THE UNIVERSITY of EDINBURGH
informatics

Advanced Robotics

1 - Overview of Robotics
16 Sep 2024

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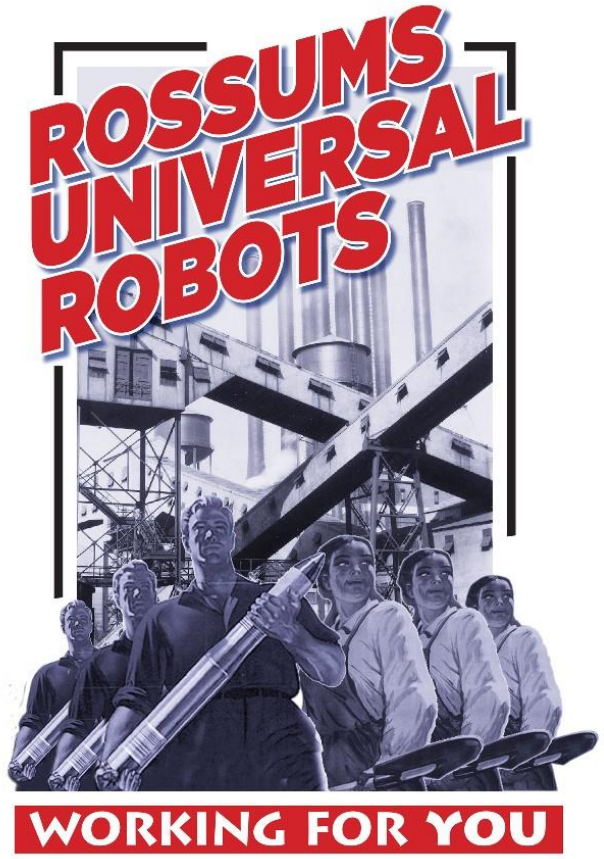
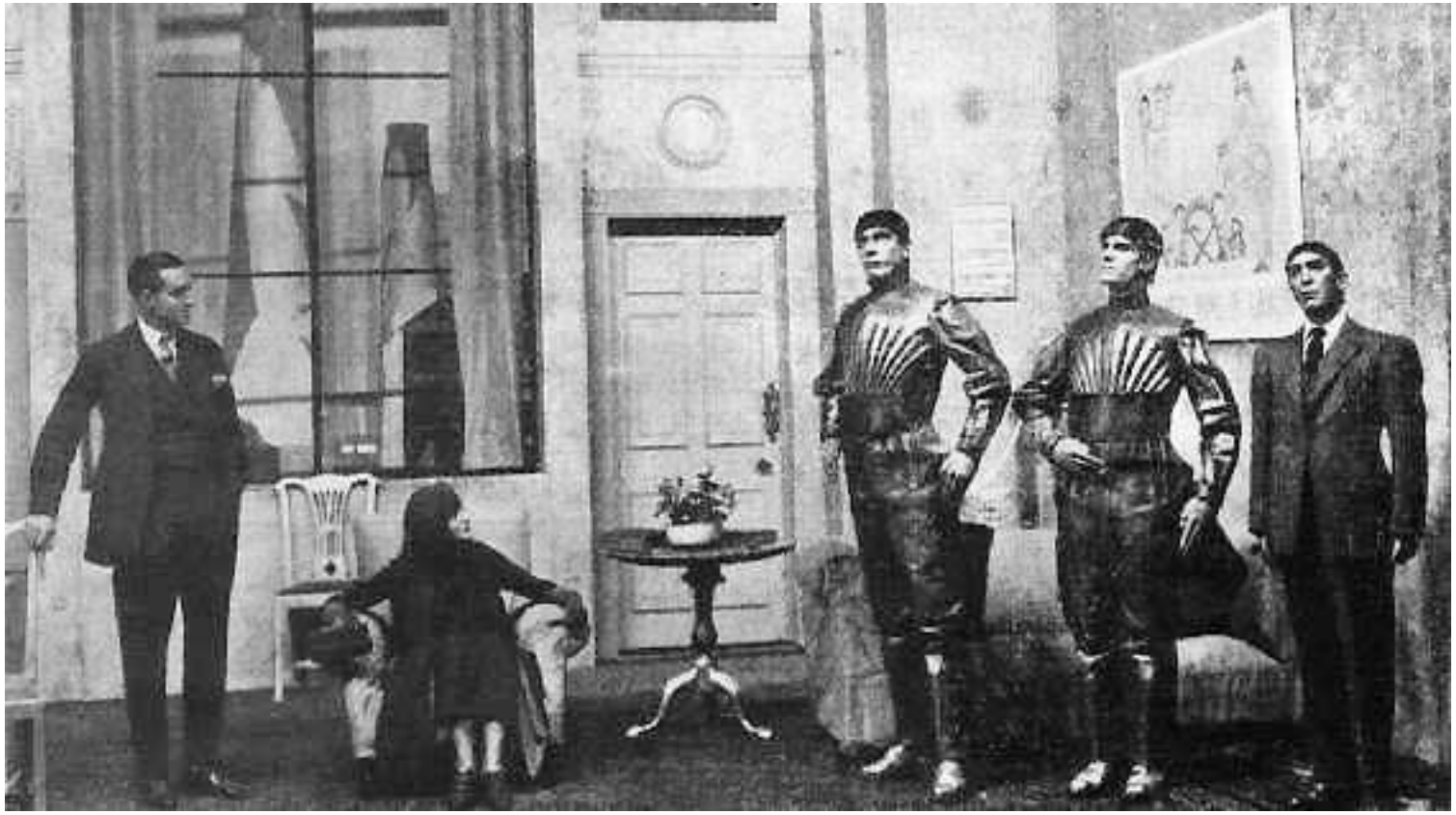
Rossum's Universal Robots



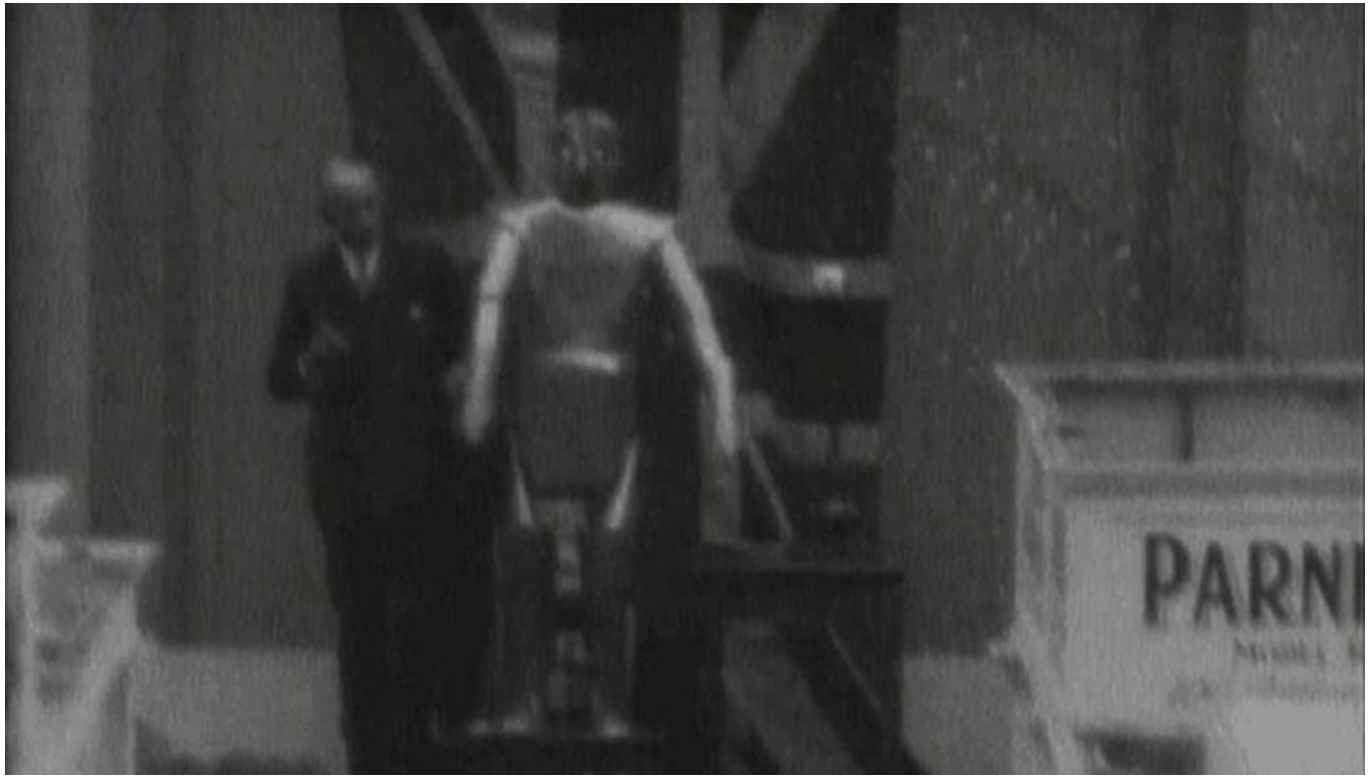
© Edward Alderton Theatre, image by Kevin Coward



© R.U.R. - Wikipedia

Eric: UK's first robot

UK’s first robot, and most interestingly, it is a humanoid robot.



