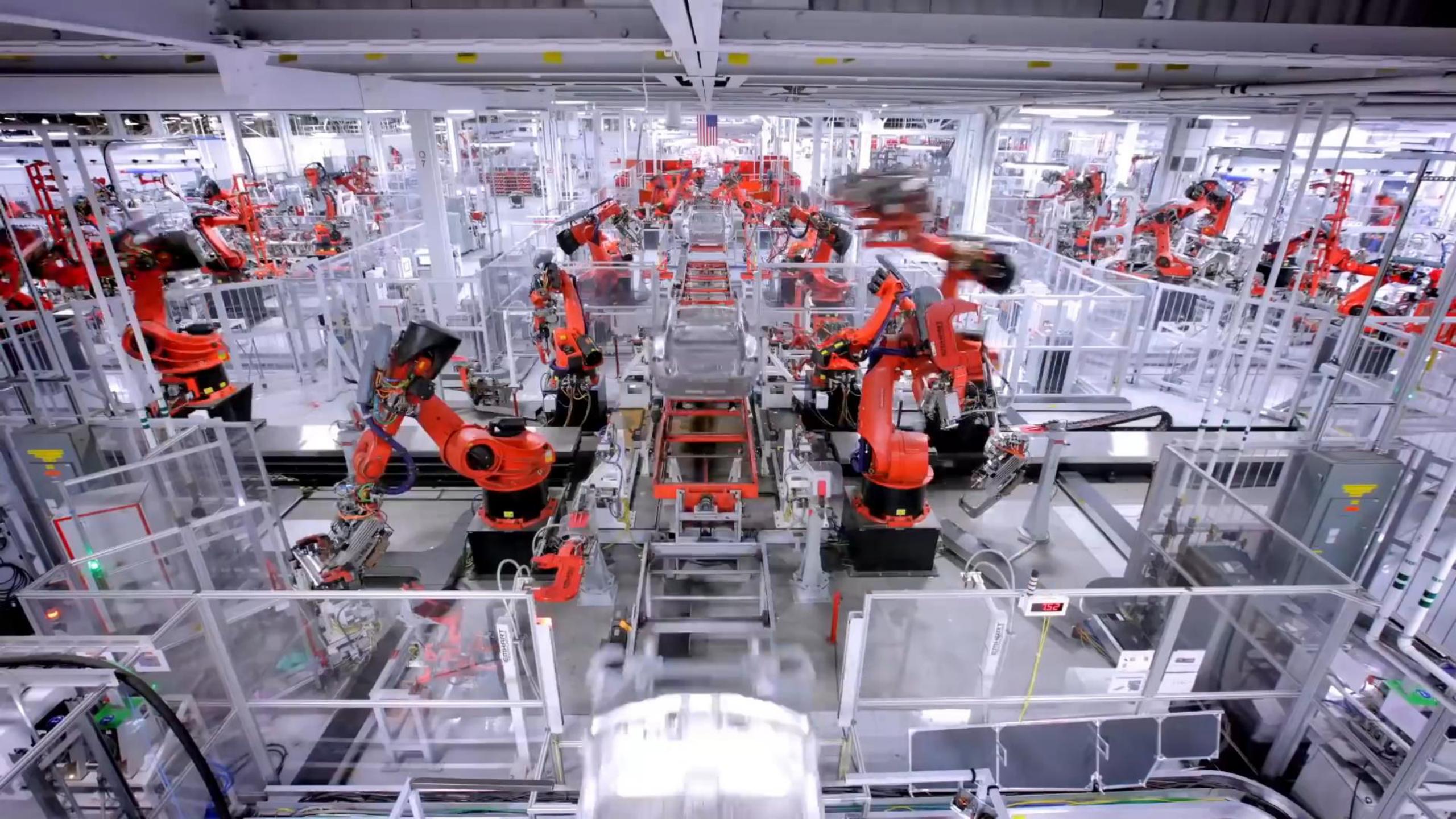


Building a computer that defeats
Chess World Champion Gari
Kasparow: **Easy**



Build a robot with "healthy human
understanding" (i.e. motor skills):
Difficult



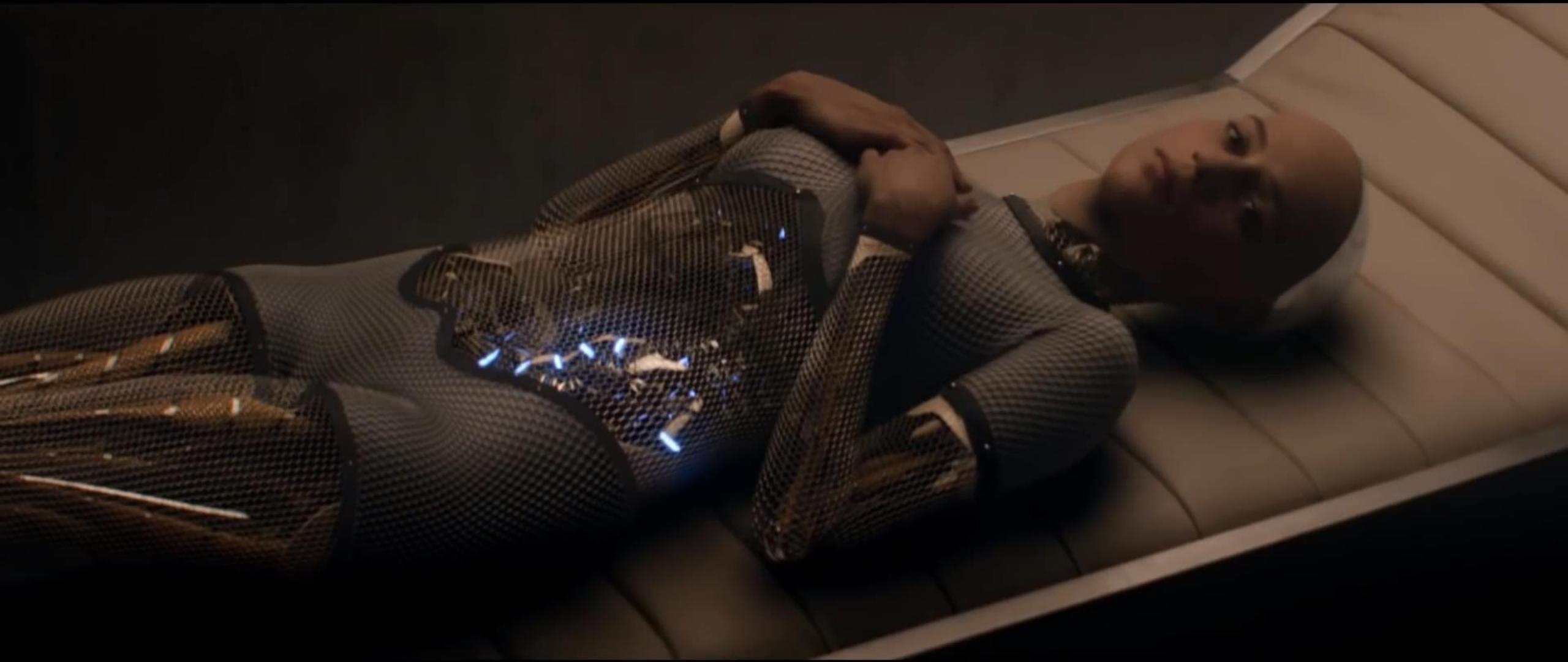


Traditional Industrial Robots

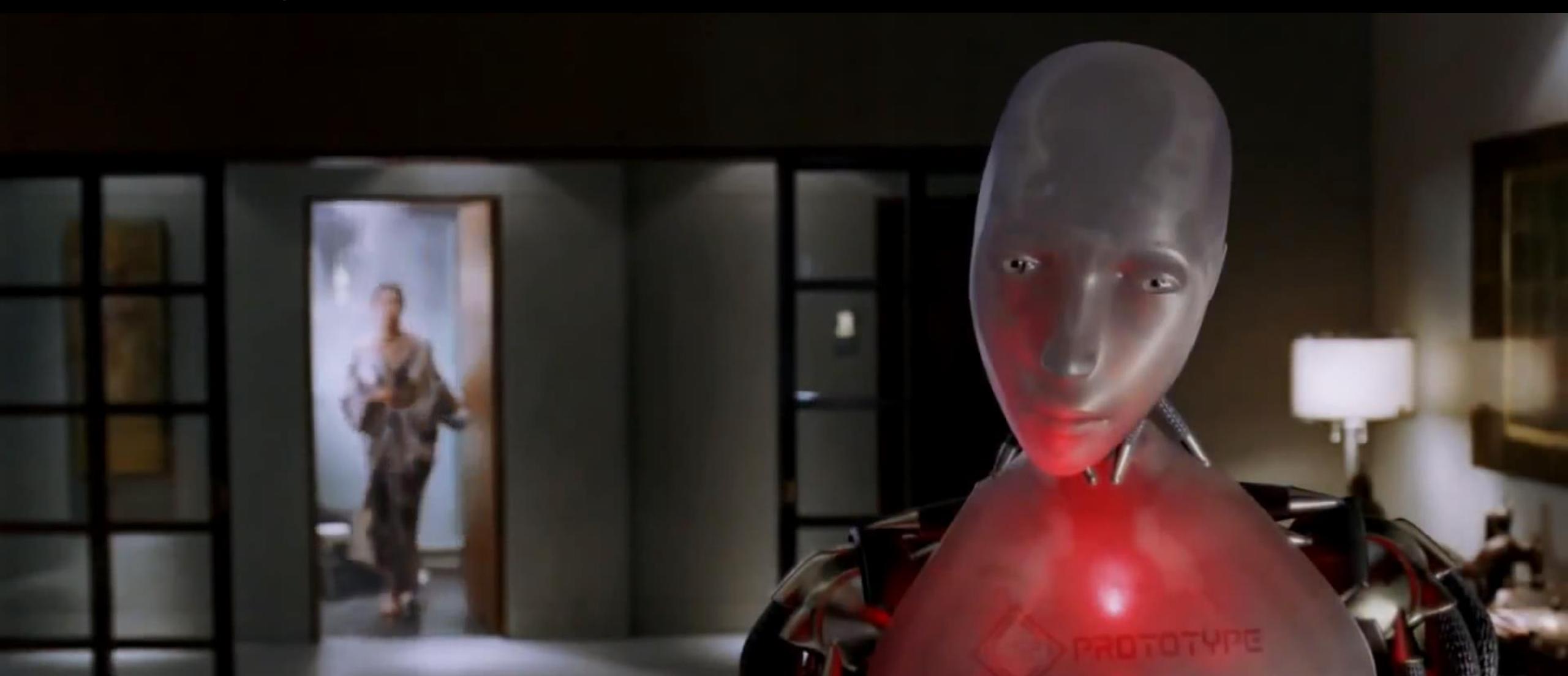
- ... high precision and velocity
- ... high programming effort (through experts)
- ... inflexible
- ... stationary
- ... high driven potential, protection fences necessary
- ... high integration/commissioning effort
- ... only isolated sensor integration, no environment detection



What do we really want?



What do we really want?



Introduction

Robots getting smart!



- Adaptability
- Motion Ability

Introduction

Robots getting smart!



- **Adaptability**
- Motion Ability

Adaptability for Industrial Robots

- Robot reacts to changes in the operating environment
- Auto-Configuration strategies
 - Self-Learning strategies

Introduction

Robots getting smart!



- Adaptability
- **Motion Ability**

Motion Ability for Industrial Robots

- Kinematics/Dynamics for advanced reconfigurable work cells
- Positioning
 - Navigation

Introduction

Robots getting smart!



- Adaptability
- Motion Ability
- **Interaction Ability**

Interaction Ability for Industrial Robots

Interaction with Operators, Robots and other Systems

- Interaction must be safe
- Interaction must be intuitive
- Interaction must be appropriate

Introduction

Robots getting smart!



- Adaptability
- Motion Ability
- Interaction Ability
