Introduction to Robotics

Robotics – COMS4045A/7049A

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&

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Course Details

- Lecturers:
  - Prof. Benjamin Rosman / Dr Pravesh Ranchod
- Contact details:
  - Offices: MSB UG22 / MSB UG14
  - Email: Benjamin.Rosman1@wits.ac.za / pravesh.ranchod@wits.ac.za
- Lecture Venues and Times:
  - All lectures are in MSL110 on Thursdays from 14h15 - 16h00.
- Format:
  - Lectures will be posted online. In person sessions will be labs and tuts. Please make sure you watch the relevant lecture before its session.
  - Robotics is a practical subject, so lab time is critical to the course!

What we'll do

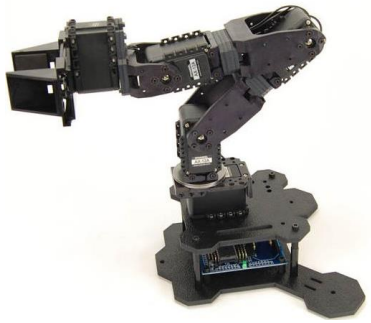
- Programming a robot using ROS (Robot Operating System)
- Modelling and controlling a robot arm
  - Kinematics and dynamics
- Controlling a mobile robot
  - Control theory
- Working with sensors
- Planning – Navigating environments
- Localization – Requires a map
- Mapping – Requires positioning information
- SLAM – Simultaneous Localization and Mapping

Assessments

- Labs: 10%
  - Labs will be submitted and marked
- Assignment: 20%
  - One assignment due at the end of the course (date to be announced)
- Tests: 30%
  - There will be three invigilated tests throughout the course.
- Exam: 40%

Software and hardware

- ROS
  - Robot Operating System (Kinetic)
  - Ubuntu
  - Turtlebot Simulator
  - TUM_Simulator (AR Drone)
  - Yumi Simulator
- Singularity container
- Robots
  - Turtlebot
  - AR Drones
  - PhantomX Grippers
  - RoboMaster
  - Kuri
  - Yumi
  - A1 dog



Now onto the cool stuff…

What is a robot?

- Machine that **autonomously** performs **intelligent** tasks in some world
  - Some interaction between **agent** and **environment**

What is autonomy for a robot?

- System can achieve a task **on its own**
  - Otherwise: manual, tele-operated
  - Degree of human intervention?
- **Maintain behaviour** against disturbances
  - May involve predictions

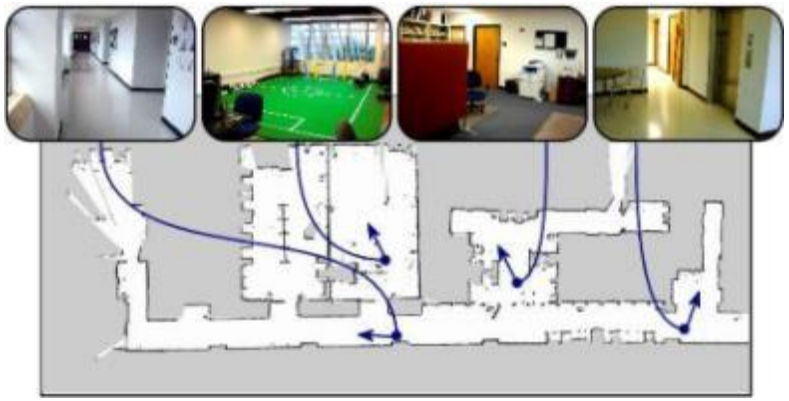
- Affected by and affects the real world around it directly
- Closed loop:
  - Output affects subsequent input and task achievement

What is intelligence for a robot?

- **Carry out tasks** that require more than a pre-programmed sequence
- **Adapt** to dynamic environments
- **Improve performance** from experience
- **Plan** (and re-plan) appropriate

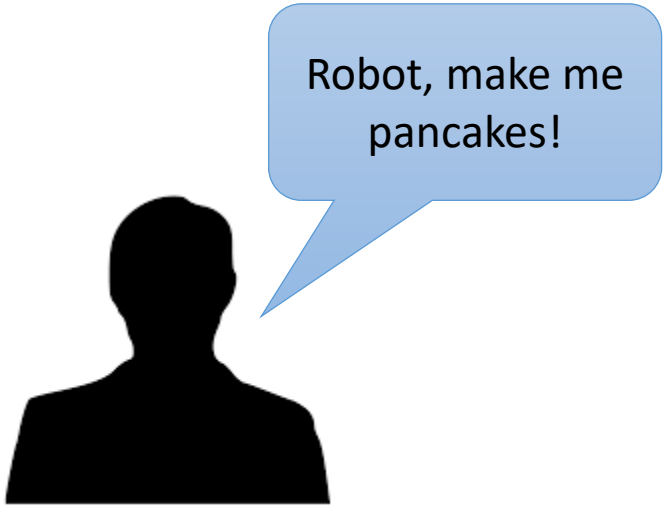
  actions given high-level goals

"HIS PATH-PLANNING MAY BE SUB-OPTIMAL, BUT IT'S GOT FLAIR."