Built in 1928 by Captain Richards & A.H. Reffell

See more at: http://www.sciencemuseum.org.uk/visitmuseum/plan_your_visit/exhibitions/eric

Robots: machines that automate some behavior

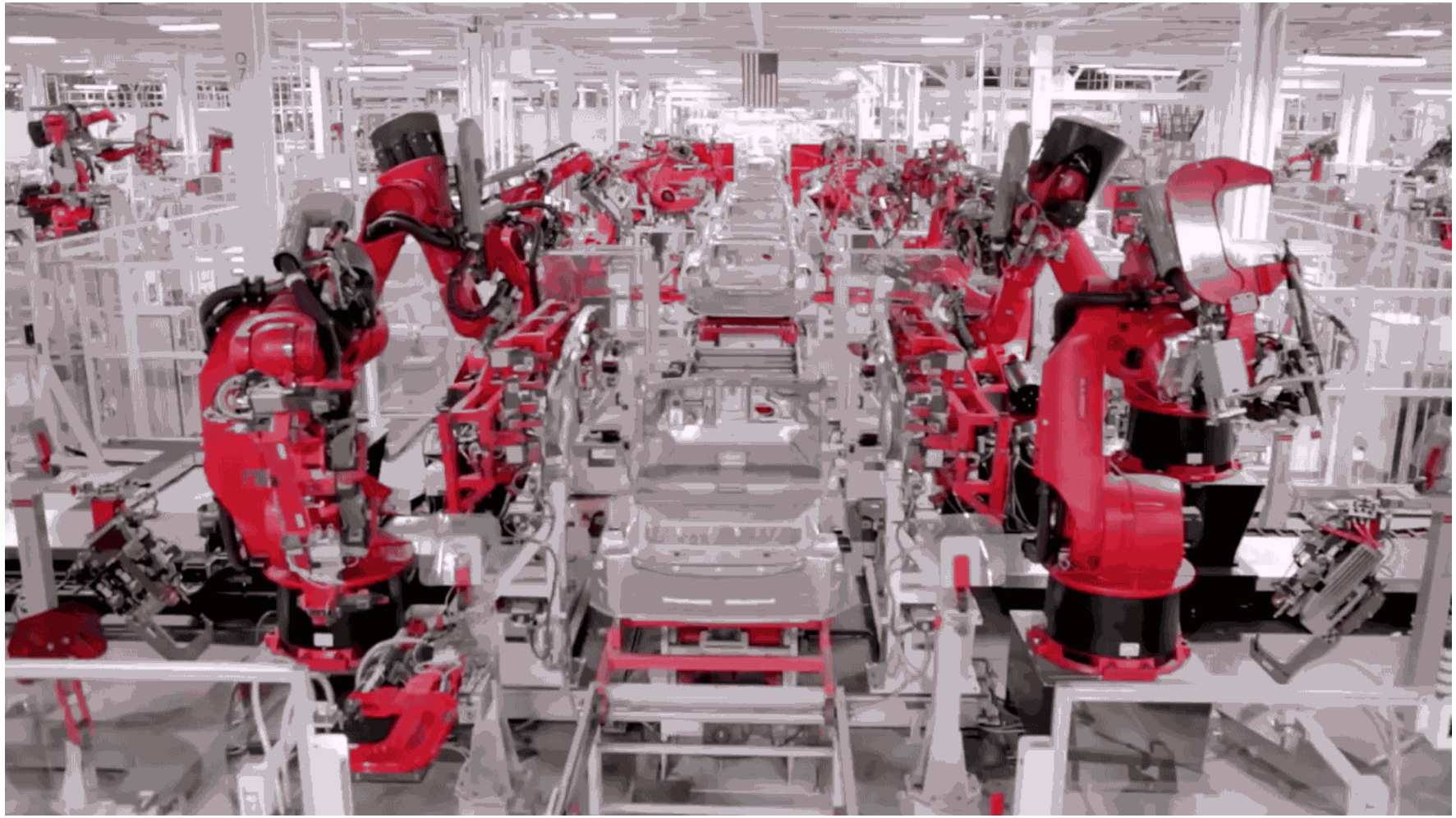
The first industrial robot: Unimate

George Charles Devol developed the prototype of Unimate in 1950s, the first material handling robot employed in industrial production work.

The first Unimate robot was sold to General Motors in 1961.

Unimate Robot, © the history channel

Robots Today: Car assembly in Tesla

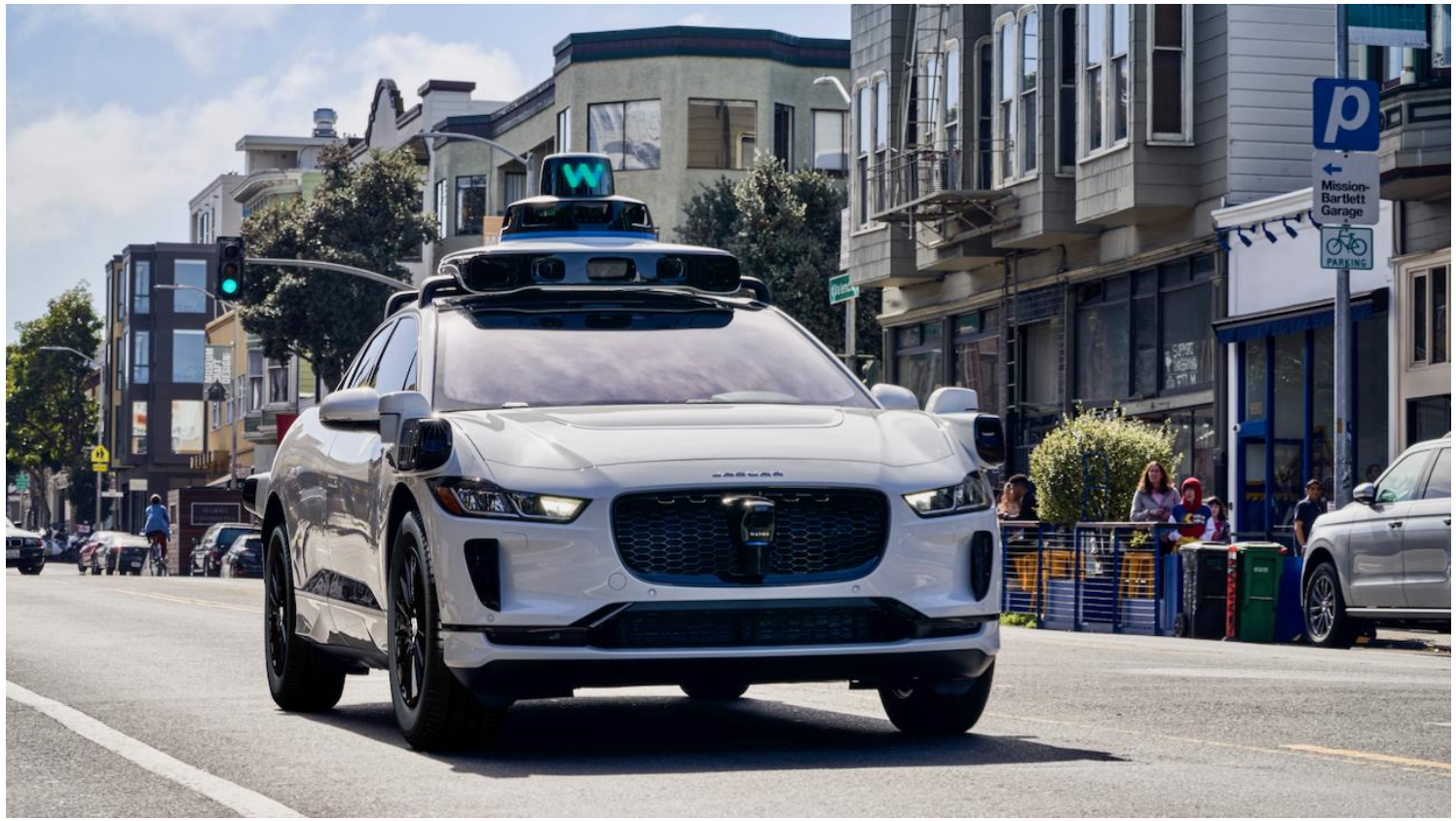


Picture source: pinterest.com

What is (not) a Robot?