- Manipulation Ability

Manipulation Ability for Industrial Robots

Handle material objects and tools

- Adaptability
- Robustness
- Accuracy
- Repeatability

Introduction

Robots getting smart!



- Adaptability
- Motion Ability
- Interaction Ability
- Manipulation Ability
- Perception Ability
- Cognitive Abilities
- Decisional Autonomy

Perception Ability for Industrial Robots

Environment Sensing

- Choice of Sensing Modality
- Efficient Signal and Data Analysis
- Generating Maximum Information Output from the Data
- Guaranteed Safe Perception

Introduction

Robots getting smart!



- Adaptability
- Motion Ability

- Interaction Ability

- Manipulation Ability

- Perception Ability
- **Cognitive Abilities**
- Decisional Autonomy

Cognitive Abilities for Industrial Robots

“In the context of manufacturing, the **greatest potential** is for functions that contribute to a **reduction of programming and configuration requirements** in deployed systems. There are clear benefits for small lot size systems in reducing the time and skill needed to reconfigure and adapt systems to new processes.”

Introduction

Robots getting smart!



- Adaptability
- Motion Ability
- Interaction Ability
- Manipulation Ability
- Perception Ability
- Cognitive Abilities
- **Decisional Autonomy**

Decisional Autonomy for Industrial Robots

Increase level of responsibility in the control process

- Reducing energy consumption
- Increasing throughput
- Providing Context Aware Task Control

Introduction

Robots getting smart!



