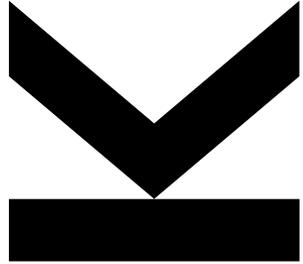
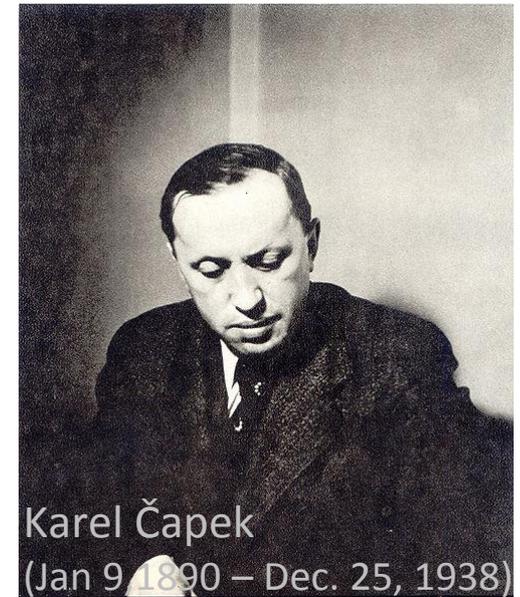


INTELLIGENT ROBOTICS VS. ROBOTIC INTELLIGENCE



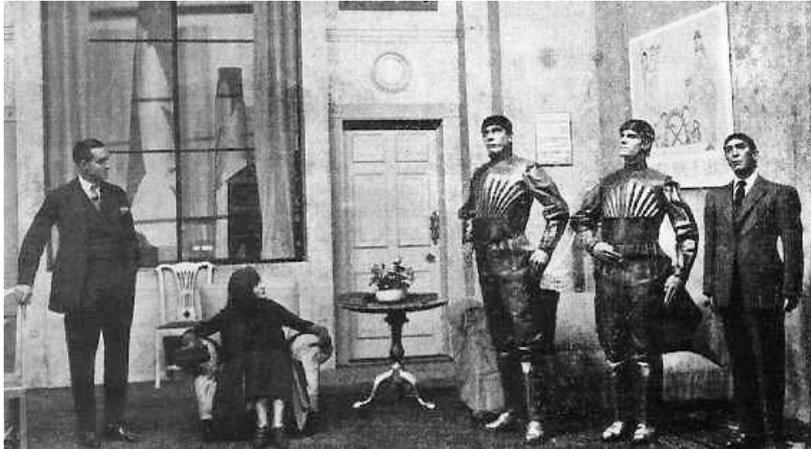
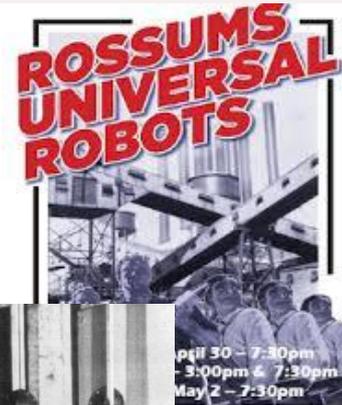
- The term “*Robot*” first appeared in the play „*R.U.R. (Rossums Universal-Robots)*” by Karel Čapek



- It is derived from Czech word „*robota*” meaning „drudgery” or „hard work”
- In original play Robot was with capital “R”
- Name was suggested by his brother, the painter and writer Josef Čapek.

What is a Robot?

- R.U.R. was staged in Prague in 1921, later in Europe and USA
- Staged in Tokyo in 1924 under the name “Artificial Human”



A scene from the play, showing three robots.



A scene from the play, showing the robots in rebellion.

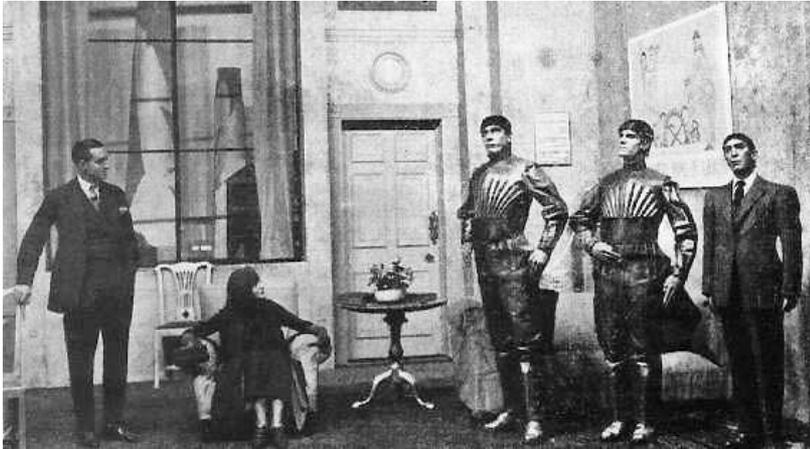
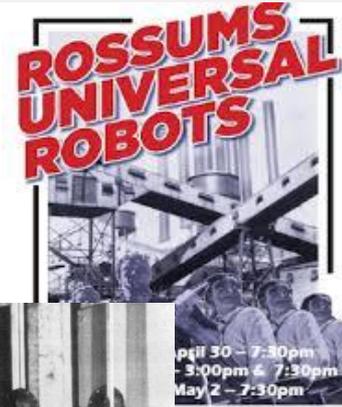
Robots of the world! The power of man has fallen!

A new world has arisen: the Rule of the Robots! March!

(Closing words of R.U.R. Act III)

What is a Robot?

- R.U.R. was staged in Prague in 1921, later in Europe and USA
- Staged in Tokyo in 1924 under the name “Artificial Human”



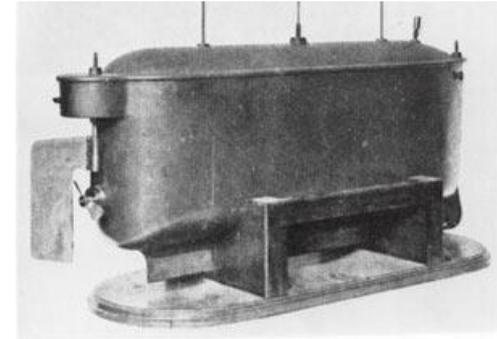
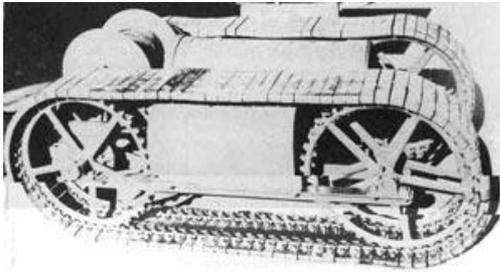
A scene from the play, showing three robots.



A scene from the play, showing the robots in rebellion.

- Beyond its historical value the play expresses important philosophical and technological issues in robotics.
- Robots in R.U.R. story were not of electromechanical type. They were produced through a chemical synthesis and were human-like.