[Source: http://www.robotronica.qut.edu.au]

What is (not) a Robot?

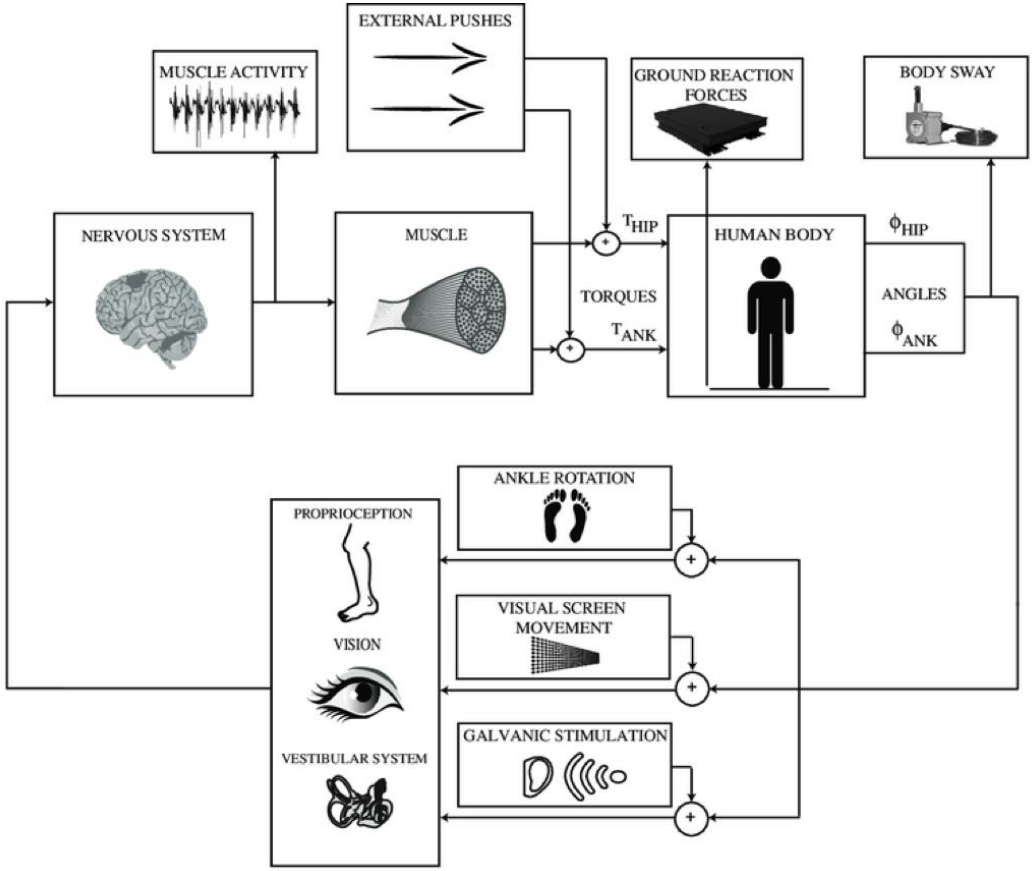


[Source: https://waymo.com/blog/2023/07/doubling-down-on-waymo-one/]

One Definition: Achieve Human-like *Behaviours*

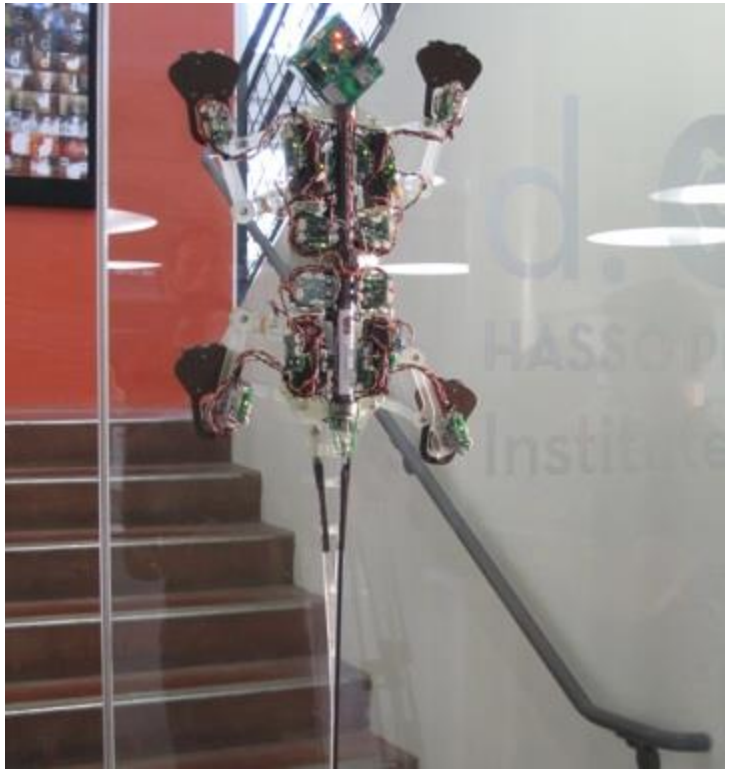
[Source: https://2024.robocup.org/leagues/robocupsoccer/]

Example: Control Needed “Just” to Stand Still



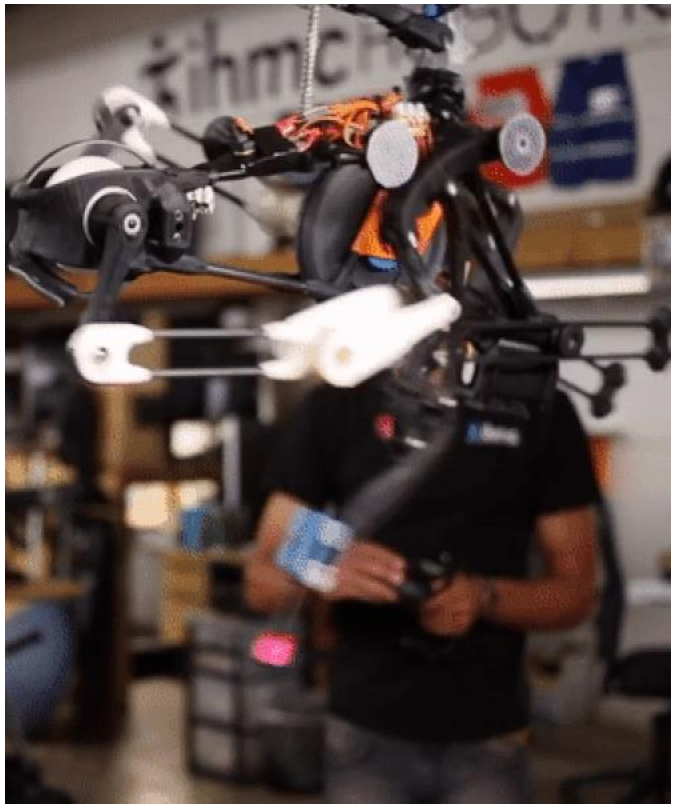
[Pasma et al., Neurosci. 2014]

Often Robots Need Clever Body Designs



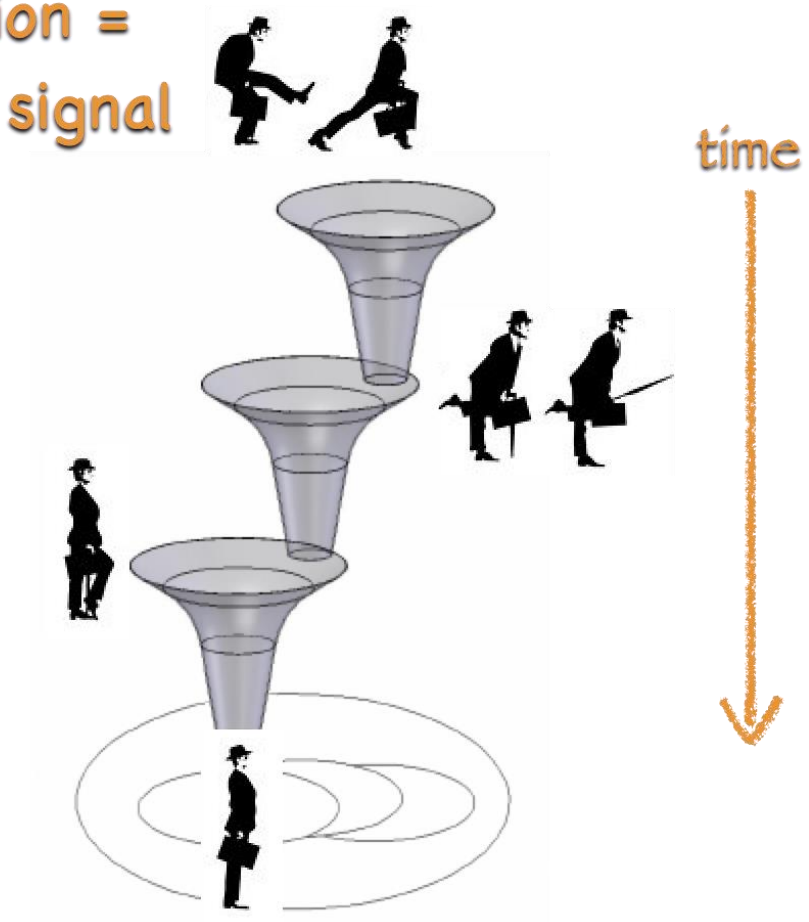
Biomimetics and Dexterous Manipulation Lab, Stanford