- Adaptability
- Motion Ability

- Interaction Ability

- Manipulation Ability

- Perception Ability
- Cognitive Abilities
- Decisional Autonomy

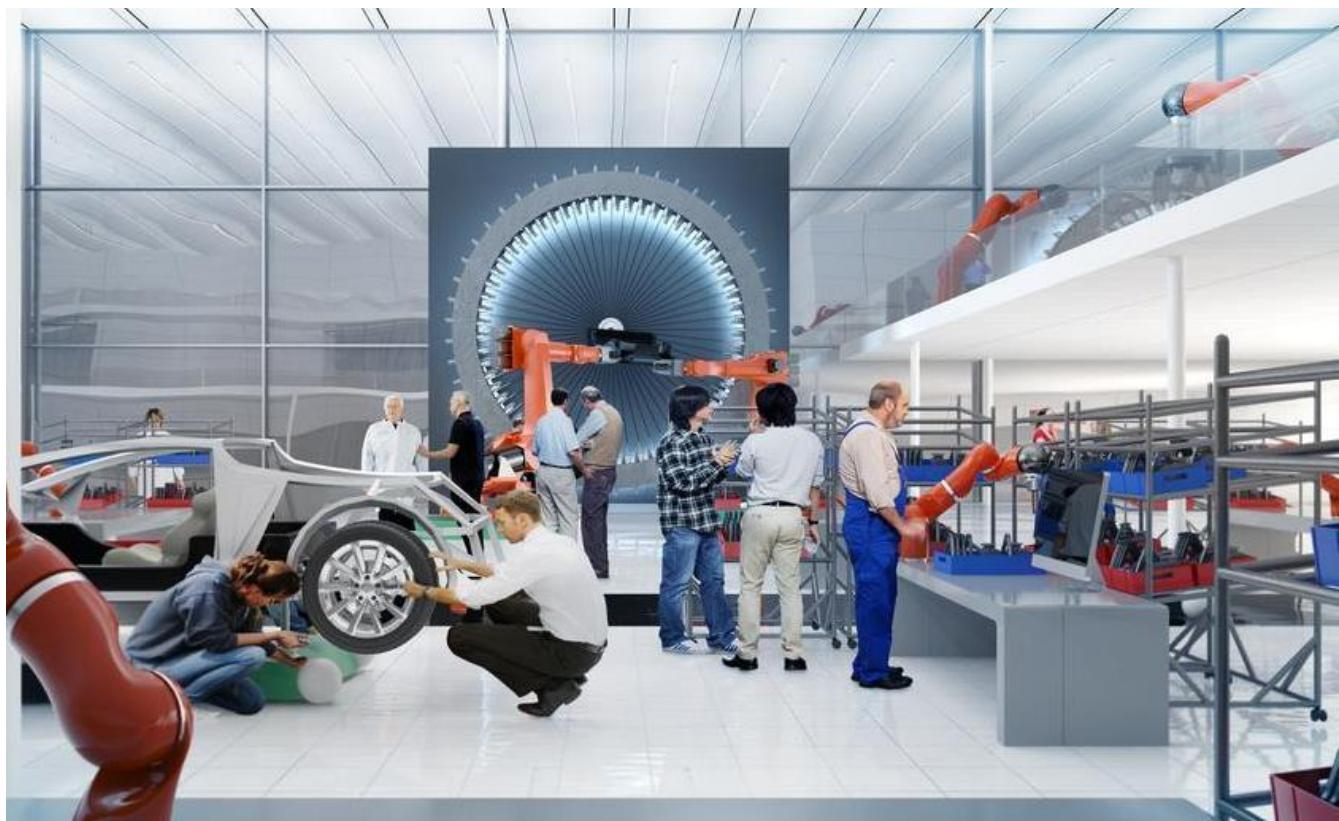


What will be the impact of
smart robots in the
manufacturing industry?

Introduction

Industrial Robots of the Future

- ... work together with humans
- ... do not pose a risk to humans
- ... interact intuitively with humans (multimodal)
- ... are easy to program
- ... possess a wide range of sensory abilities
- ... are flexible to use
- ... have a high degree of autonomy



This week topic

How can we implement
intelligence in industrials
robots?

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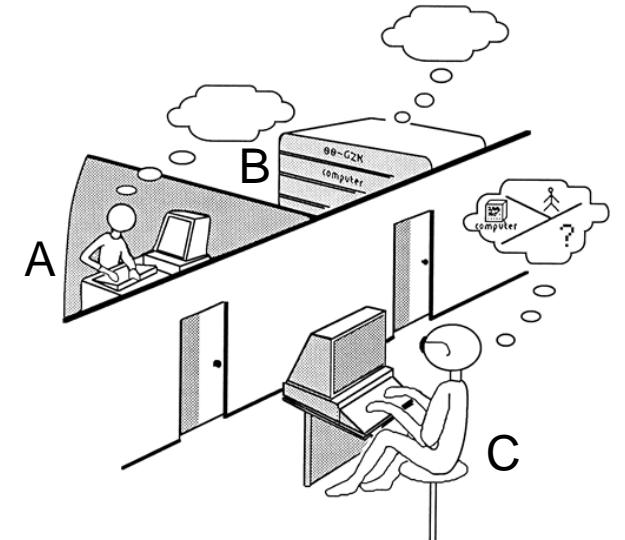
Introduction

What is Artificial Intelligence?

“Instead of trying to produce a programme to simulate the adult mind, why not rather try to produce one which simulates the child's? If this were then subjected to an appropriate course of education one would obtain the adult brain.”, Alan Turing

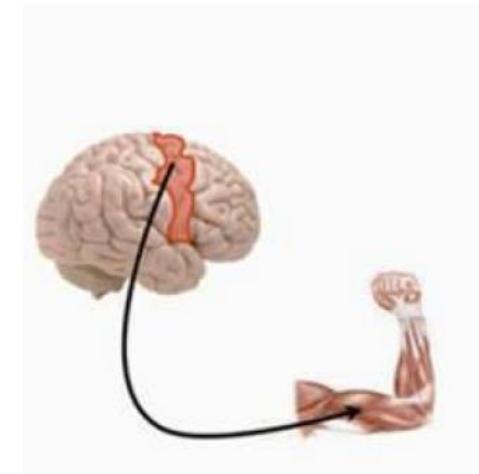
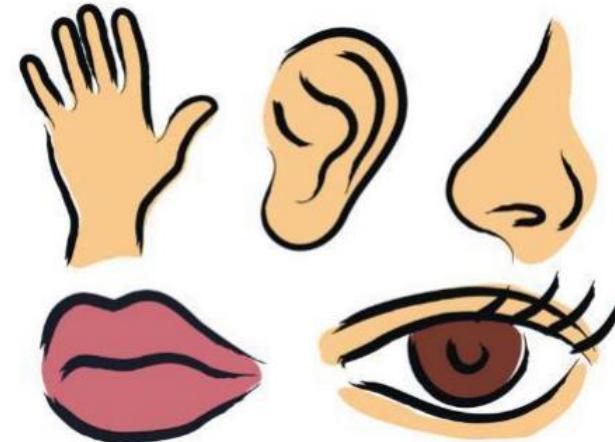


- The (simplified) **Turing Test** proves the existence of an AI
 - Human C talks with A and B
 - A and B try to convince that both are intelligent humans
 - If human C is not able to find out if A or B is a human, the Turing-Test is passed



What do we need for an intelligent machine?