The robot's problem

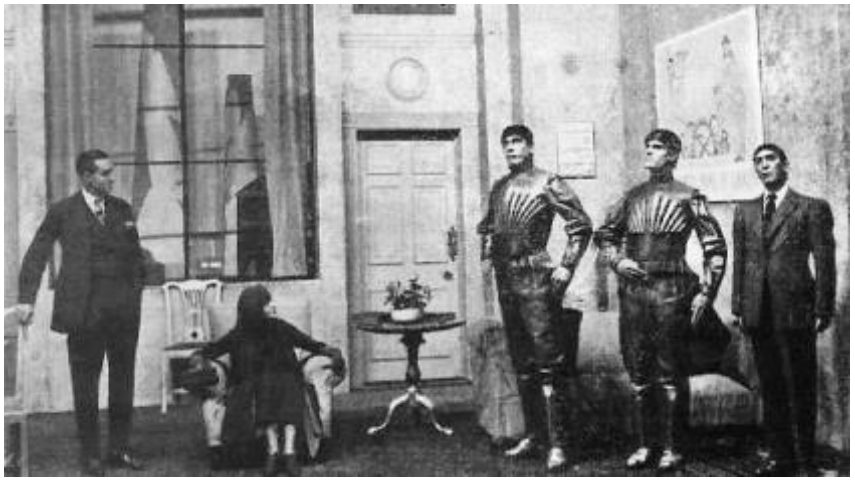
- Given (ill-posed) requirements, **compute actions** to achieve complex goals
  - Requires clever strategies to deal with **incomplete knowledge** of an **unknown future**



What is a robot?

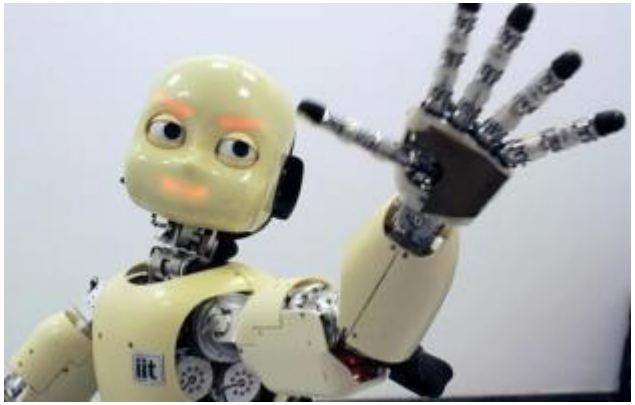
- An artificial system that can:
  1. **sense** an aspect of its environment,
  2. make **decisions** based on this information,
  3. **act** in response.

- From the Czech word for worker or labourer (1920)
  - R. U. R. (Rossum's Universal Robots) - Karel Čapek

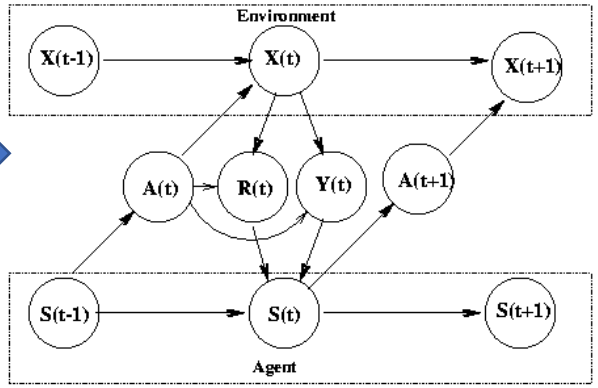


Perception-action loop architecture

Sense the environment



Plan behaviours



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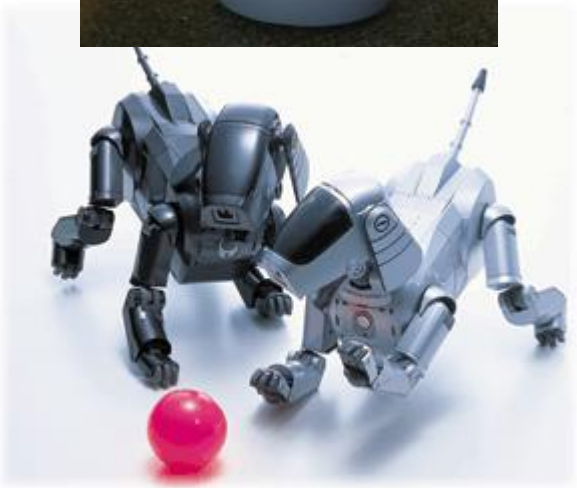
Execute actions

Why robotics?

- Dull, dirty, dangerous jobs

Why robotics?