Efficient Mechanisms Yield Major benefits



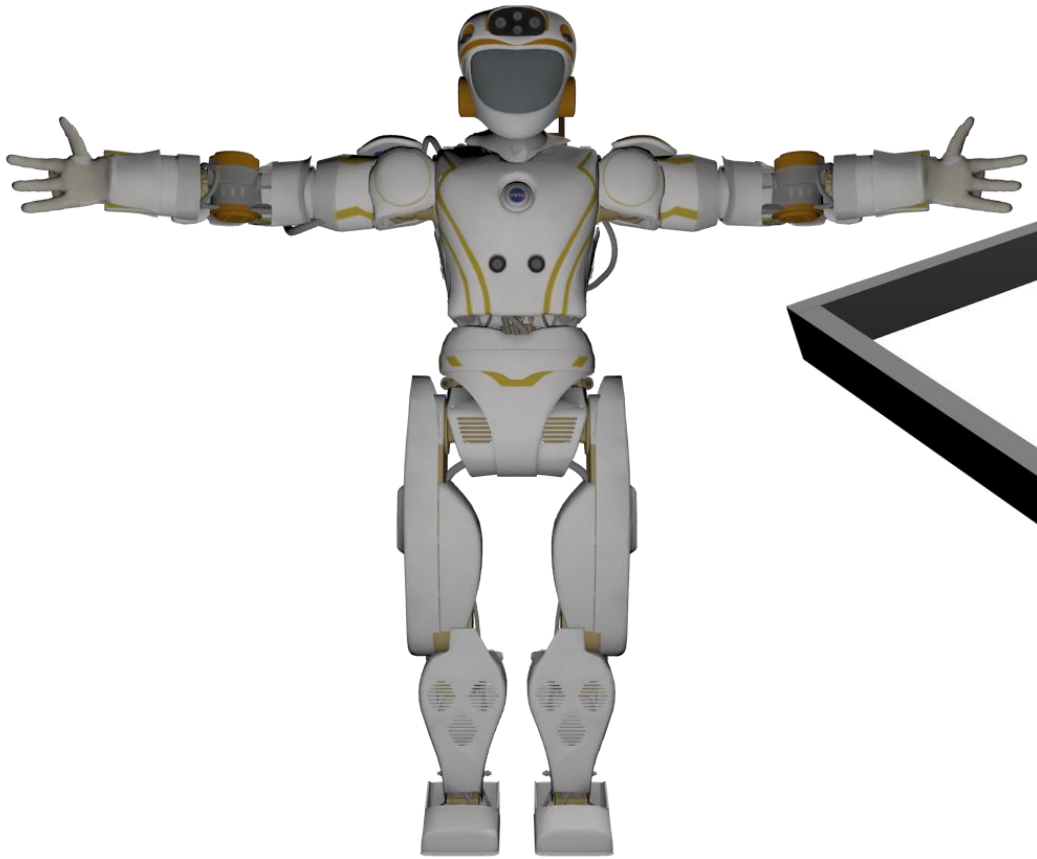
Our Focus: General *Computational* Principles