- People in Europe were living the aftermath of WWI. Technologies were used in warfare: airplanes, heavy gunfire, biological weapons. Early versions of “*warbots*”:



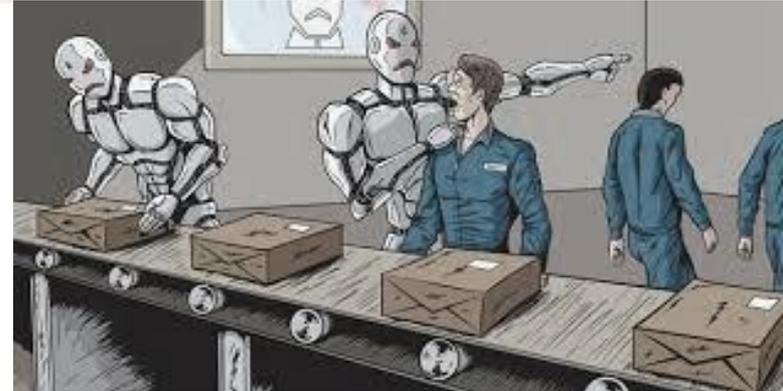
- In societies there was a widespread concern about *industrialization* and assembly-line production.
- *Skepticism* towards technology emerged. In R.U.R. these advances were epitomized by the artificial creatures that were called “Robots.”

Summary of R.U.R. ACT II

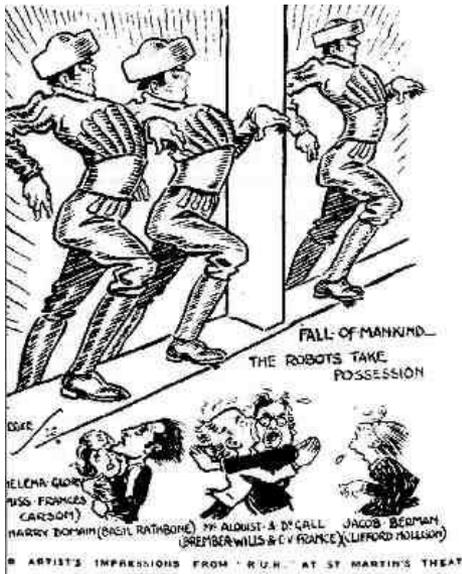
- Robots are employed as labor, prices drop, unemployment rises.
- Robots are also used as soldiers.
- Robots are further developed and acquire a soul!
Revolution against humans begins.
- Manifesto:

*“Robots throughout the world: We, the **first international organization of Rossum’s Universal Robots**, proclaim man as our enemy, and an outlaw in the universe.”*

- Rossum’s manuscript –a well-kept secret– is intentionally destroyed by Helena (the wife of Domin, the general manager of R.U.R.).



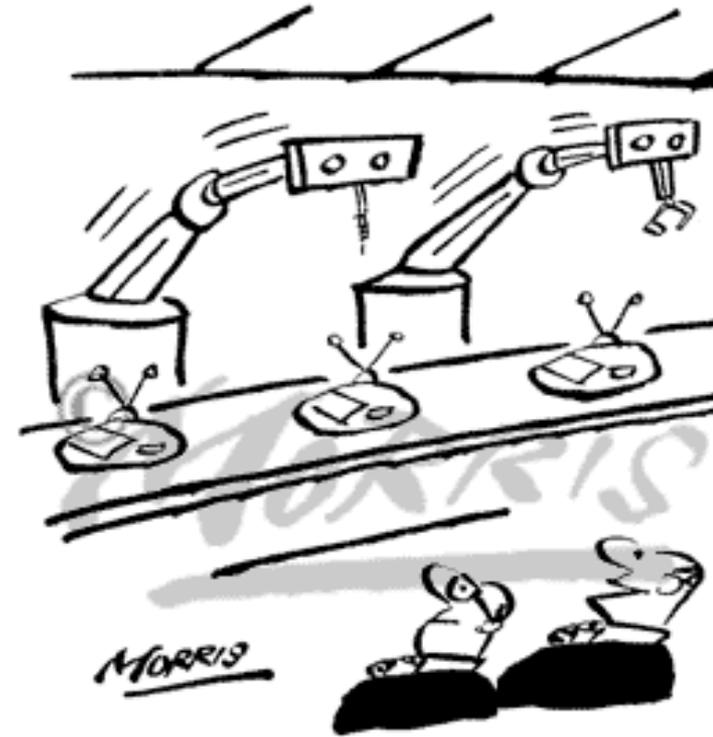
- People in factory are surrounded by menacing robots but are unable to react.
- Robots kill the remaining humans except Alquist (the builder) because *“he works with his hands like the robots”*



- Robots are anxious about the continuation of their existence.
- Alquist desperately tries to help them recover the robot formula but without any success.
- Two robots begin to exhibit human qualities in their behavior towards one another appearing ready to assume the roles of “**Adam and Eve**”.
- The curtains fall with a revived hope for the survival of “*Humanity*”



- In R.U.R. human reproduction drops while the robots population simultaneously increases.
“so many Robots are being manufactured that people are becoming superfluous.”
- An inner fear is also expressed that robots may not exist in harmony with nature.
“You might almost think that nature was offended at the manufacture of the Robots.”



"I like robots - they don't join unions, strike or ask for a payrise."

- In R.U.R. human reproduction drops while the robots population simultaneously increases.
“so many Robots are being manufactured that people are becoming superfluous.”
- An inner fear is also expressed that robots may not exist in harmony with nature.
“You might almost think that nature was offended at the manufacture of the Robots.”
- Nowadays more robots will be required to compensate for a declining workforce but also help coping with an increasing number of elderly individuals (e.g., Japan, China).
- This justifies an emphasis on **Manufacturing Robotics** and **Service Robotics** (including Anthropomorphic).

South Korea	437
Japan	323
Germany	282
USA	152
China	30

Number of robots
per 10,000 workers
[IFR 2015]

- **China** is already the **biggest robot market**
- Prediction for 2017:
428,000 robots