- Entertainment, service industry

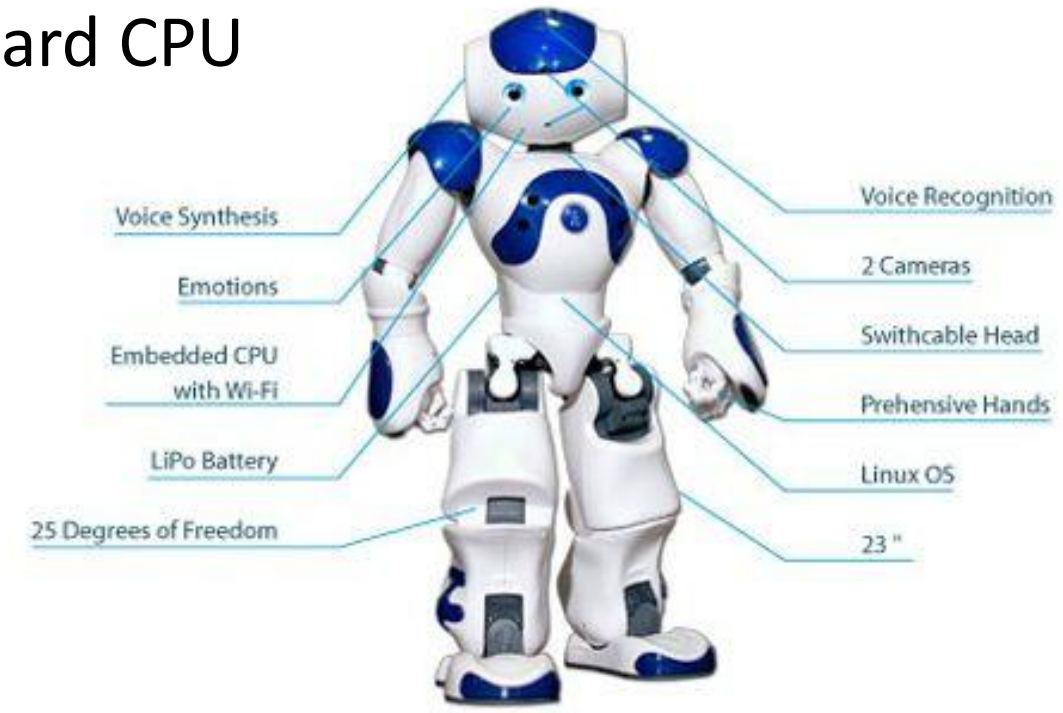


Why robotics?

- Science:
  - Understanding of actions and decisions
  - Incorporates all aspects of AI

Anatomy of a robot

- Sensing – external and internal
  - Exteroception vs proprioception
- Moving – actuators
- Processing – on-board CPU