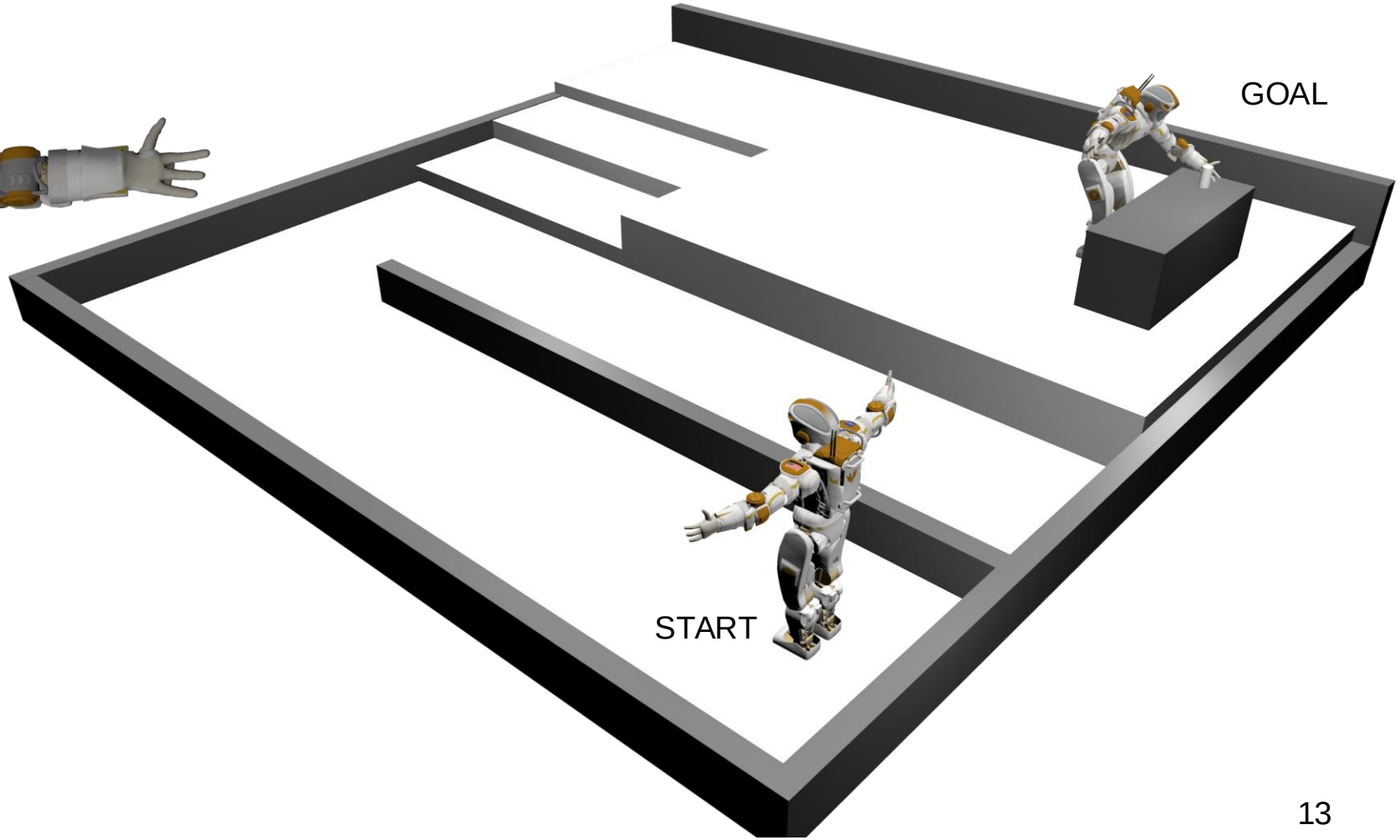
Control action =
Gain x Error signal



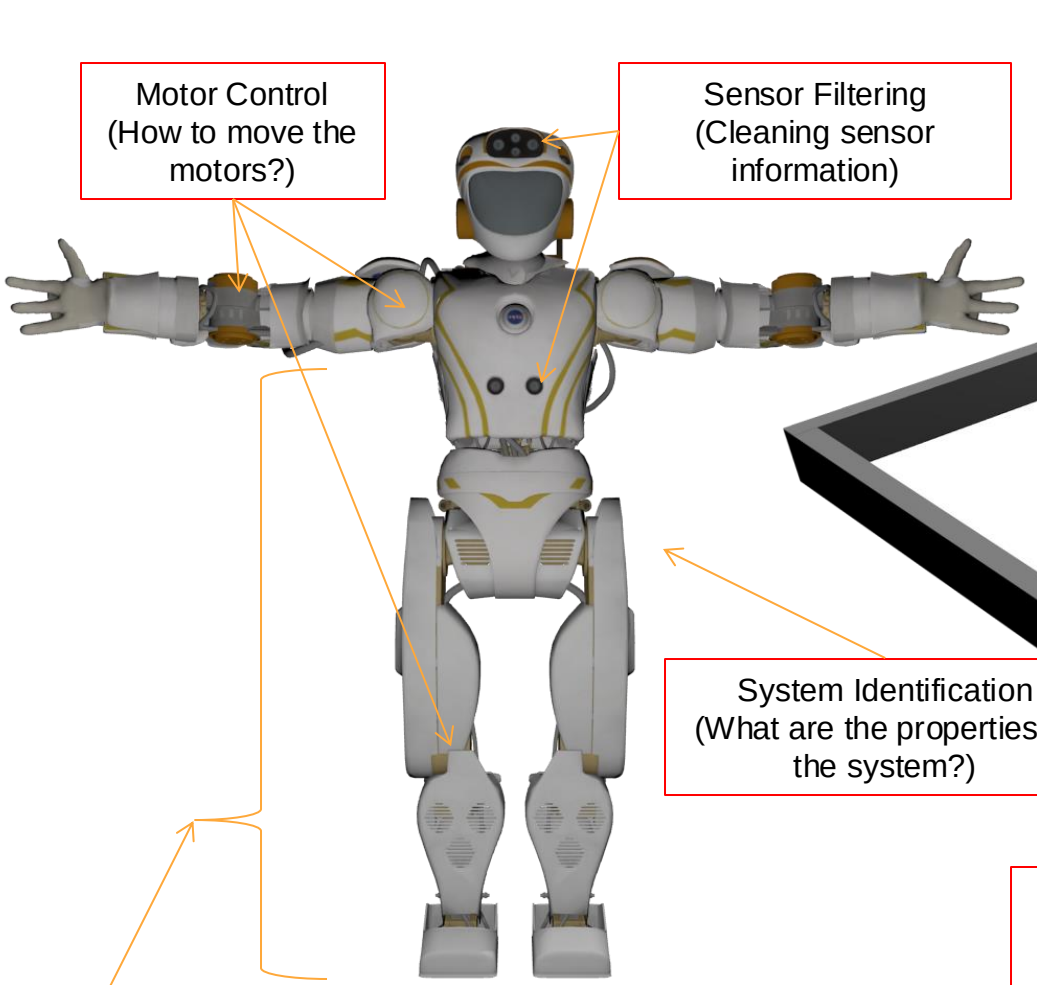
What is a Robot?

Can you name some of the things we need in order to move the Valkyrie robot from the start position to the end goal, picking up the object?





What is a Robot?



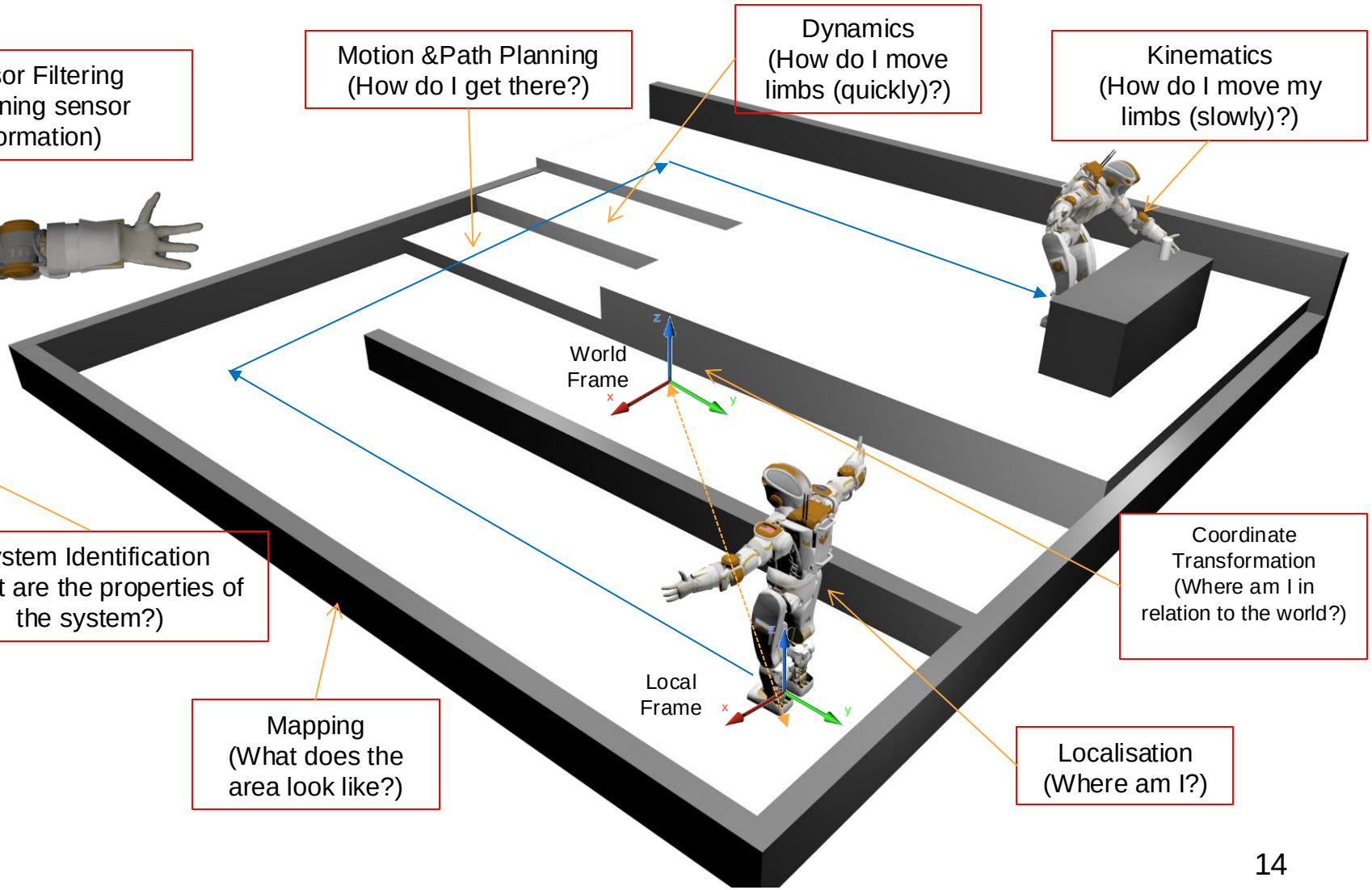
Motor Control
(How to move the motors?)

Sensor Filtering
(Cleaning sensor information)

Motion &Path Planning
(How do I get there?)

Dynamics
(How do I move limbs (quickly)?)

Kinematics
(How do I move my limbs (slowly)?)



System Identification
(What are the properties of the system?)

Coordinate Transformation
(Where am I in relation to the world?)

Mapping
(What does the area look like?)

Localisation
(Where am I?)

Optimisation:
General: How do I minimise some cost function?
QP: How do I move the whole body?

What do we learn in this course?

- Knowledge of fundamental topics relevant to robotics:
  - Motion Planning
  - Dynamics, Kinematics and Control
  - Optimisation and more
- Experience (tutorial + practical) conceptualising a robotic solution to a problem
  - Build/run a simulated robot
  - Program it
  - Achieve dynamic tasks in the simulation