'Western' approach to robotics
Tireless Machines

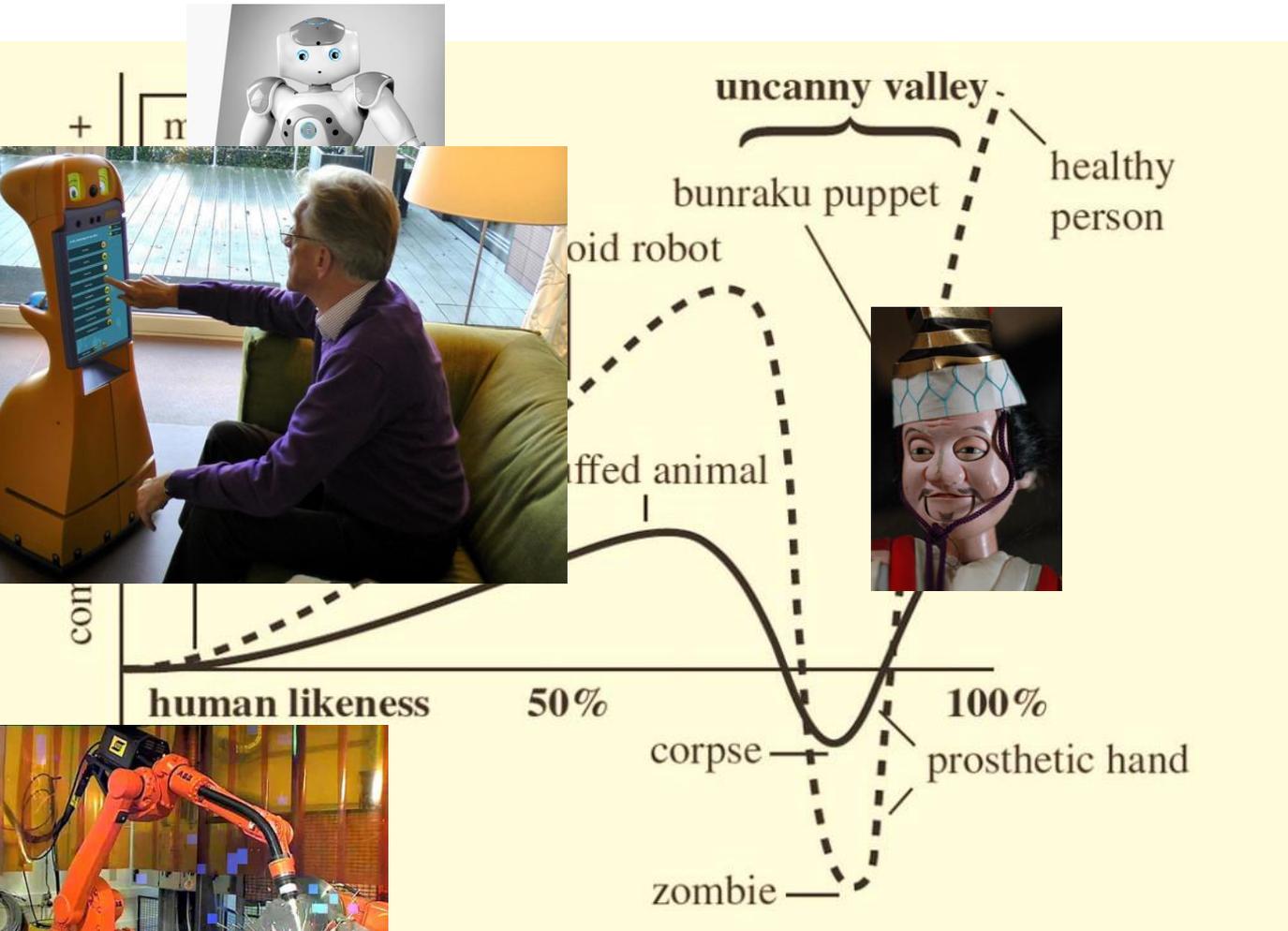


'Japanese' approach to robotics
Humanoids – Artificial Humans



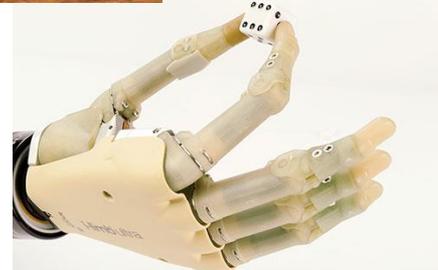
➔ “Escape by Design”:
Robot design should target the first peak.

‘Japanese’ approach to robotics
Humanoids – Artificial Humans



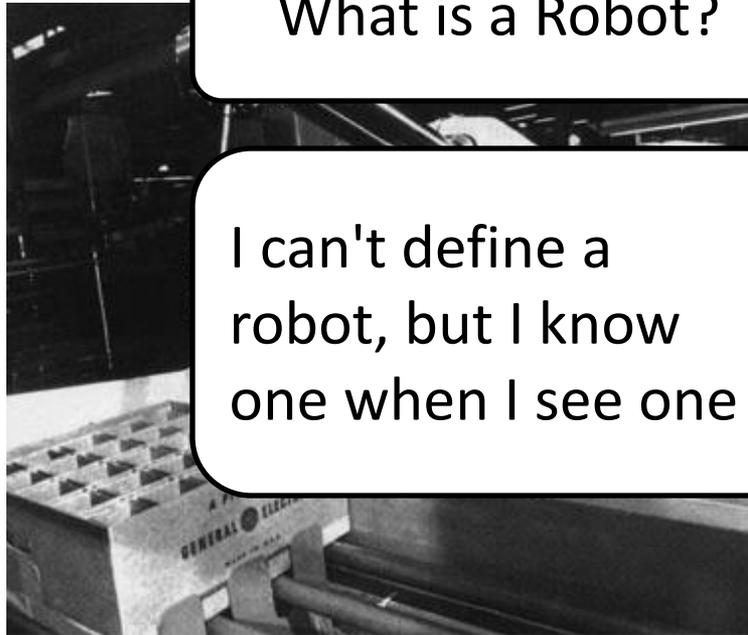
and the Uncanny Valley [Mori-1970]

Today's "Robots"

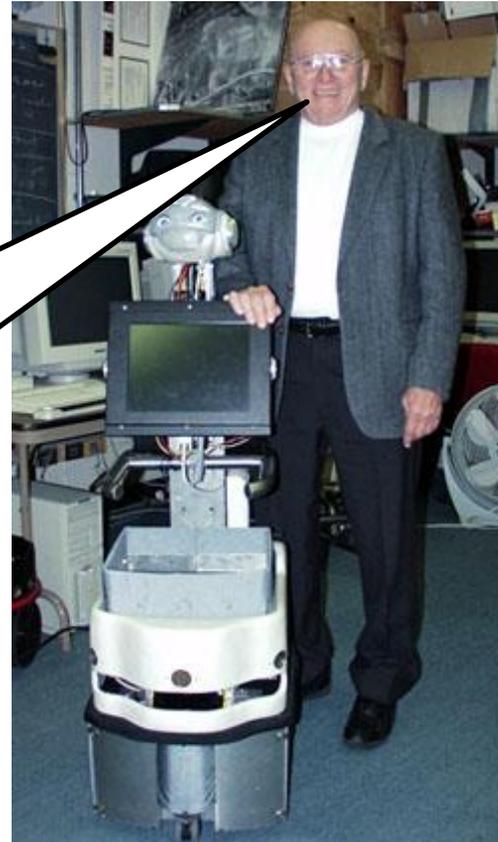


What is a Robot?

I can't define a robot, but I know one when I see one



**The Unimate Robot
(Unimation – Universal Automation)
GM assembly line 1961**



**Joseph Engelberger
(*"father of robotics"*)**

A Robot is

a *Controlled Electromechanical System*

with sensory and physical *interaction* with its environment.

The control can possess different levels of *autonomy*.

It can be associated a certain level of *intelligence*.

- It is a Mechanism  Mechanism Theory
- It is a Controlled Dynamical System  Non-Linear Control Theory
- It is an Intelligent Autonomous System  Artificial Intelligence (AI)
Artificial General Intelligence (AGI)

- Mechanism dictates the *way a robot can move*
- Controller *coordinates* the motion

Embodied Intelligence

Intelligence requires a **body** which has to be able to embody cognitive processes that **affects** and is **affected** by the environment.