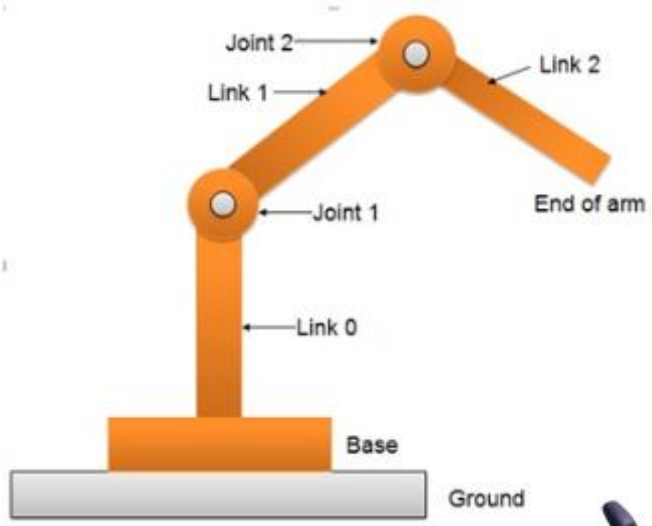


Anatomy of a robot

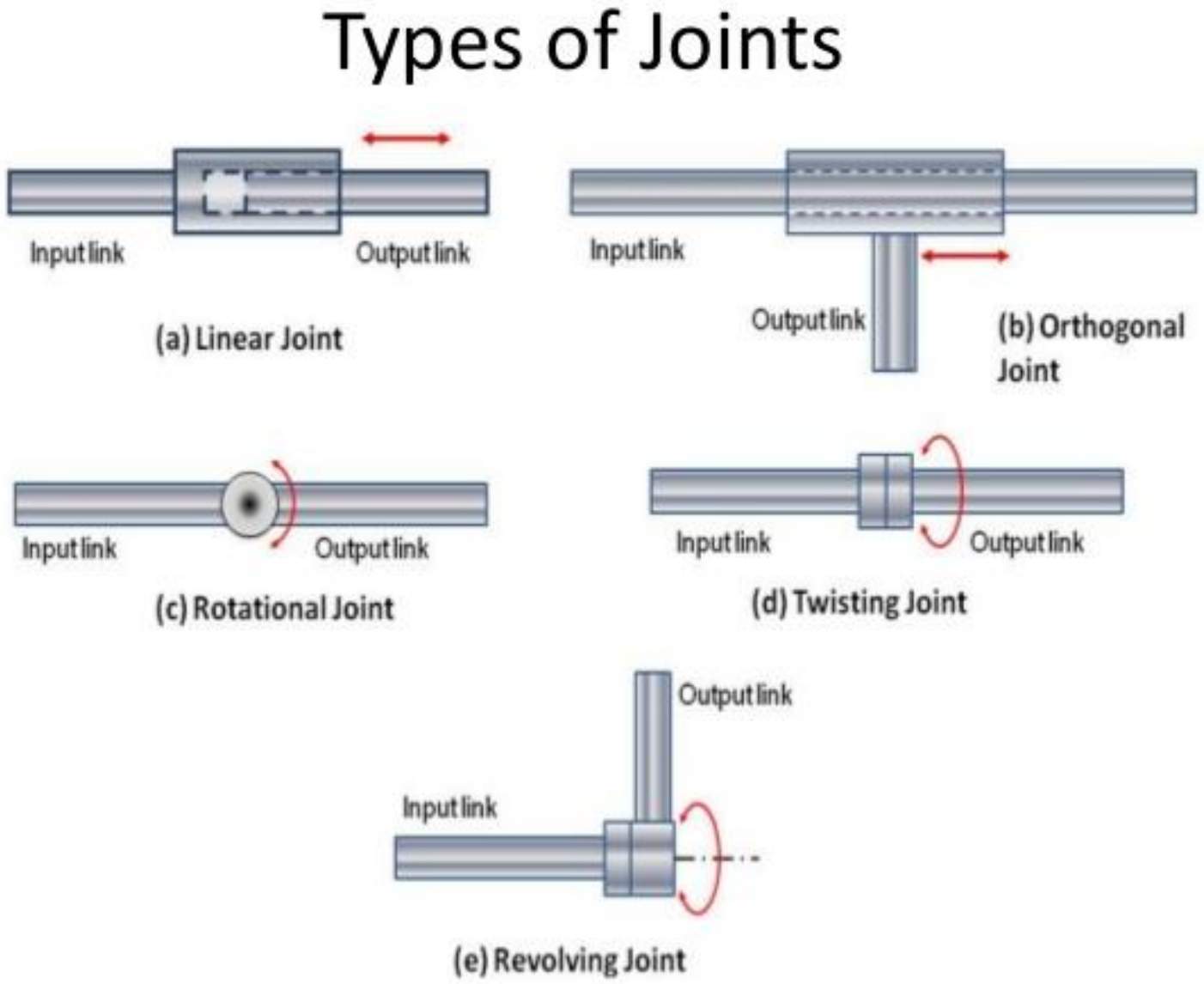
- Links and joints (degrees of freedom)
- DoF of robot