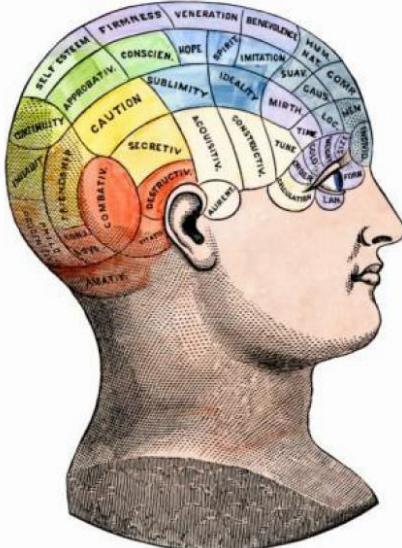
- Need for interpreting heterogeneous sensor values
 - (What does interpreting mean?)
- Need for choosing and acting complex actions



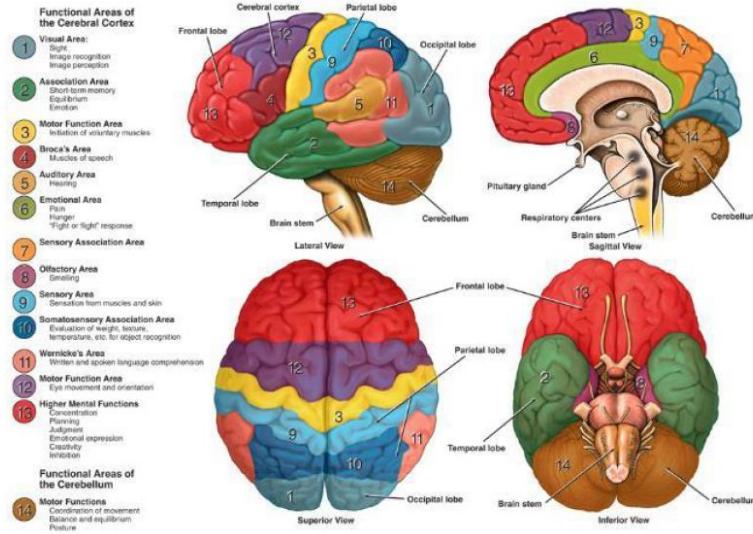
Introduction

How would you start to build an intelligent machine?

"We have a brain for one reason and one reason only: to produce adaptable and complex movements", Daniel Wolpert TED 2011 (Neuro-Scientist)



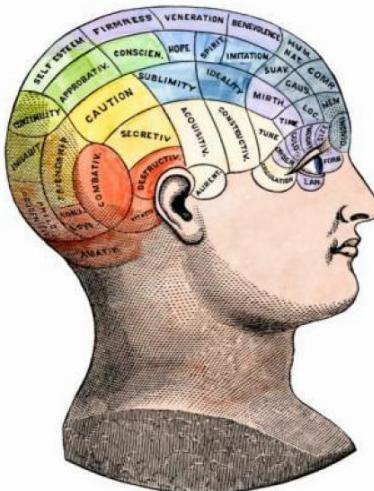
Anatomy and Functional Areas of the Brain



Introduction

How would you start to build an intelligent machine?

An algorithm for each component in the brain?



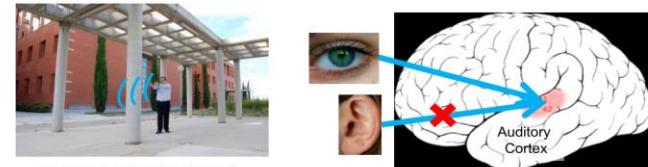
Standard technology



A single flexible algorithm?



Seeing with your tongue

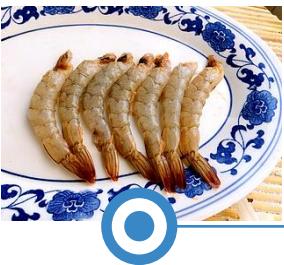


[BrainPort; Martinez et al; Roe et al.]
adapted from A. Ng



End-to-End Learning
(z.B. Deep Learning)

Standard Cooking vs End-to-End Cooking



Standard

Robots as an Example for Intelligent Machines

The central questions of robotics

What is it all about?

MOTION

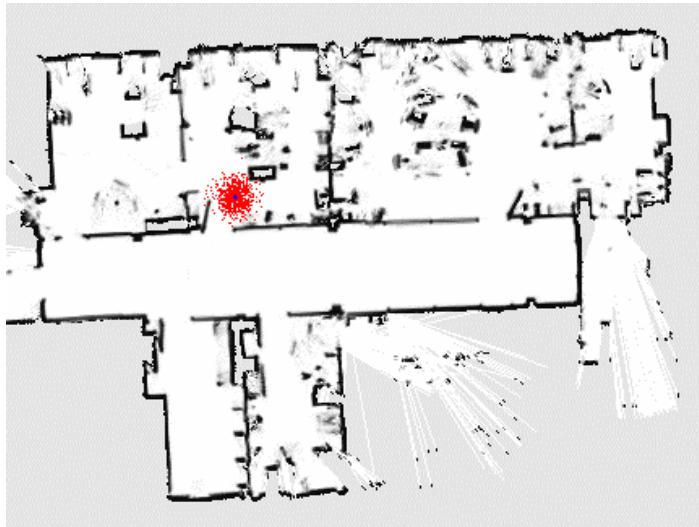


Robots as an Example for Intelligent Machines

The central questions of robotics

Three main question:

Where am I?



- Easy in Industrial Robotics
- Hard in Mobile Robotics

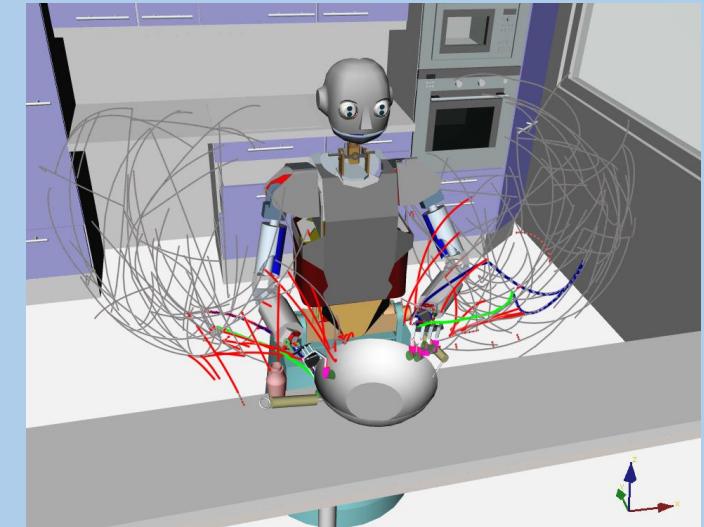
Where should I go?