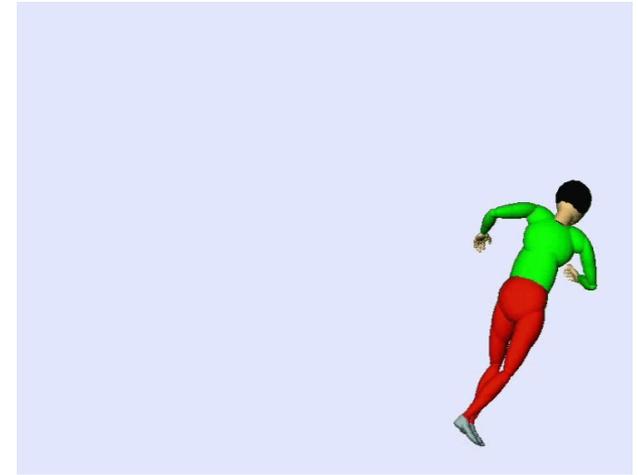
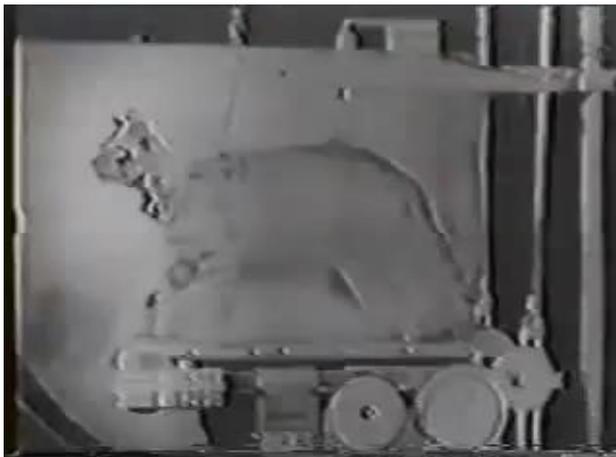


Figure skating
(computer reconstruction)



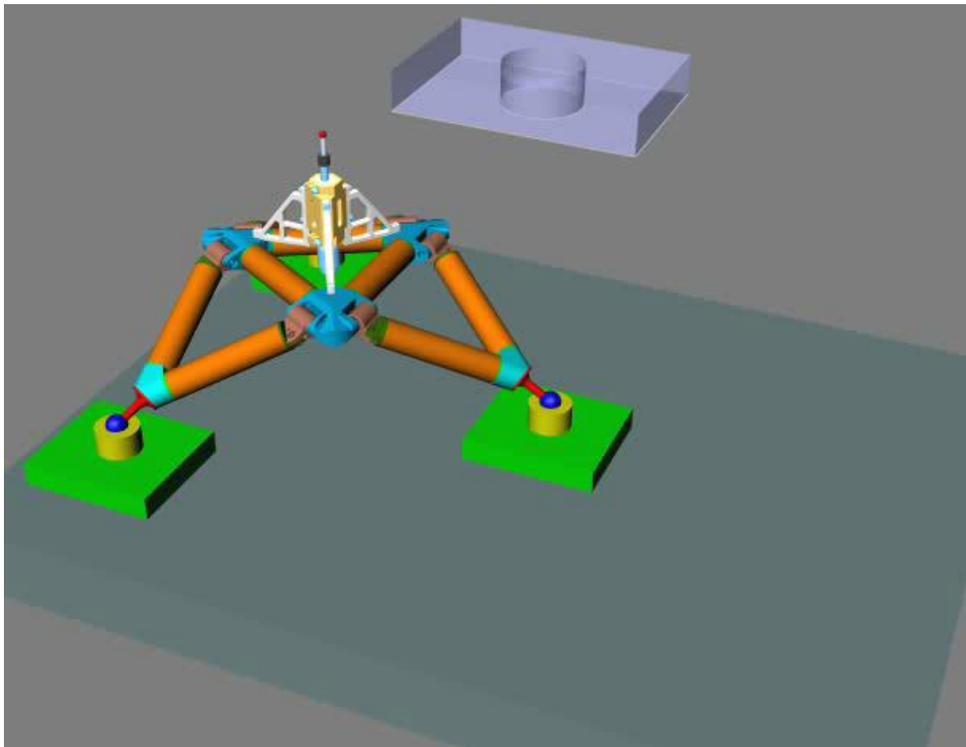
Decerebrate Cat running



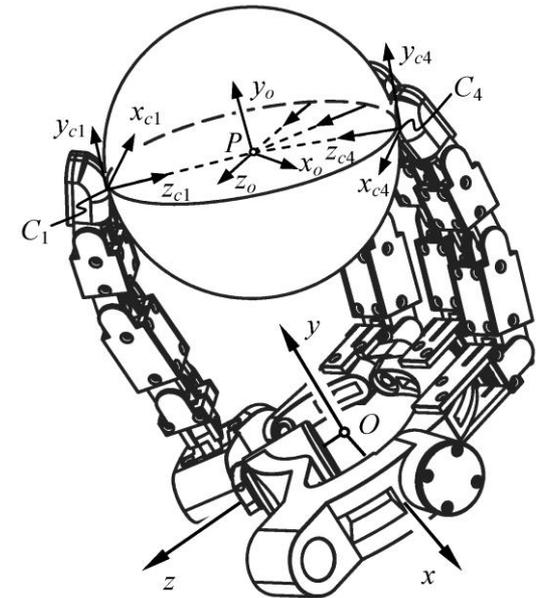
Humanoid Robot (Atlas – Boston Dynamics)

Mechanism Theory:

- Given specified function – *design* a mechanism realizing this function



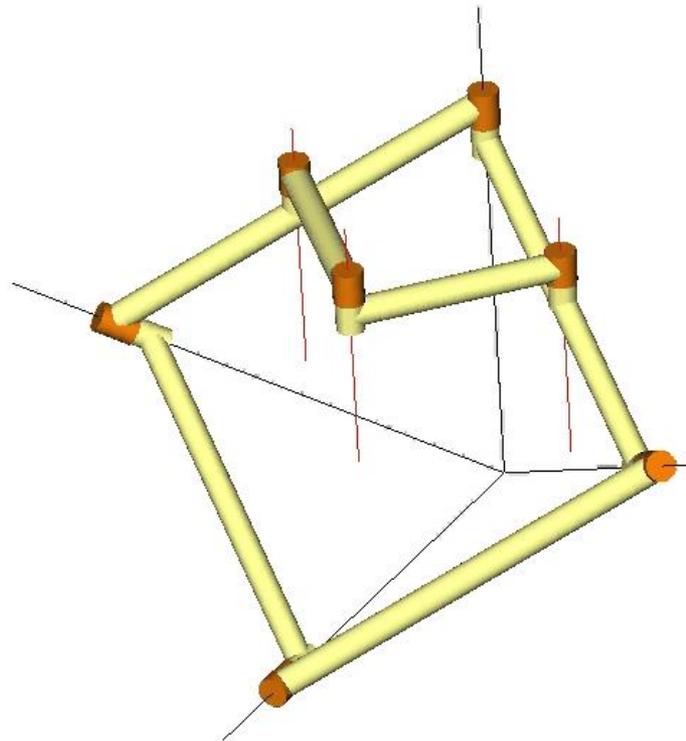
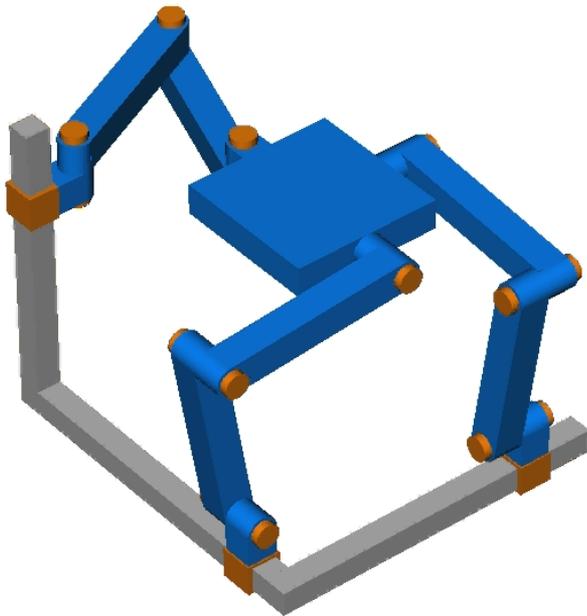
Parallel manipulator



Robotic hand

Mechanism Theory:

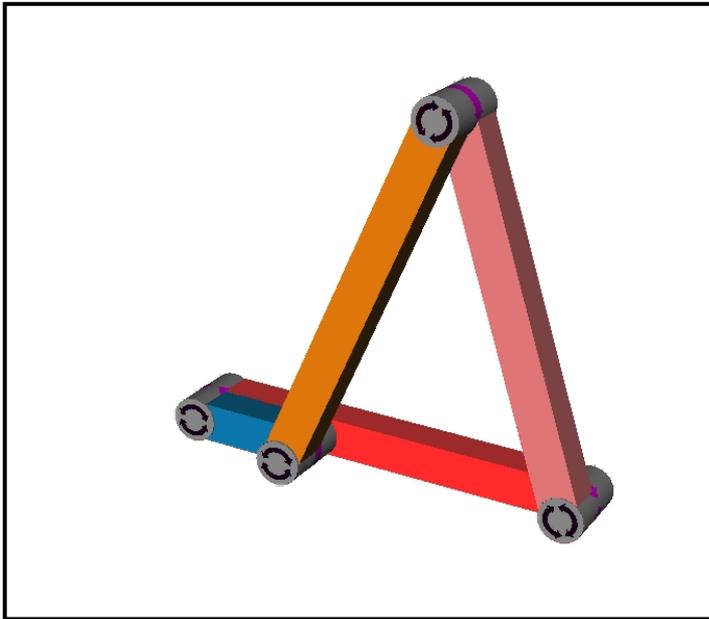
- Given specified function – *design* a mechanism realizing this function
- Given a mechanism – *analyze* its function



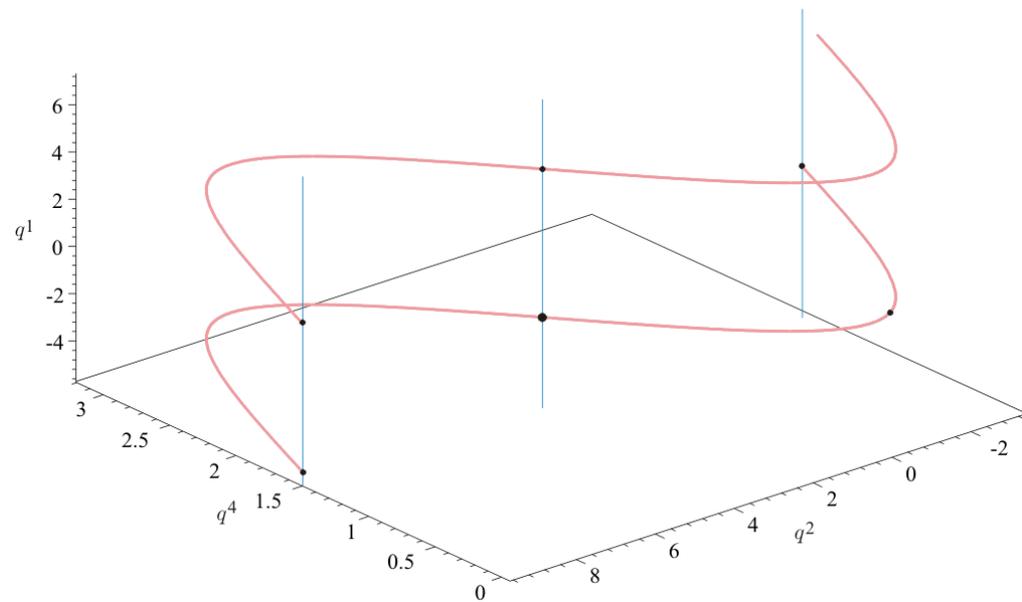
- Joint variables: $\mathbf{q} \in \mathbb{V}^n$
- Constraints: $h(\mathbf{q}) = \mathbf{0}$
- Constraint mapping: $h : \mathbb{V}^n \rightarrow \mathbb{R}^r$

Configuration space

$$V := \{\mathbf{q} \in \mathbb{V}^n \mid h(\mathbf{q}) = \mathbf{0}\}$$



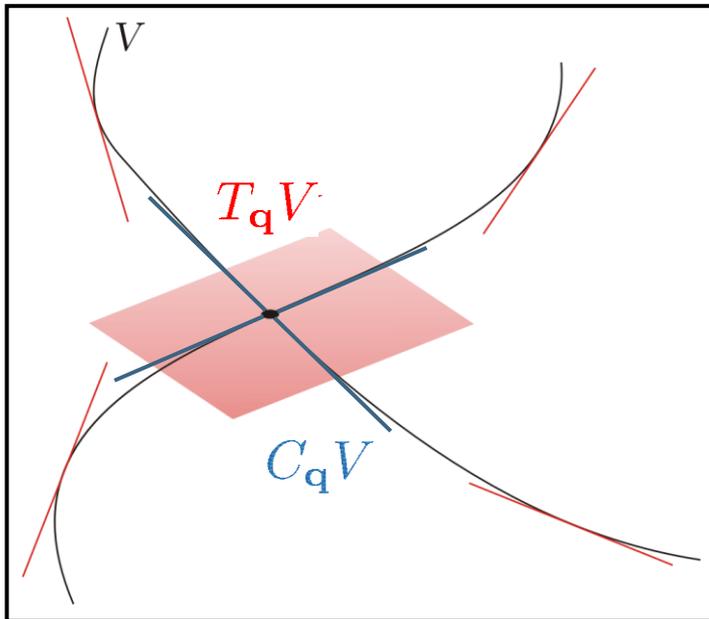
C-space is **non-smooth** at singularity