  = number of joints

- End effectors

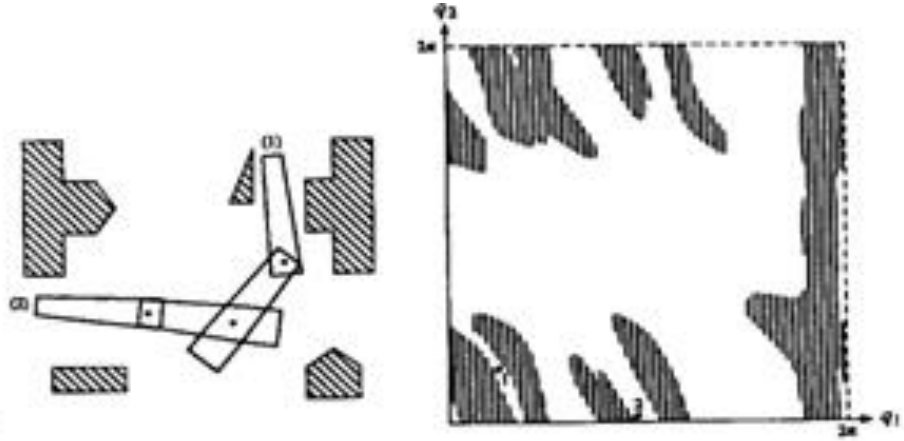


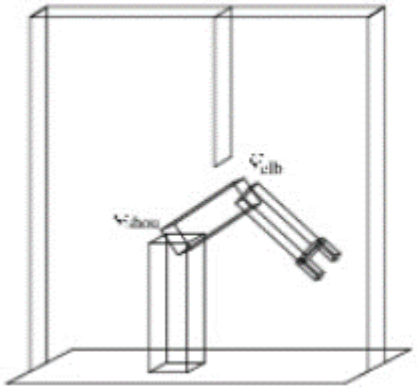
Anatomy of a robot

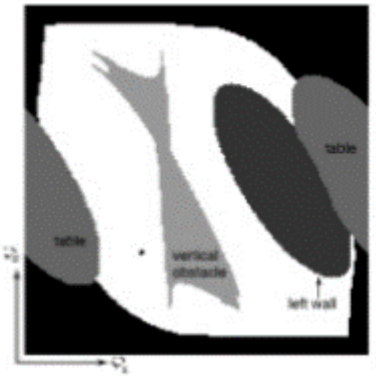


Anatomy of a robot

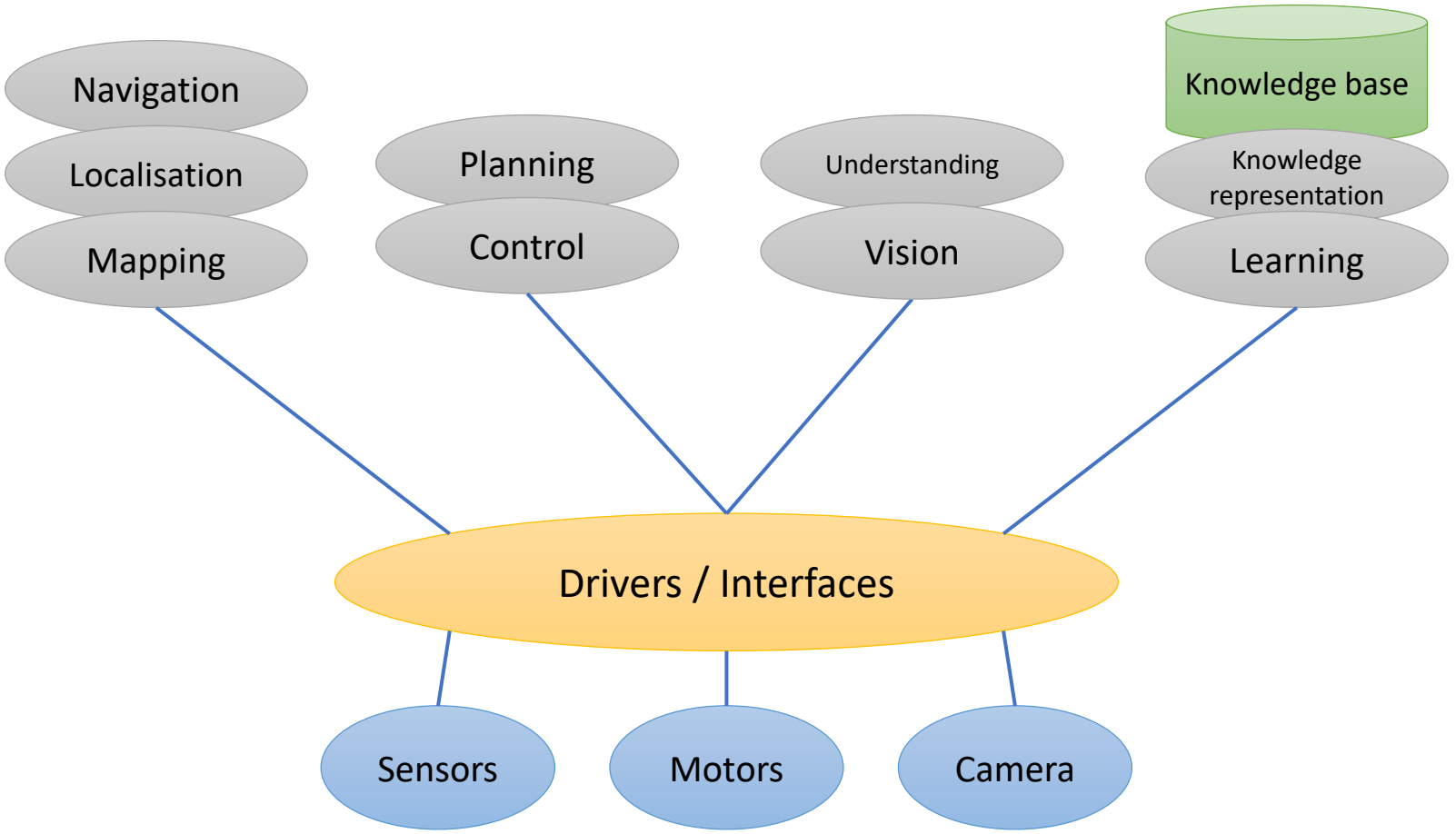
- Configuration space vs work space
- Work space (or task space):
  - Physical environment
  - Robot occupies volume in space
  - (x,y,z) co-ordinates
- Configuration space (or joint space):
  - Space of joint values
  - Point in space corresponds to full configuration