- Often hand-engineered
- Or a Result of Task Planning

This weeks focus!

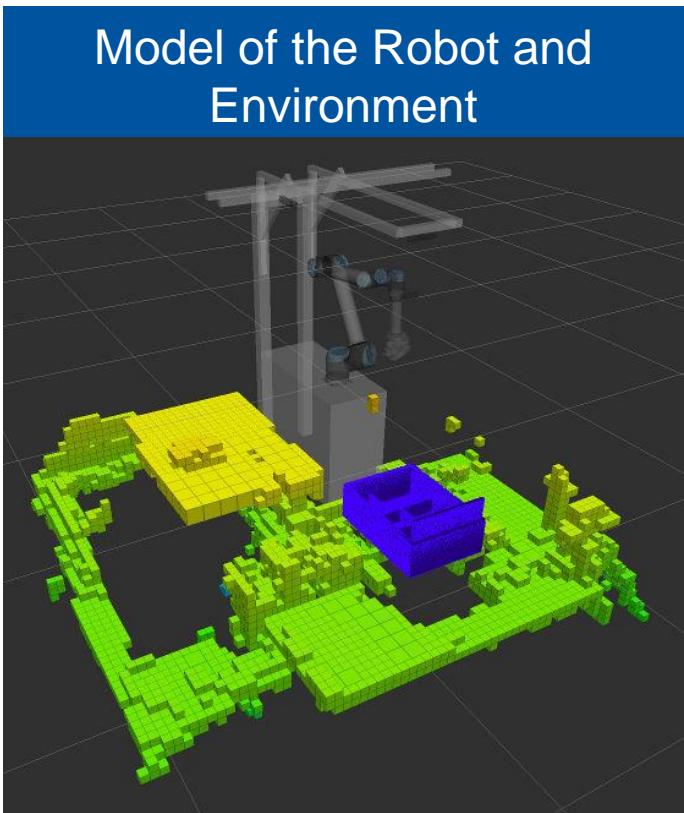
How do I go there?



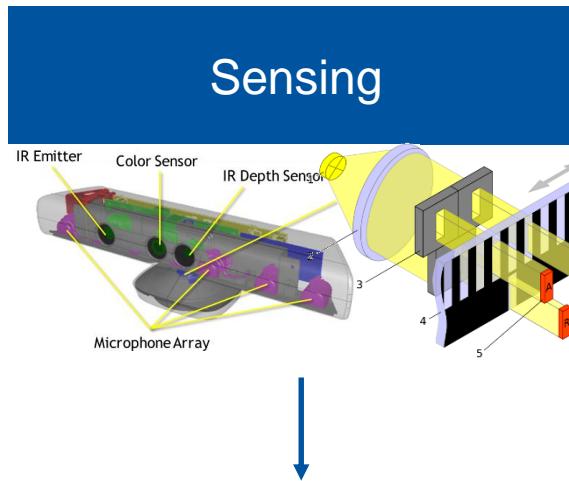
- Comparable Easy in Mobile Robotics
- Hard in Industrial Robotics

Robots as an Example for Intelligent Machines

How do I (the robot) go there?



$$\begin{bmatrix} \ddot{x} \\ \ddot{\dot{x}} \\ \ddot{\phi} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \frac{-(I+m\ell^2)b}{I(M+m)+Mm\ell^2} & \frac{m^2g\ell^2}{I(M+m)+Mm\ell^2} \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} x \\ \dot{x} \\ \dot{\phi} \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{I+m\ell^2}{I(M+m)+Mm\ell^2}u \\ \frac{m\ell}{I(M+m)+Mm\ell^2} \end{bmatrix}$$



This weeks topic!

Motion Planning

Requires Goalstate:

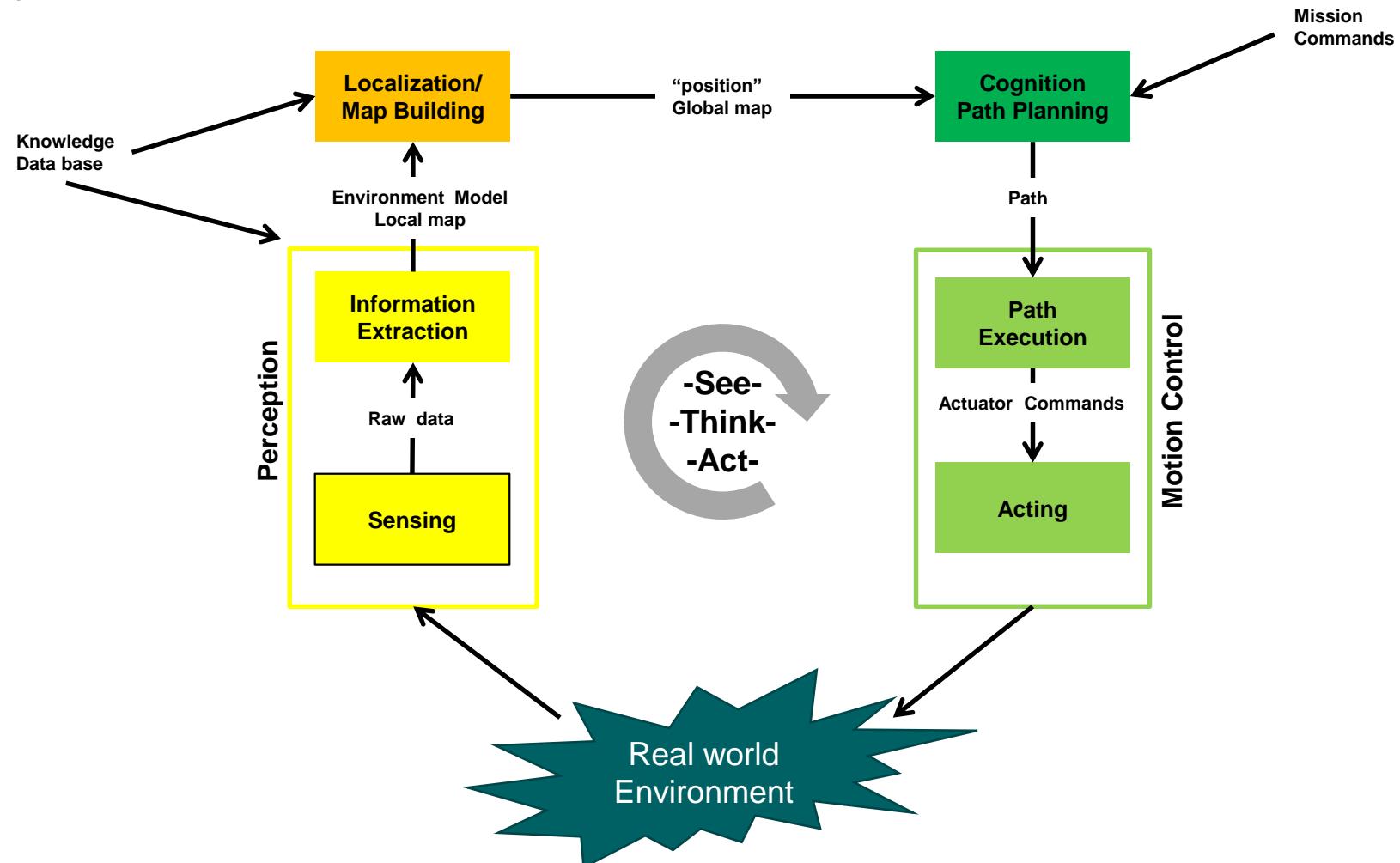
- i.e. hand-engineered
- i.e. via a cost function