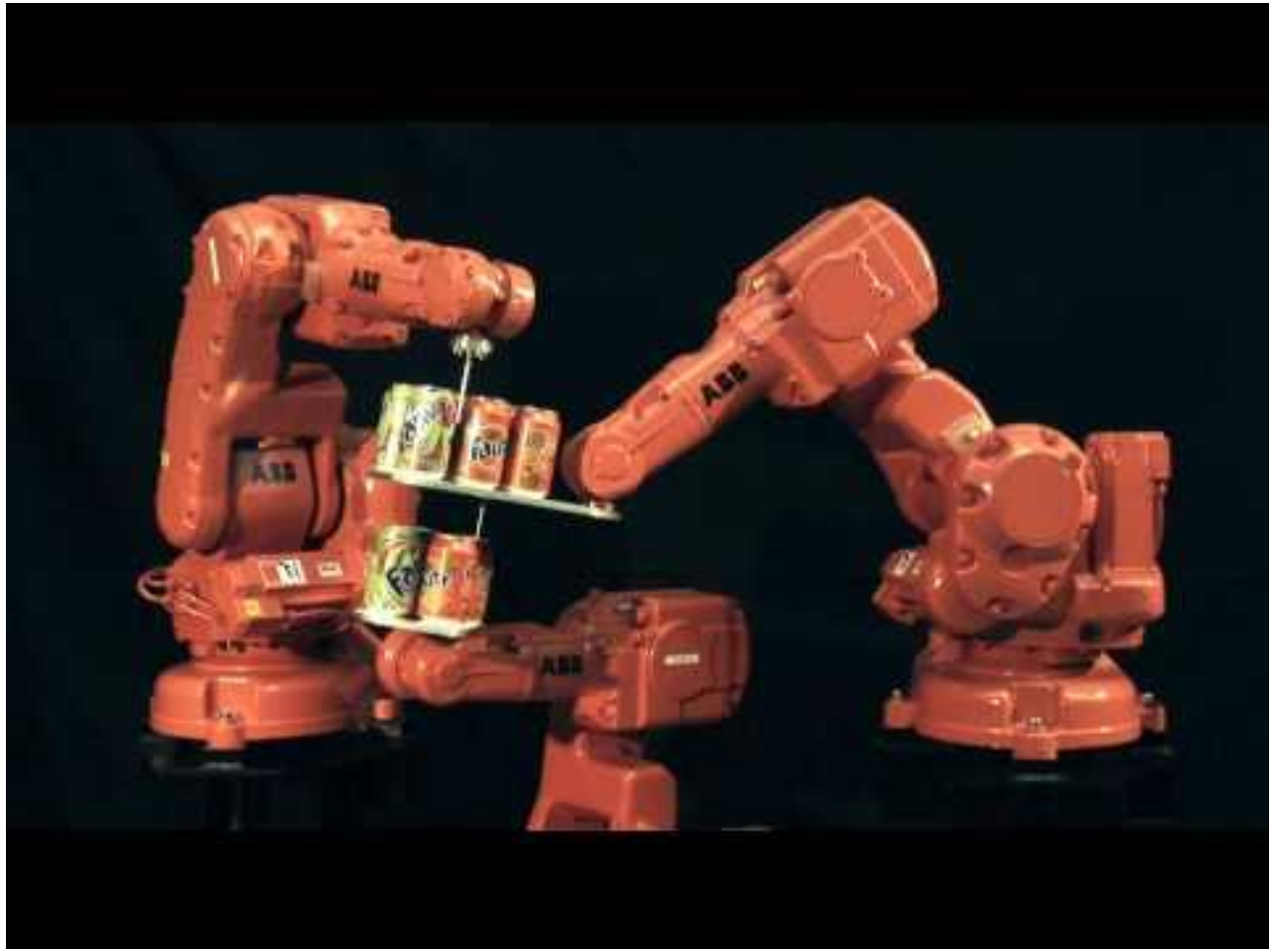
Robot *intelligence* – Levels of Autonomy

Level 5	Intelligently dealing with the unexpected
Level 4	Task-level programming
Level 3	Structured programming
Level 2	Motion primitive programming
Level 1	Point to point programming

Robots: Mapping Behaviours to Concepts Needed

High-speed motion control

Robot Kinematics & Dynamics
System Identification
Kalman Filter
Digital System & control
Design of Advanced Controllers
Trajectory Planning and Motion Planning

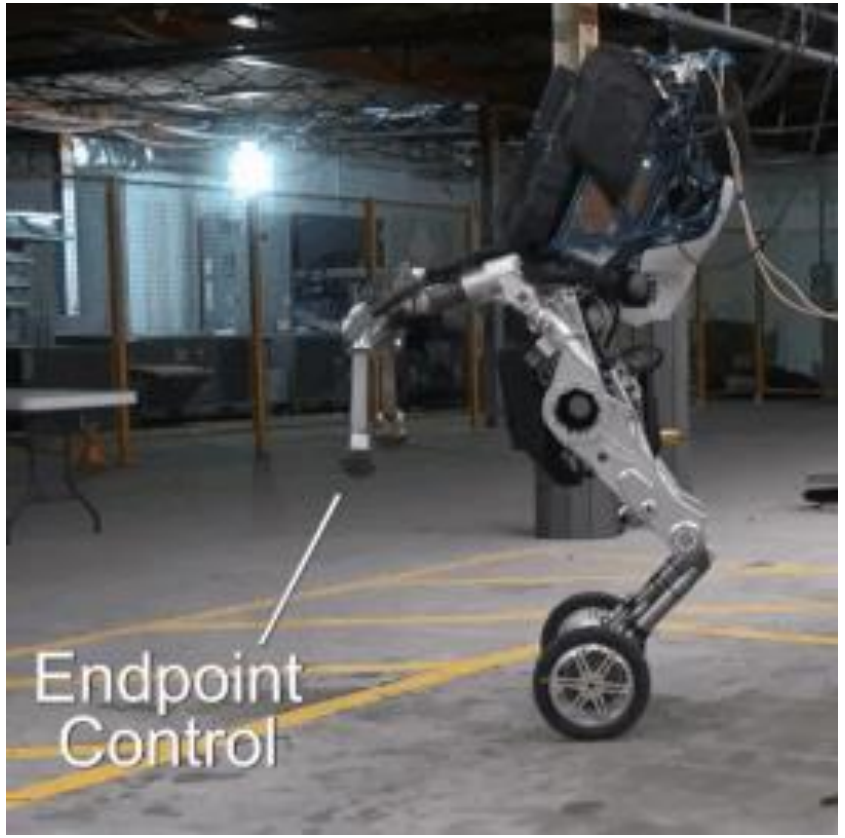


Robots: Mapping Behaviours to Concepts Needed

Sorting parcels in warehouse application

Digital System & control
Localization and Mapping
Path & Motion Planning

Robots: Mapping Behaviours to Concepts Needed

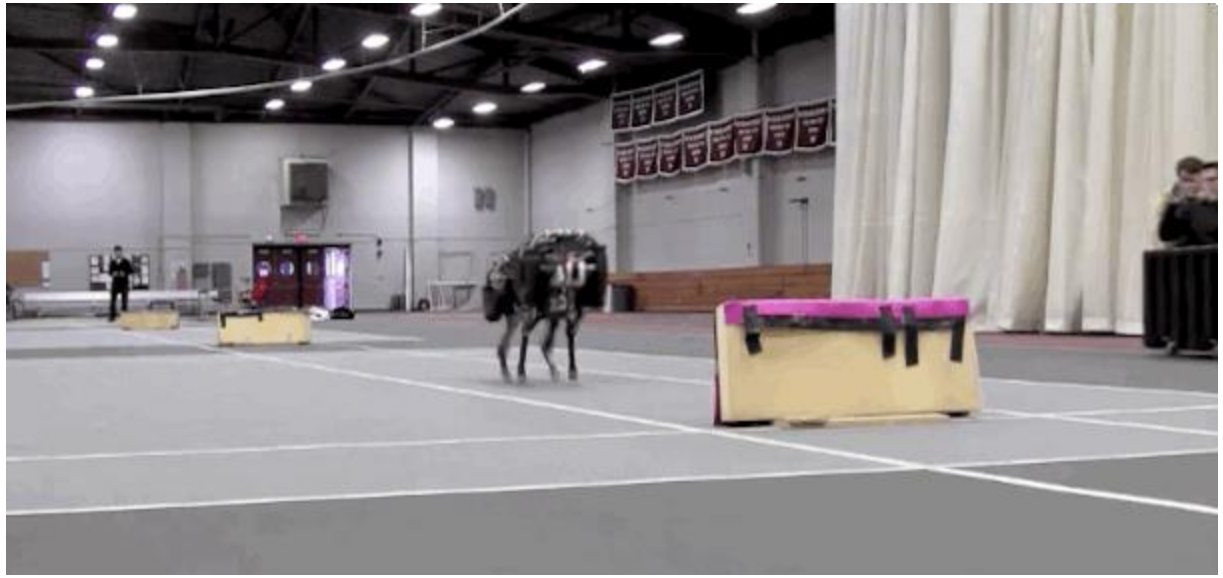


Spot-mini and Handle robots from Boston Dynamics

Robots: Mapping Behaviours to Concepts Needed

Tasks and performance that can only be achieved by dynamic motions

Source: Boston Dynamics (Atlas)



Source: MIT (Cheetah)