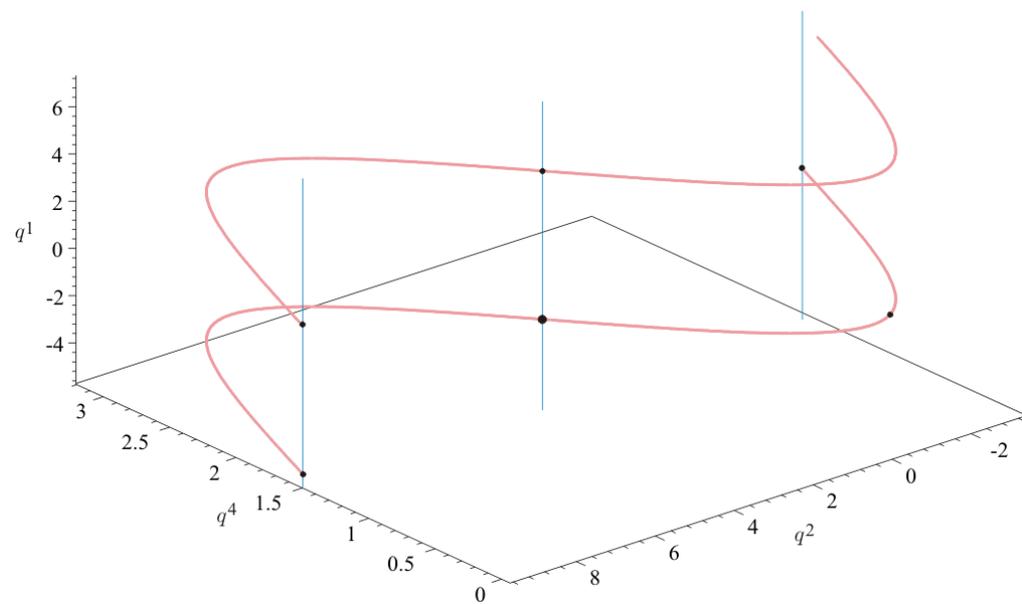
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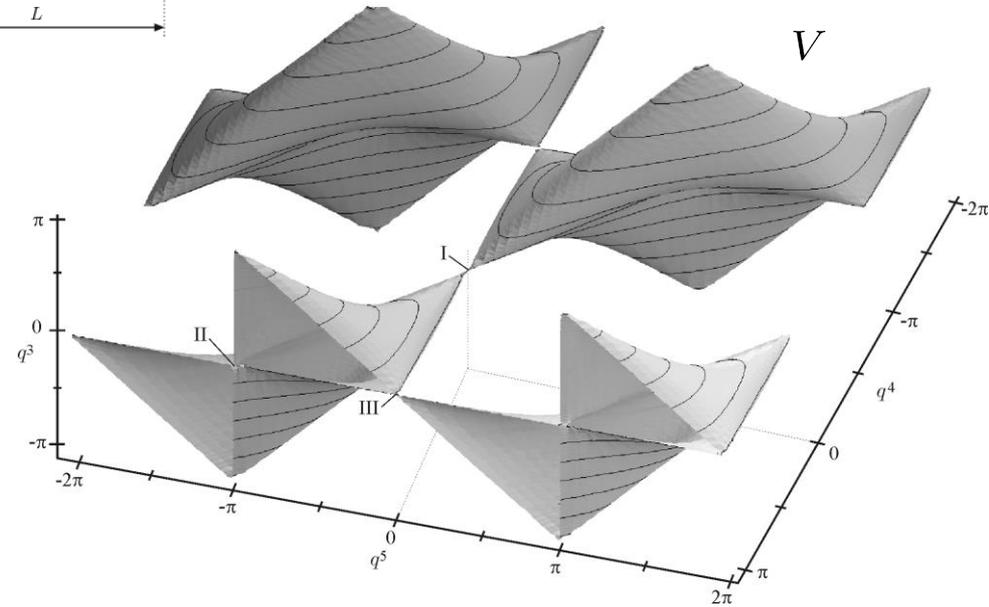
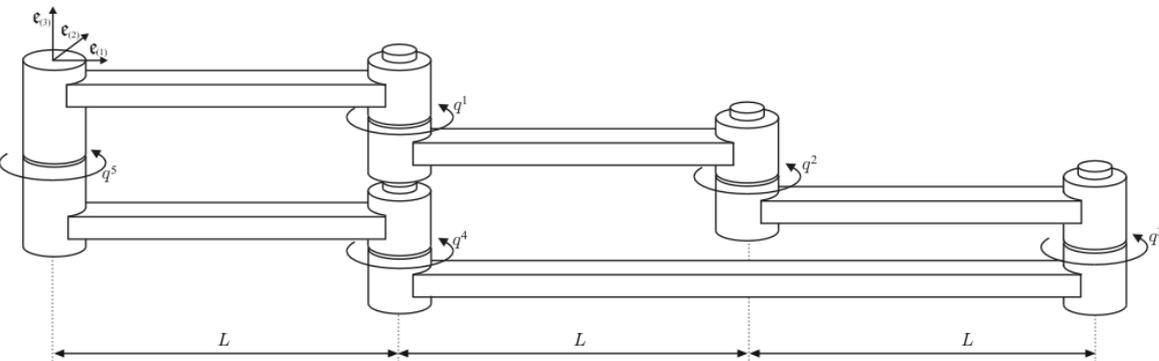
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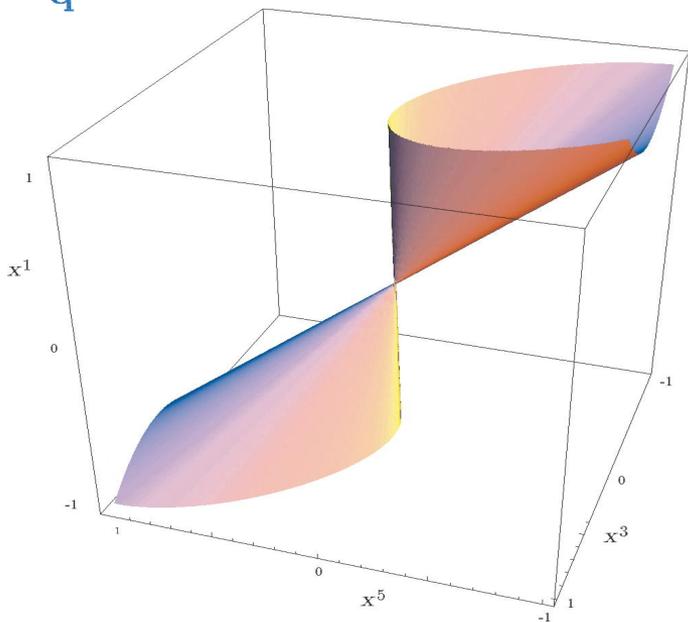


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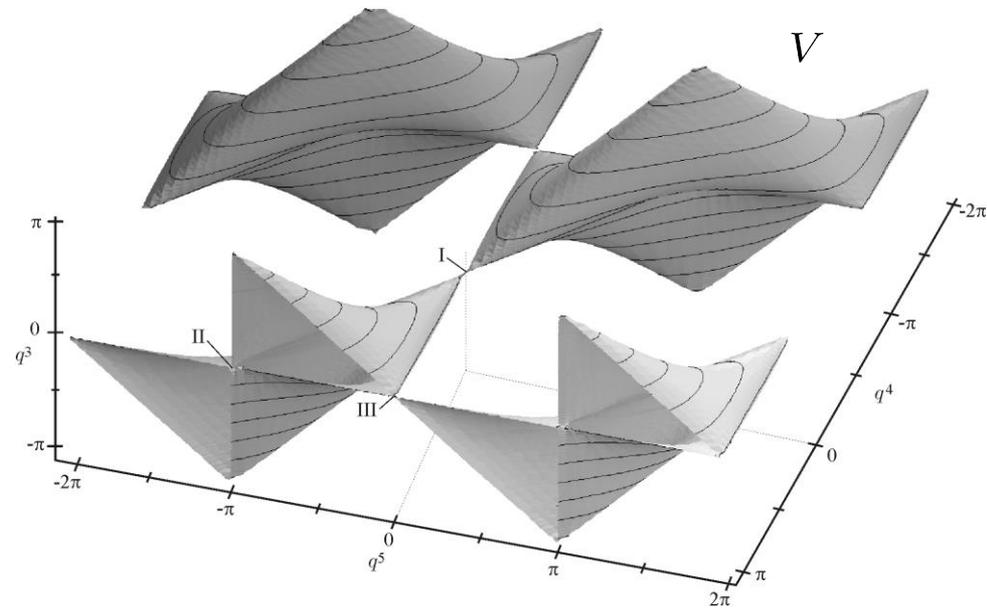
Configuration space