Robots as an Example for Intelligent Machines

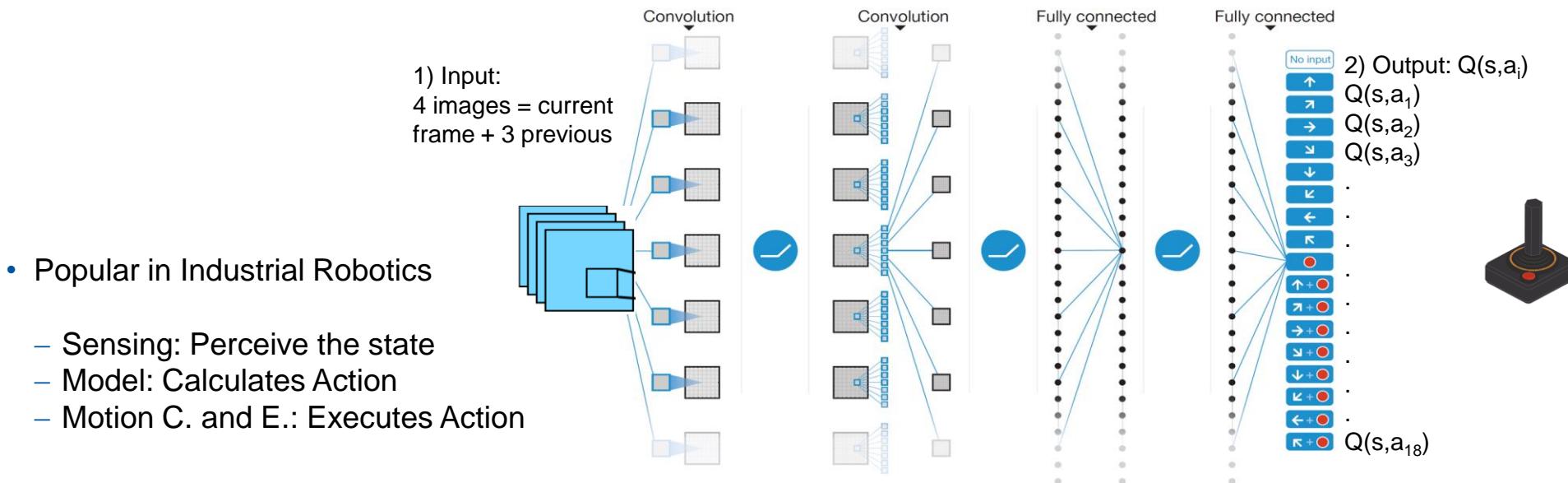
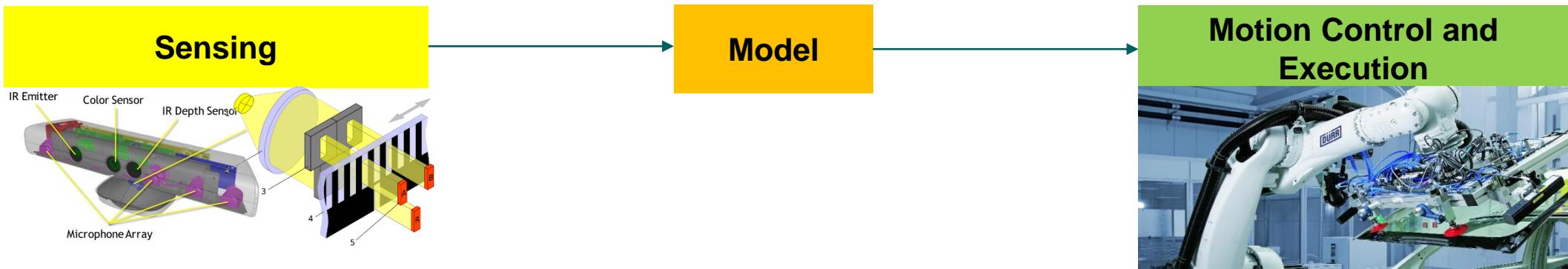
Robot-Architecture: See-Think-Act Cycle

- Popular in Mobile Robotics
 - See: Perceive the environment
 - Think: Path Planning
 - Act: Execute Path



Robots as an Example for Intelligent Machines

Robot-Architecture: End-To-End Control

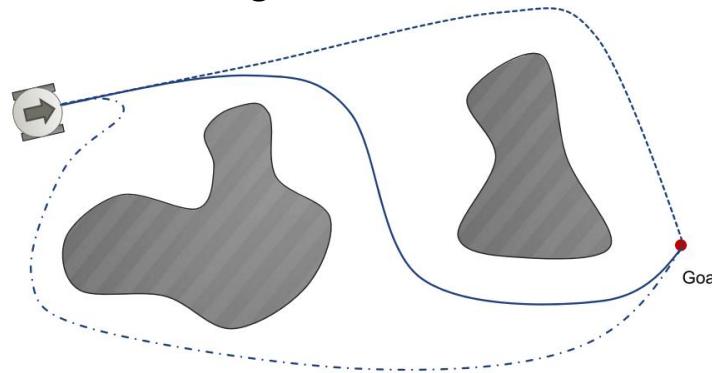


- Popular in Industrial Robotics
 - Sensing: Perceive the state
 - Model: Calculates Action
 - Motion C. and E.: Executes Action

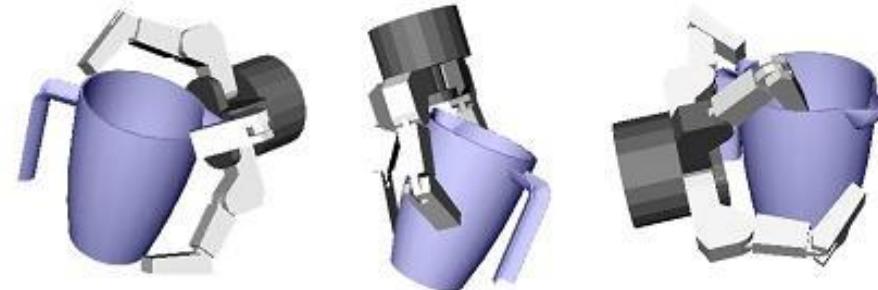
Robots as an Example for Intelligent Machines