Robots: Mapping Behaviours to Concepts Needed

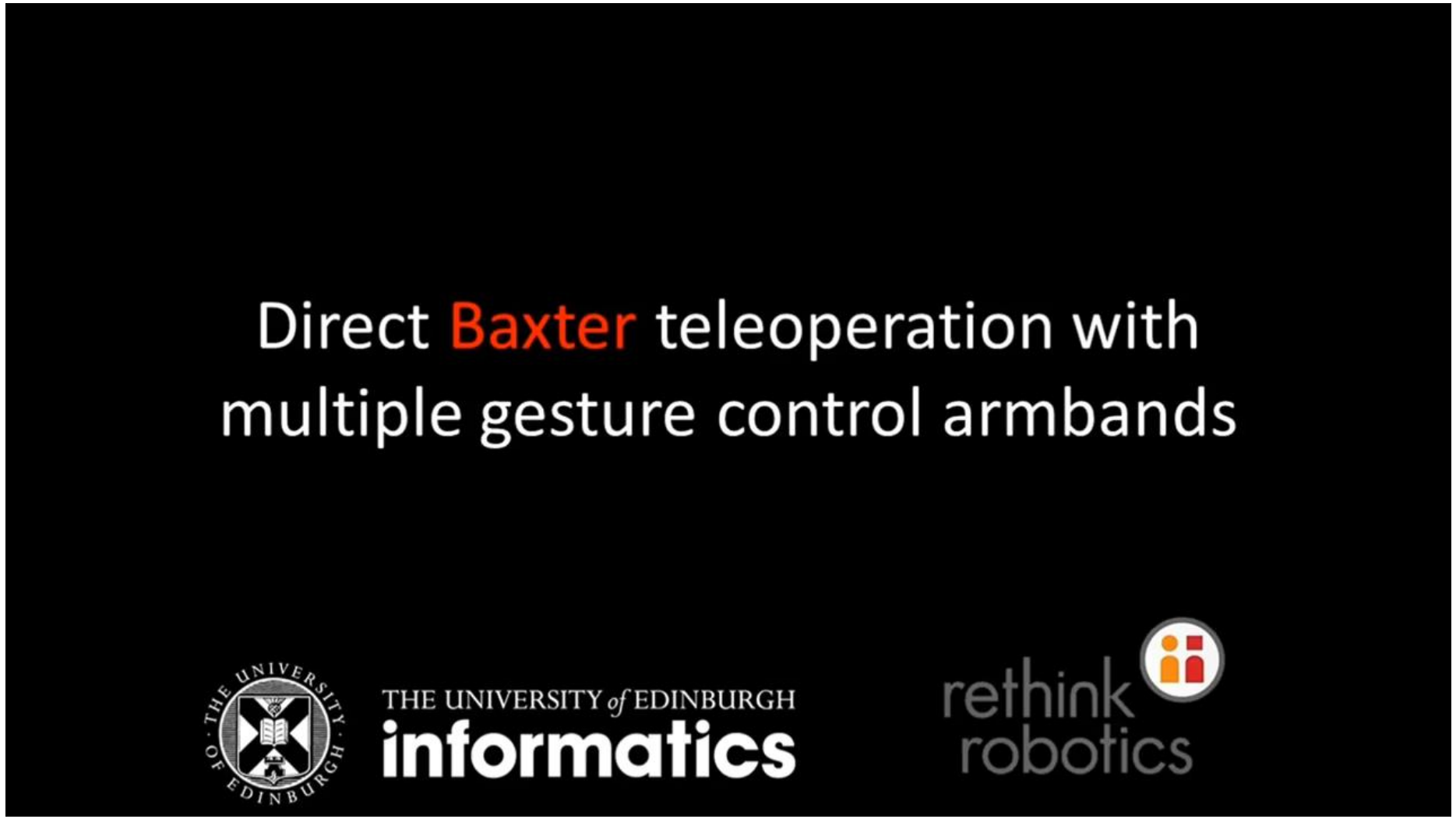
Ocean one, © Stanford University

Robots: Mapping Behaviours to Concepts Needed

What do robots need to know about their environment?

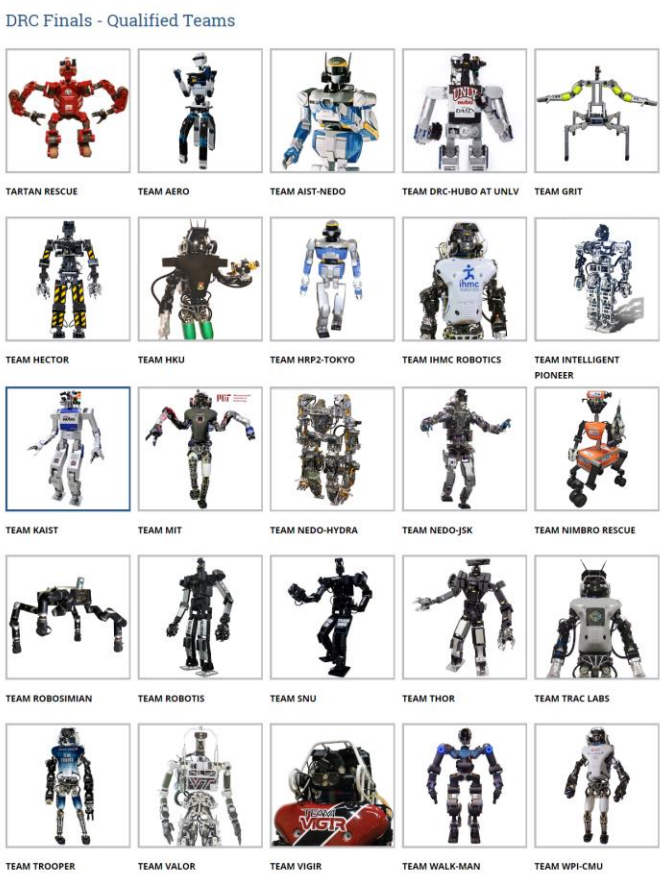
Yiming Yang et al., “HDRM: A Resolution Complete Dynamic Roadmap for Real-Time Motion Planning in Complex Environments”, 2017

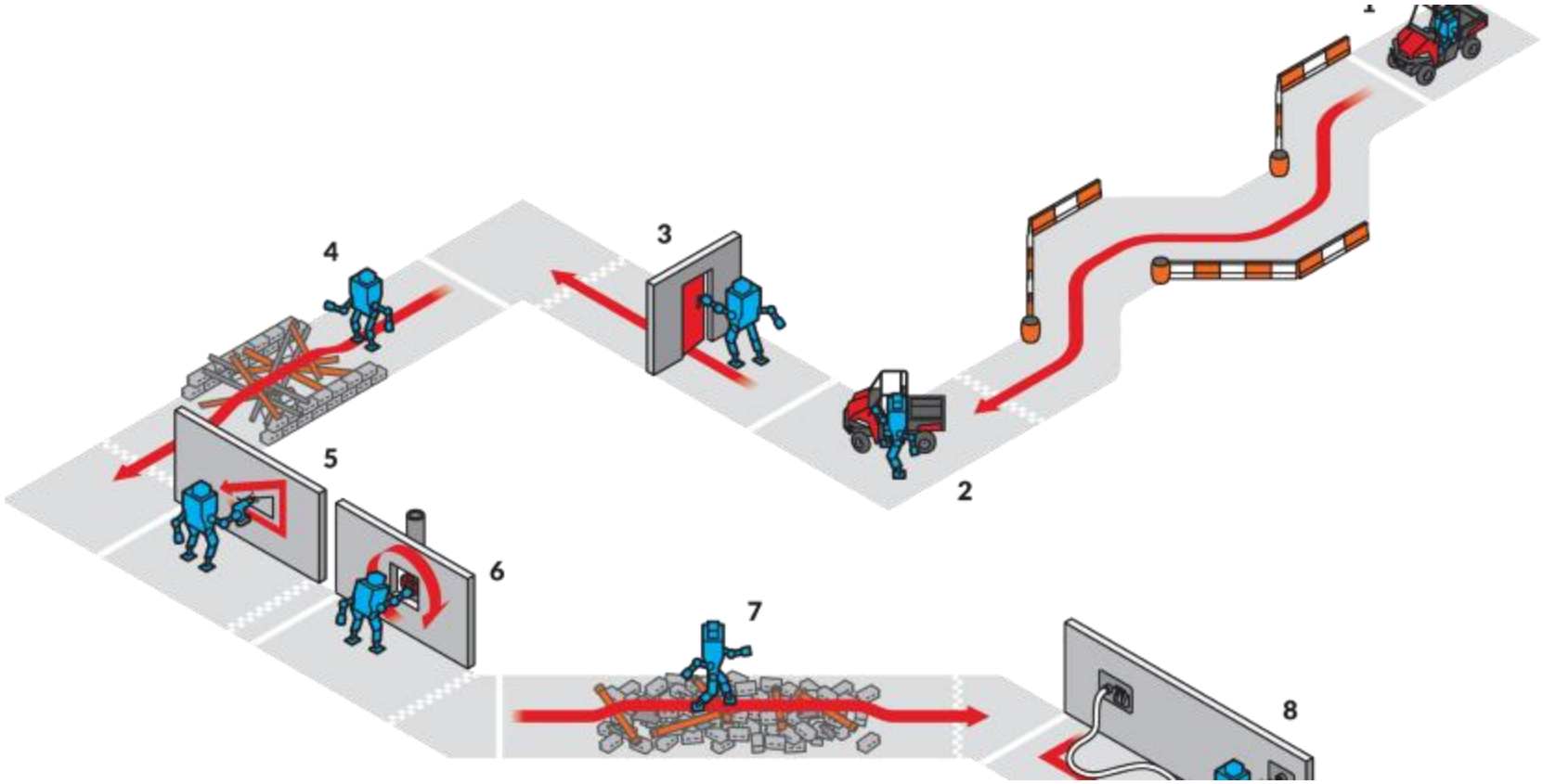
Robots: mapping behaviours to concepts needed