$$V := \{\mathbf{q} \in \mathbb{V}^n \mid h(\mathbf{q}) = \mathbf{0}\}$$

$C_q V$



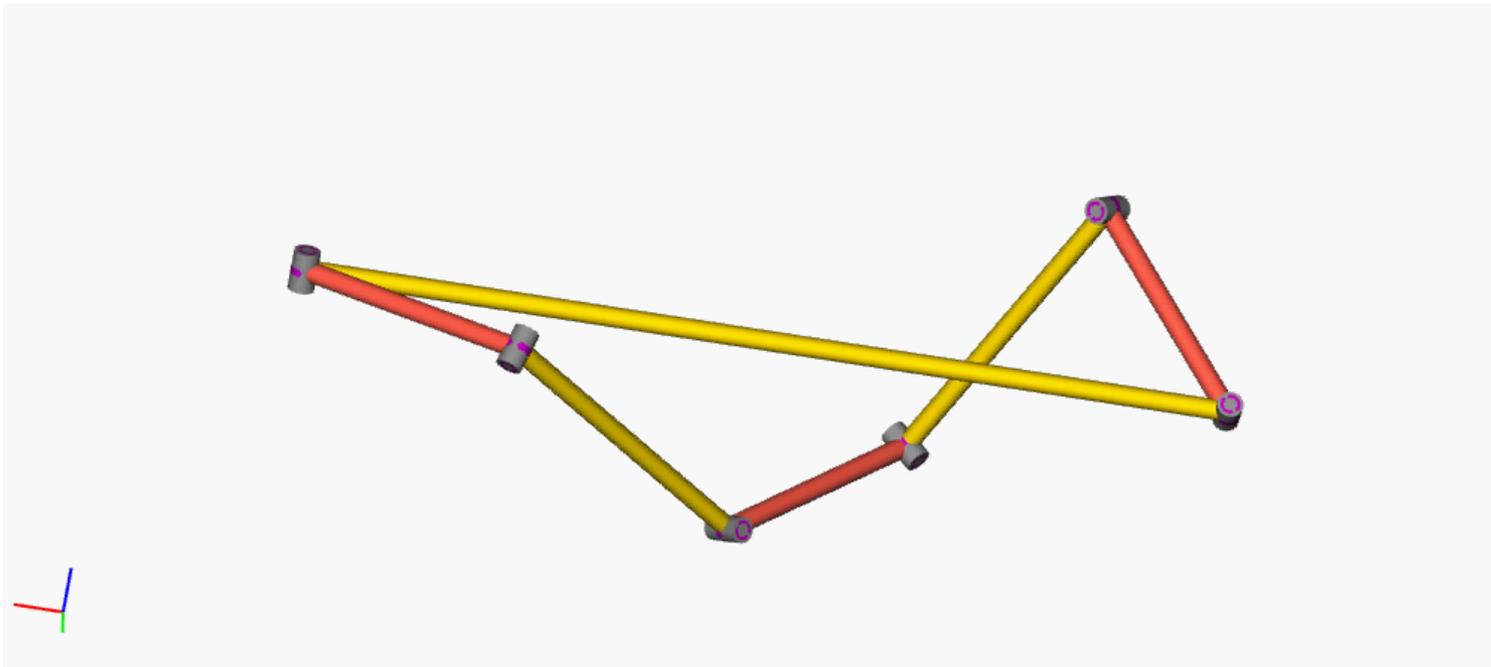
C-space is **non-smooth** at singularity



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Configuration space

$$V := \{\mathbf{q} \in \mathbb{V}^n \mid h(\mathbf{q}) = \mathbf{0}\}$$



Configuration space is a **smooth 1-dim manifold**



Increased instantaneous mobility but **no c-space singularities**

Two approaches:

1. Analytic Description

- Analytic mapping

$$h : \mathbb{V}^n \rightarrow \mathbb{R}^r$$

- Analytic variety

$$V_{\text{an}} := \{\mathbf{q} \in \mathbb{V}^n \mid h(\mathbf{q}) = \mathbf{0}\}$$

- Analysis of V_{an} with

- Lie group theory
- Screw theory

- Efficient algorithms

- Yields local results only

2. Algebraic Description

- Polynomial system

$$p_1(\mathbf{q}) = 0, \dots, p_k(\mathbf{q}) = 0$$

- Algebraic variety

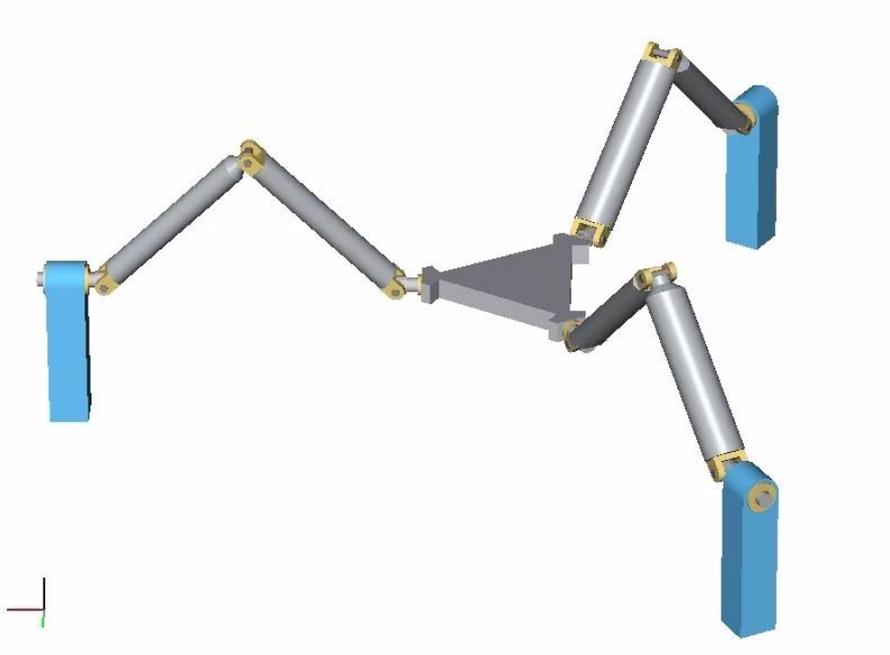
$$V_{\text{al}} := \mathbf{V}(p_1(\mathbf{q}), \dots, p_k(\mathbf{q}))$$

- Analysis of V_{al} with

- Computational algebraic geometry
- Homotopy methods

- NP hard algorithms,
fail for most problems

- Yields global results



Lock-Up mode

Planar mode

Input: u

Output: y



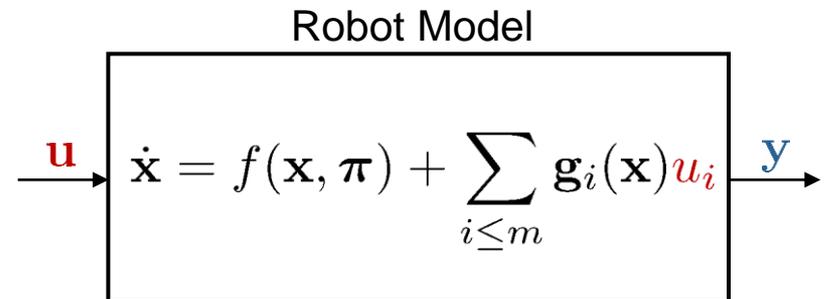
Robot is a Non-linear Control System

- with internal dynamics
- with model uncertainties
- with incomplete sensory information
- operating in uncertain environment

Control of a gantry crane

Model-Based Robot Control

- Anticipate required **input** from desired **output** → Model inversion
- Based on dynamic model
- Estimate “non-measurable” data