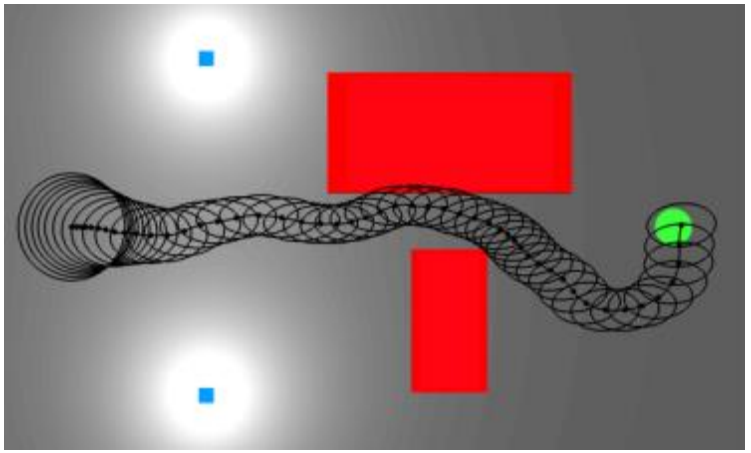
Anatomy of a robot



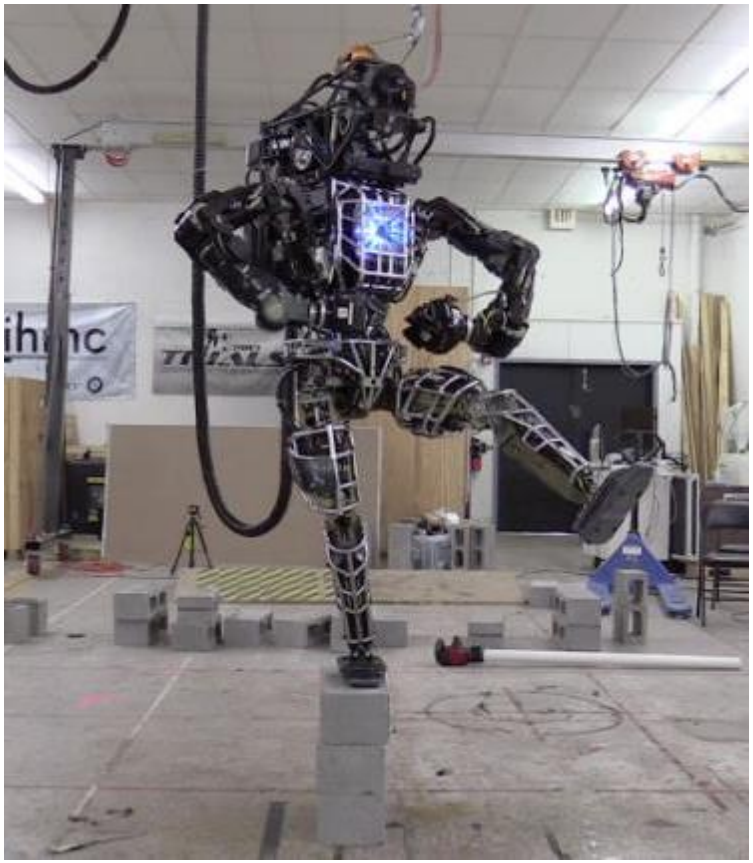
What is hard?

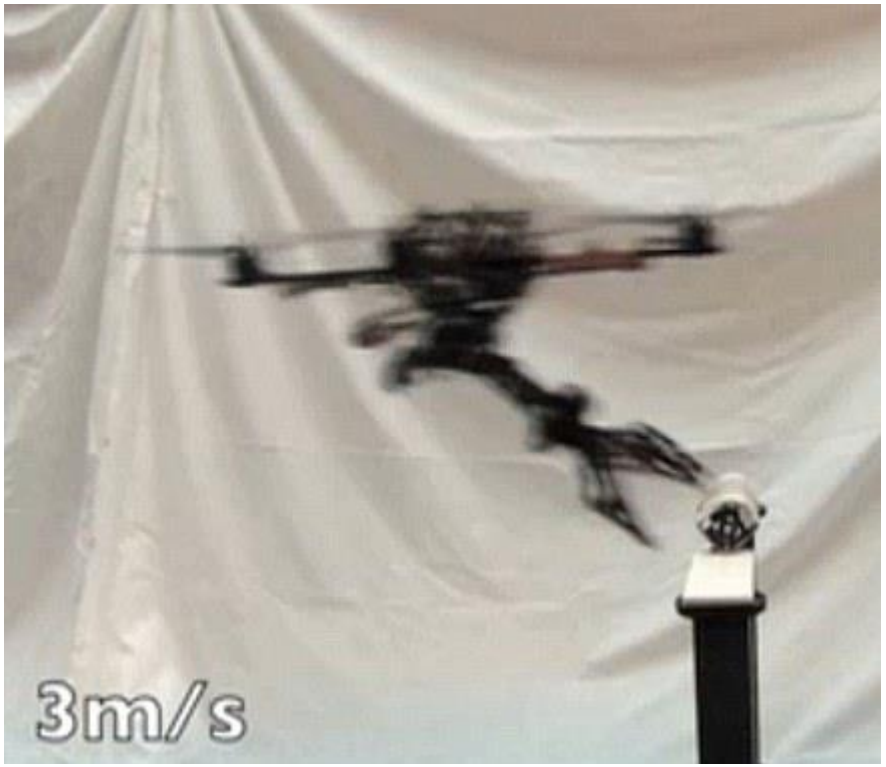
- **Uncertainty** is inherent to robotics
- Robot's knowledge is limited to:
  - What it has been told (typically very high level)
  - What its sensors tell it (typically limited range and quality)
- Effects of actions are uncertain
- The world may change (and is only **partially observed**)
- **Fuse** all this information and