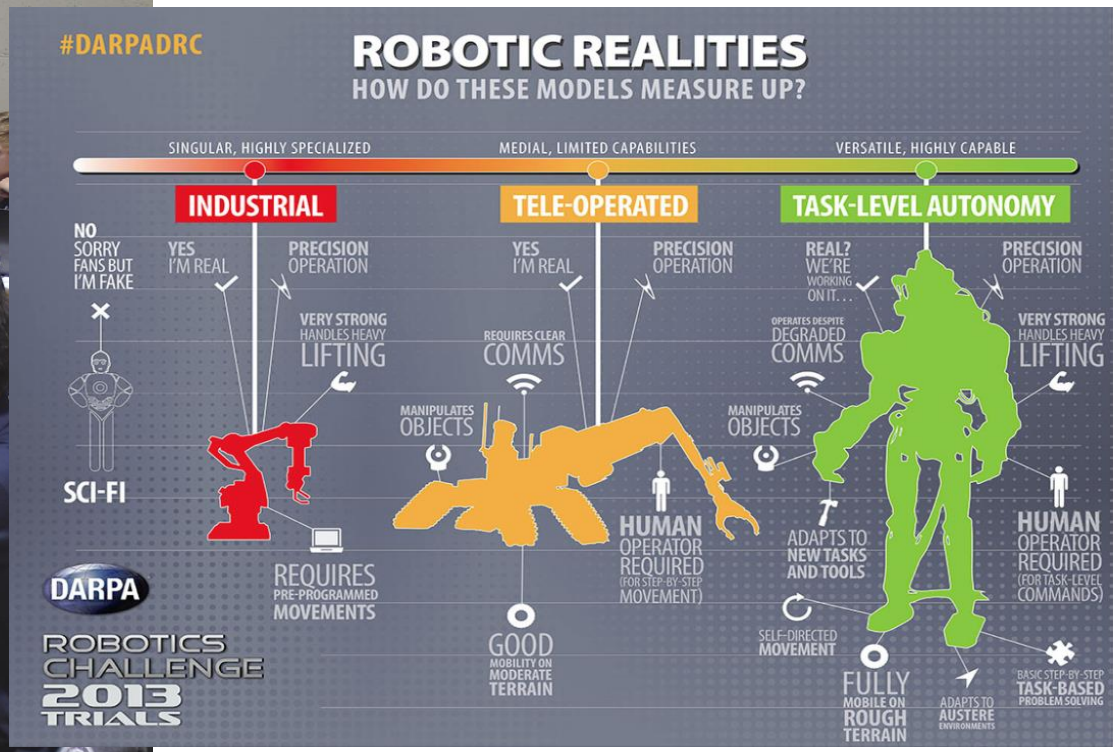
Robots: Mapping Behaviours to Concepts Needed

Towards Autonomy in General Environments





Human Intervention & Supervision in DRC 2013



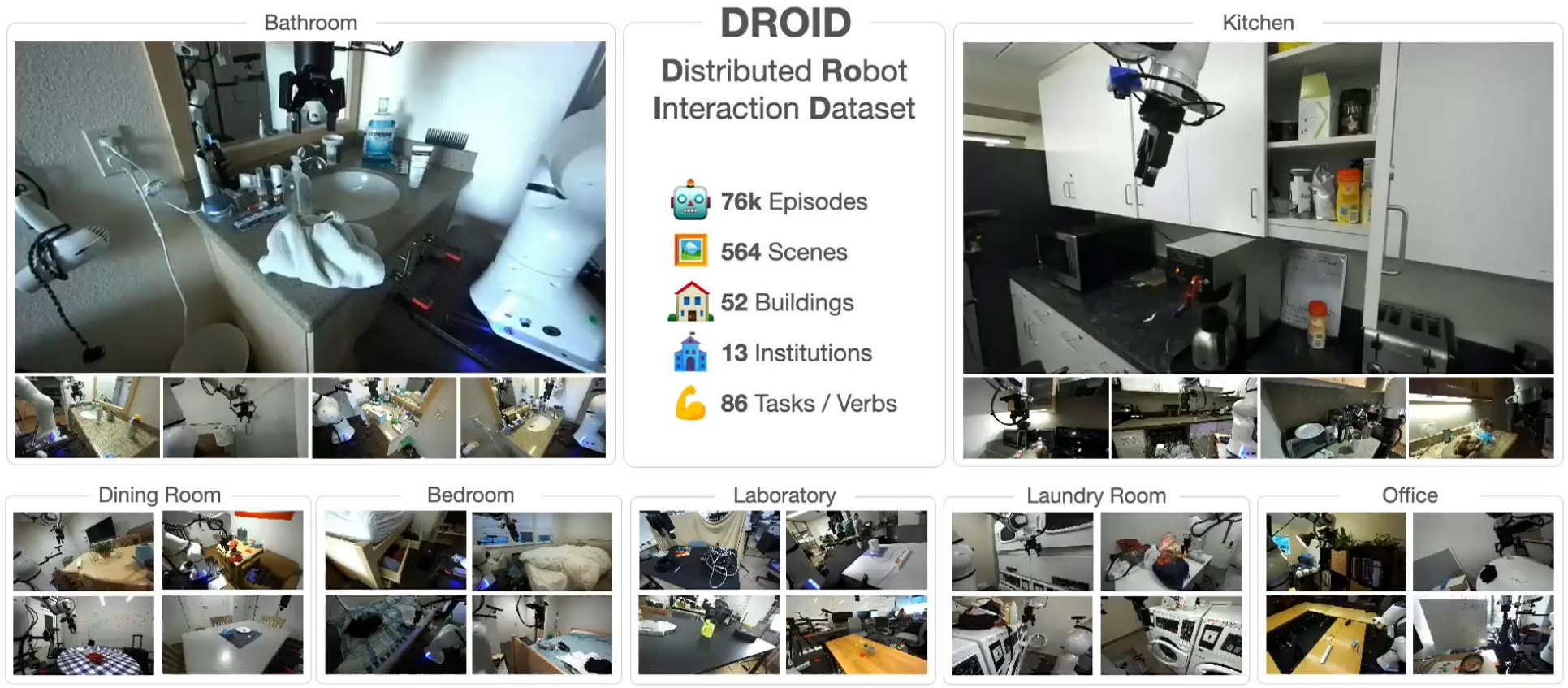
Towards task level autonomy, today…

ALOHA Unleashed: A Simple Recipe for Robot Dexterity

**Tony Z. Zhao,* Jonathan Tompson, Danny Driess, Pete Florence,
Kamyar Ghasemipour, Chelsea Finn, Ayzaan Wahid***

Google DeepMind

Role of Data


Bathroom
DROID
Distributed Robot Interaction Dataset
76k Episodes
564 Scenes
52 Buildings
13 Institutions
86 Tasks / Verbs
Kitchen
Dining Room
Bedroom
Laboratory
Laundry Room
Office

Are we there yet?

https://earlyarts.co.uk/blog/using-clay-to-nurture-young-childrens-development

Selected Readings (Optional)

	Additional reading
Trajectory Planning and Motion Planning (articulated) Design of Advanced Controllers	Siciliano, B., et al., Robotics: Modelling, Planning and Control. Franklin, Gene F., et al., Feedback control of dynamic systems.
Optimization	Jorge Nocedal, Stephen Wright – Numerical optimization
Model Predictive Control	J.M. Maciejowski, Predictive control : with constraints.
Machine Learning for Robot Control	Ian Goodfellow, et al., Deep Learning.