Motion Planning

Path-Planning



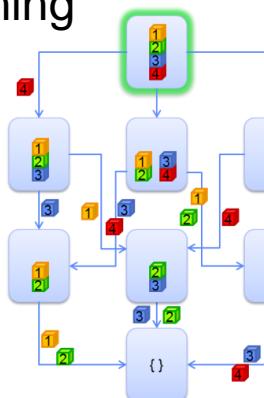
Grasp-Planning



Task-Planning

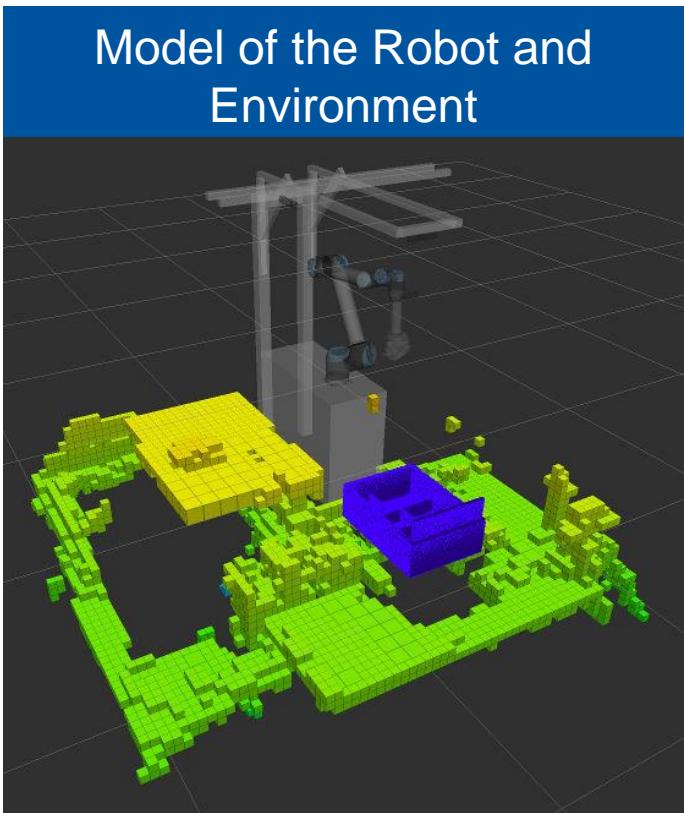


Assembly-Planning

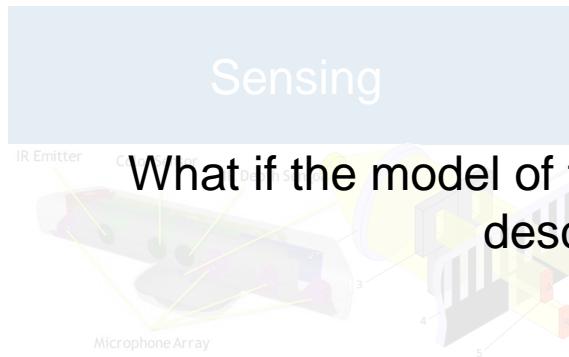


Robots as an Example for Intelligent Machines

How do I (the robot) go there?

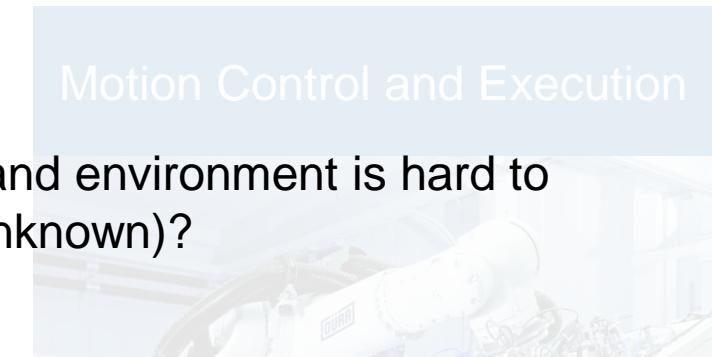


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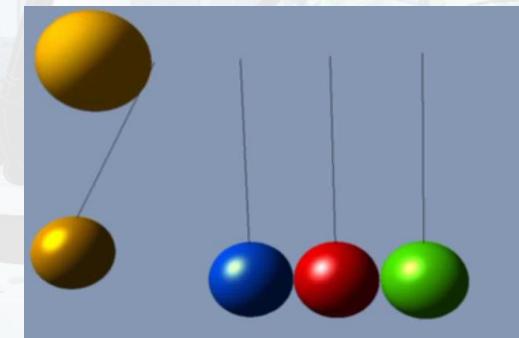


What if the model of the robot and environment is hard to describe (or unknown)?

Think about flexible objects!



Think about contact-situations!



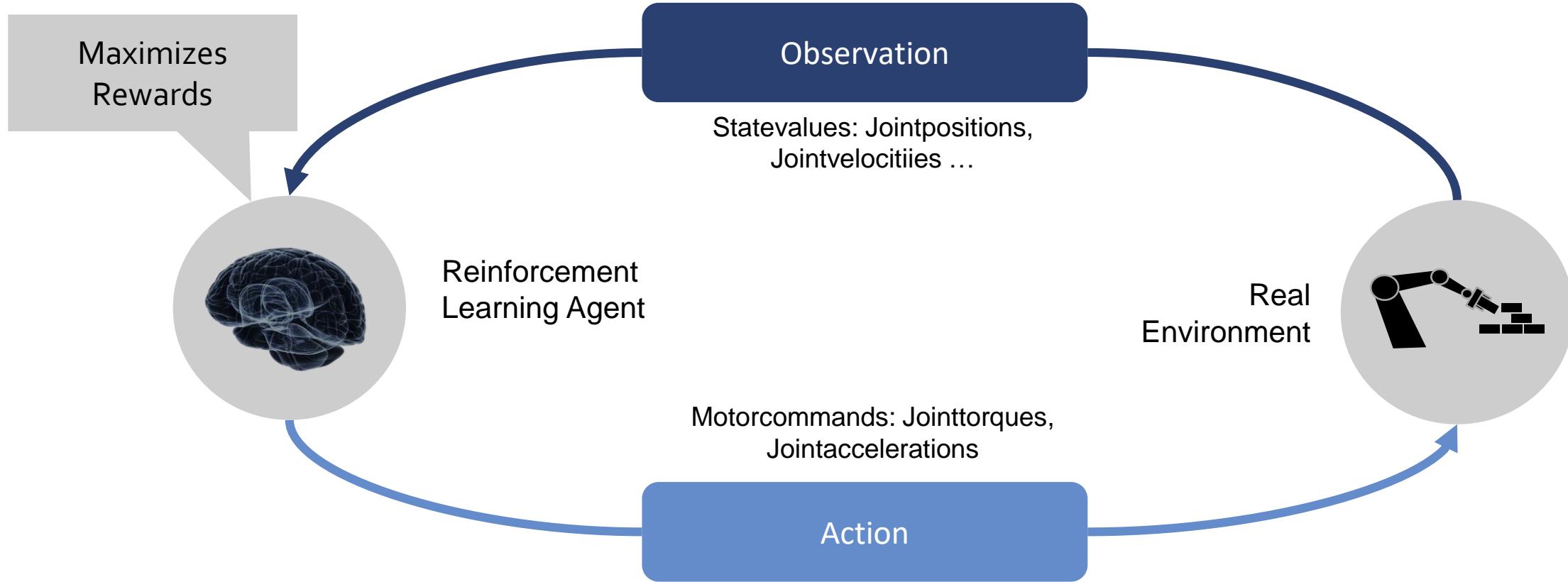
Requires Goalstate:

- i.e. hand-engineered
- i.e. via a cost function

Robots as an Example for Intelligent Machines

What if the model of the robot and environment is hard to describe (or unknown)?

- Use an Reinforcement Learning Agent!

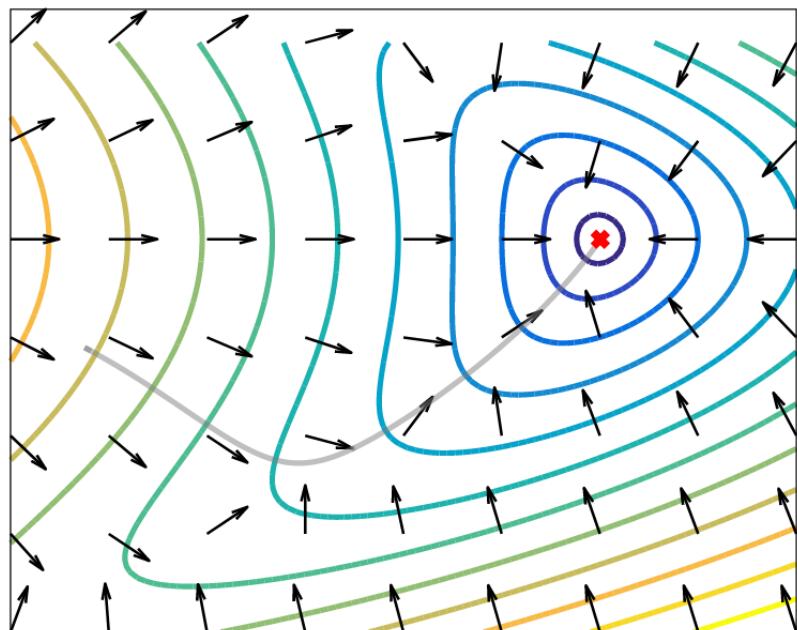


Robots as an Example for Intelligent Machines

What if the model of the robot and environment is hard to describe (or unknown)?

Closed-Loop

$$u = u(x)$$



- Global motion strategy (a “policy”)
- Robot chooses an appropriate action in each state

Open-Loop

$$u(t)$$

-Loop
 (t) **Trajectory Optimization**

/ (a “trajectory”)
ic region

- Local motion strategy (a “trajectory”)
- Only valid in a specific region

Robots as an Example for Intelligent Machines

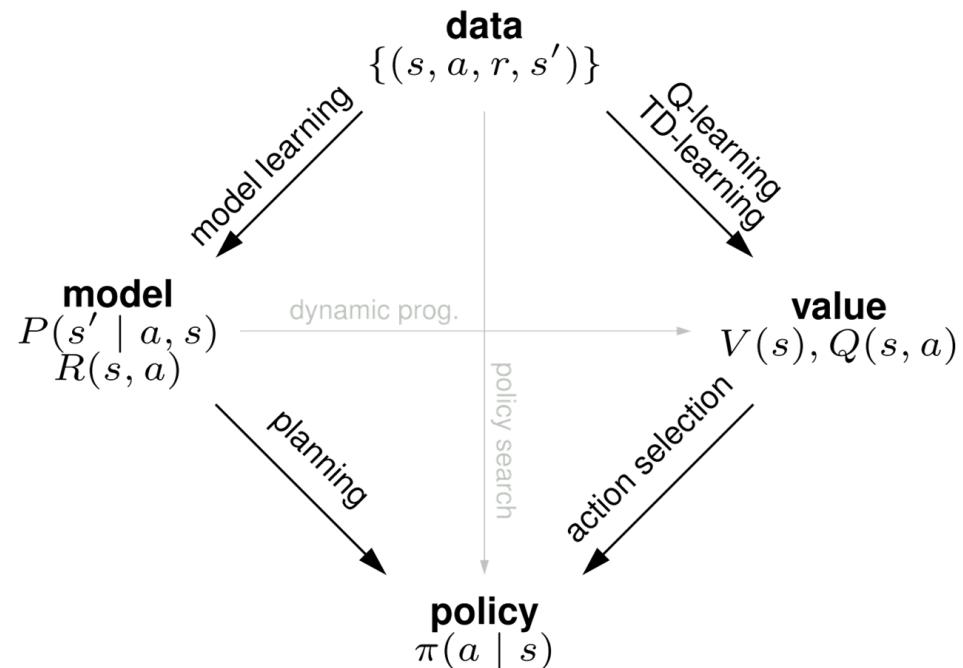
What if the model of the robot and environment is hard to describe (or unknown)?

This weeks topic!

Model-based RL:

- Learn to predict next state: $P(s'|s, a)$
- Learn to predict immediate reward $P(r'|s, a)$

model-based

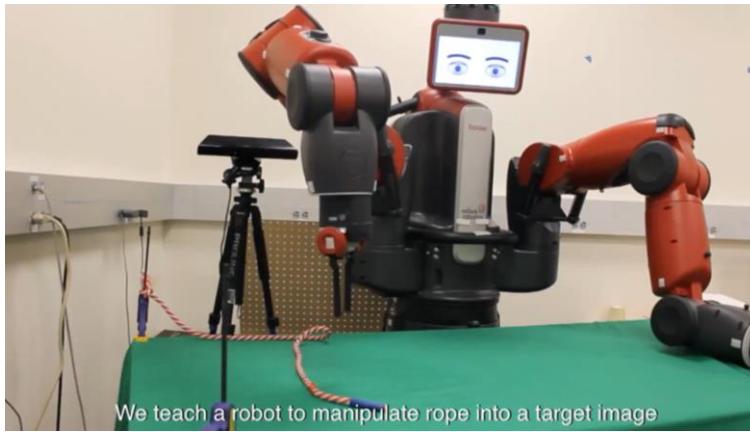


Model-free RL:

- Learn to predict value: $V(s)$ or $Q(s, a)$

s : state
 a : action
 r : reward

Reinforcement Learning with End-to-End Technology



Organizational

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