build comprehensive **models**



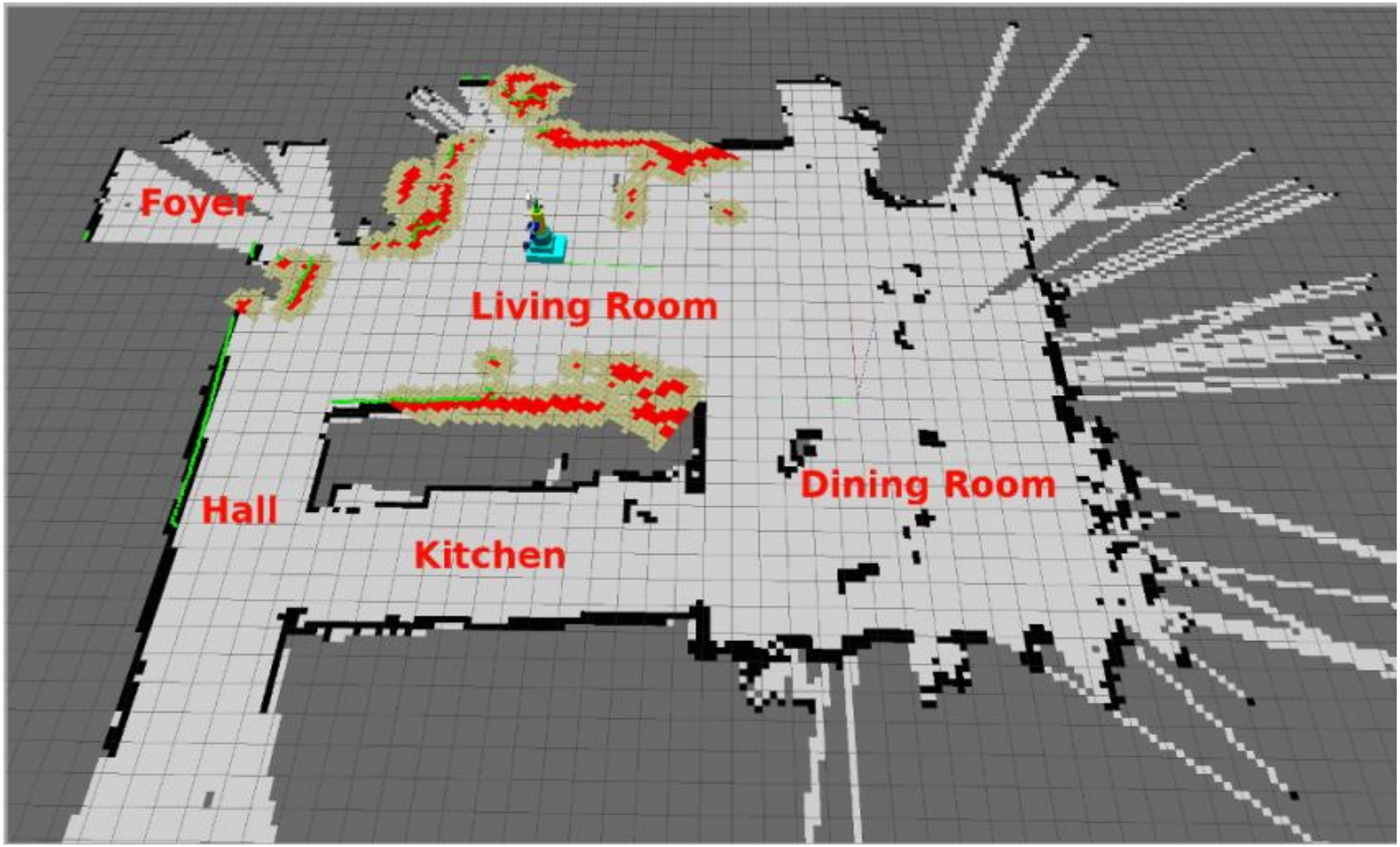
Challenges: control





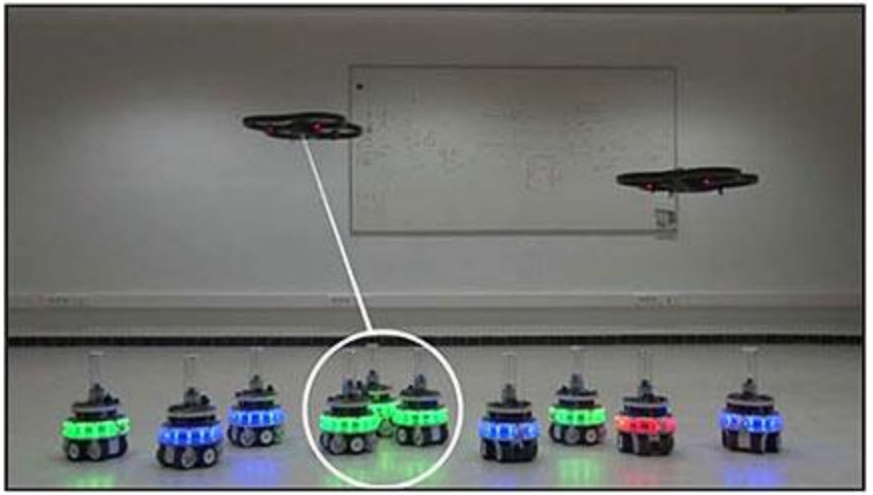
Challenges: perception

Challenges: localisation



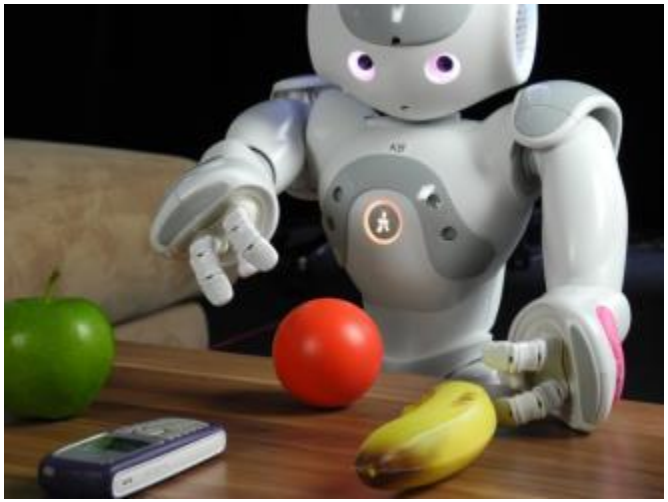
Challenges: communication

- Human-robot interaction
- Heterogeneous teams
  - Task allocation
- Homogeneous teams
  - Swarms