Input: \mathbf{u}

Output: \mathbf{y}



Robot is a Non-linear Control System

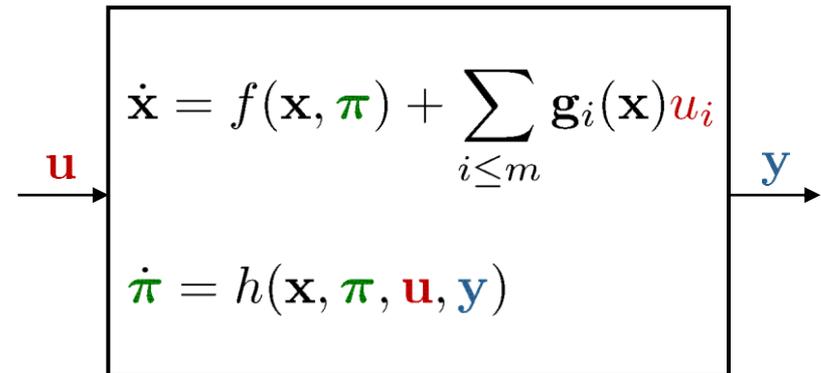
- with internal dynamics
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Control of a gantry crane

Robust Robot Control

- Adapt to variations of the model parameter $\boldsymbol{\pi}$ \rightarrow Adaptive Control
- Elasticity-Plasticity dilemma
(how much to learn – how soon to forget)

Robot Model

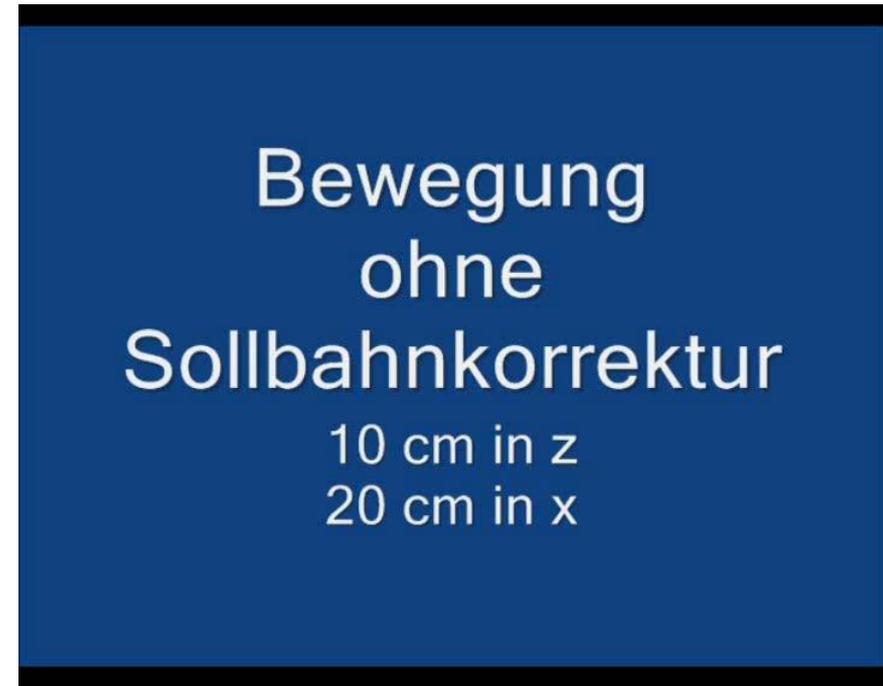


Robot is a Non-linear Control System

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Robust Robot Control

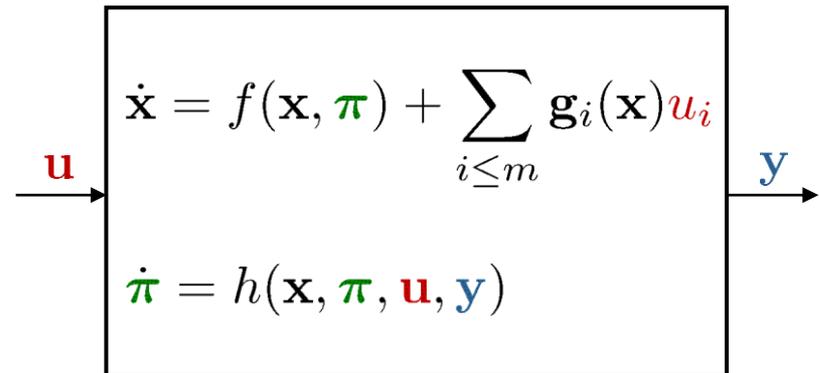
- Adapt to variations of the model parameter $\pi \rightarrow$ Adaptive Control
- Elasticity-Plasticity dilemma
(how much to learn – how soon to forget)



FFG



Robot Model



- An impact of robotics on societies seems inevitable!
- It is timely to set up and impose ethical standards in robotics to avoid unwanted consequences.
- Questions to address include the mental health of people interacting with robots or receiving robotic assistance (e.g., use of robo-pets, robo-nannies).
- Existing regulations regarding the use of robots mainly concern safety issues – not addressing ethical questions.
- Initiatives are principally *human-centered* rather than concerns regarding the *well-being or dignity of robots*.

Human Brain Project (2013 - 2023)

Six areas:

- Neuroinformatics
- Brain simulation
- High-performance computing
- Medical informatics
- Neuromorphic computing
- Neurorobotics

Subcommittees

- **Ethical, Legal and Social Aspects Committee (ELSA)**
- Research Ethics Committee (REC)

Subproject:

Simulating the **brain of a mouse**

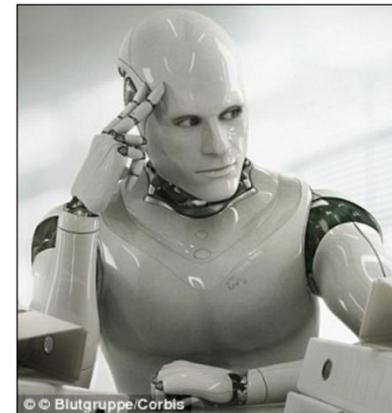
What if the “system” acquires

- Consciousness?
- Self-recognition?

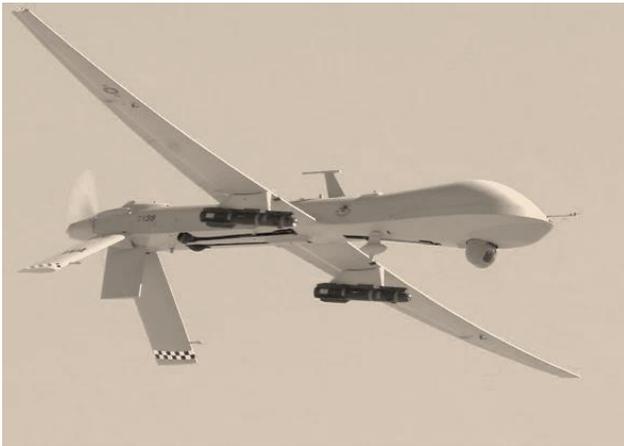
Does the Animal Protection Act apply?



Well-being or dignity of robots?

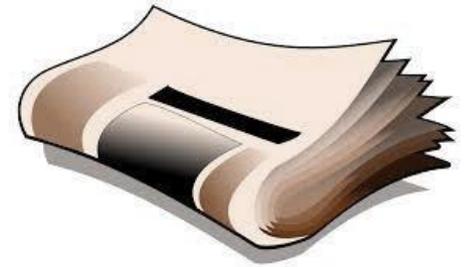


- The ethical question as expressed in R.U.R.:
“...governments turned the Robots into soldiers, and there were so many wars,” “It was criminal of old Europe to teach the Robots to fight. ...It was a crime to make soldiers of them.”



- Čapek in an interview a Prague newspaper in 1935:

“I am terrified by the responsibility for the idea that machines may replace humans in the future, and that in their cogwheels may emerge something like life, love, or revolt.”



- Royal Society says

“Machine learning which will revolutionise life in decade.”

“Only regulation will hold back artificial intelligence progress.”