Challenges: behaviour learning

- Reinforcement learning
- Learning from demonstration

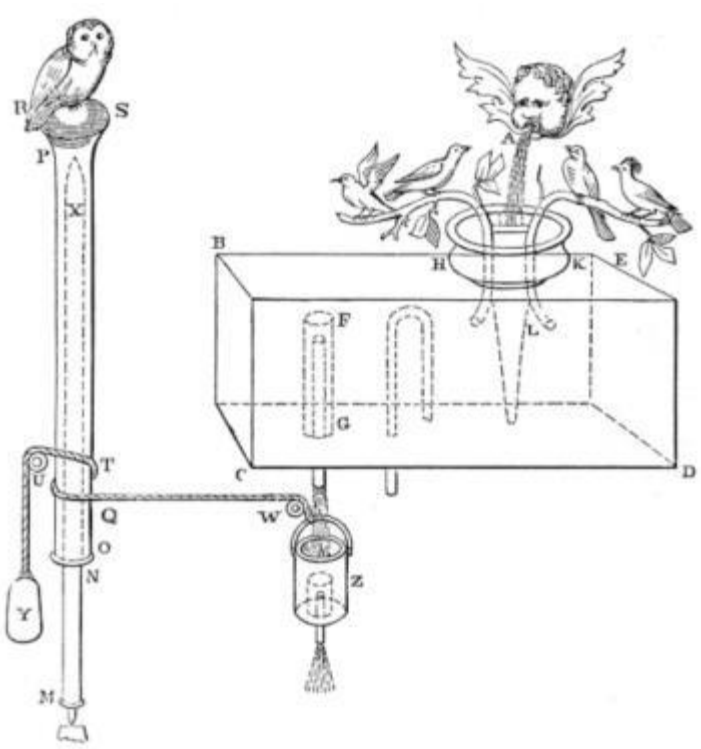


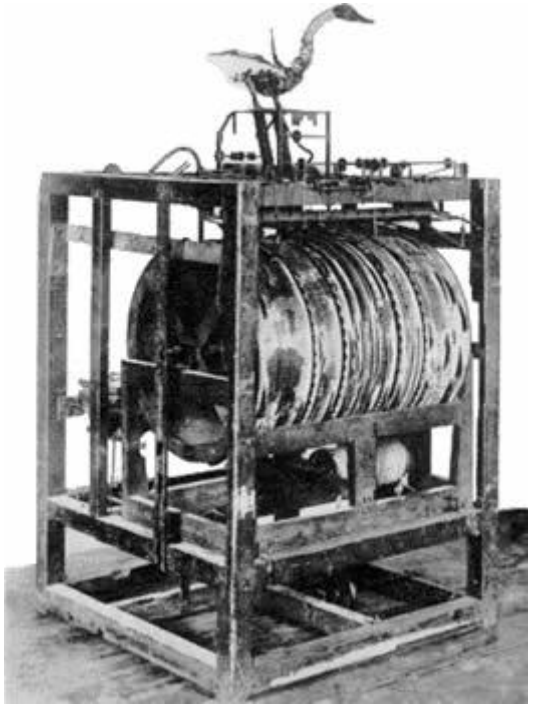
Challenges: lifelong learning

- Acquiring knowledge
  - Expanding representations
  - Abstracting data
- Increasing skill sets
  - Improving skills
  - Managing skill sets
  - Selecting appropriate skills

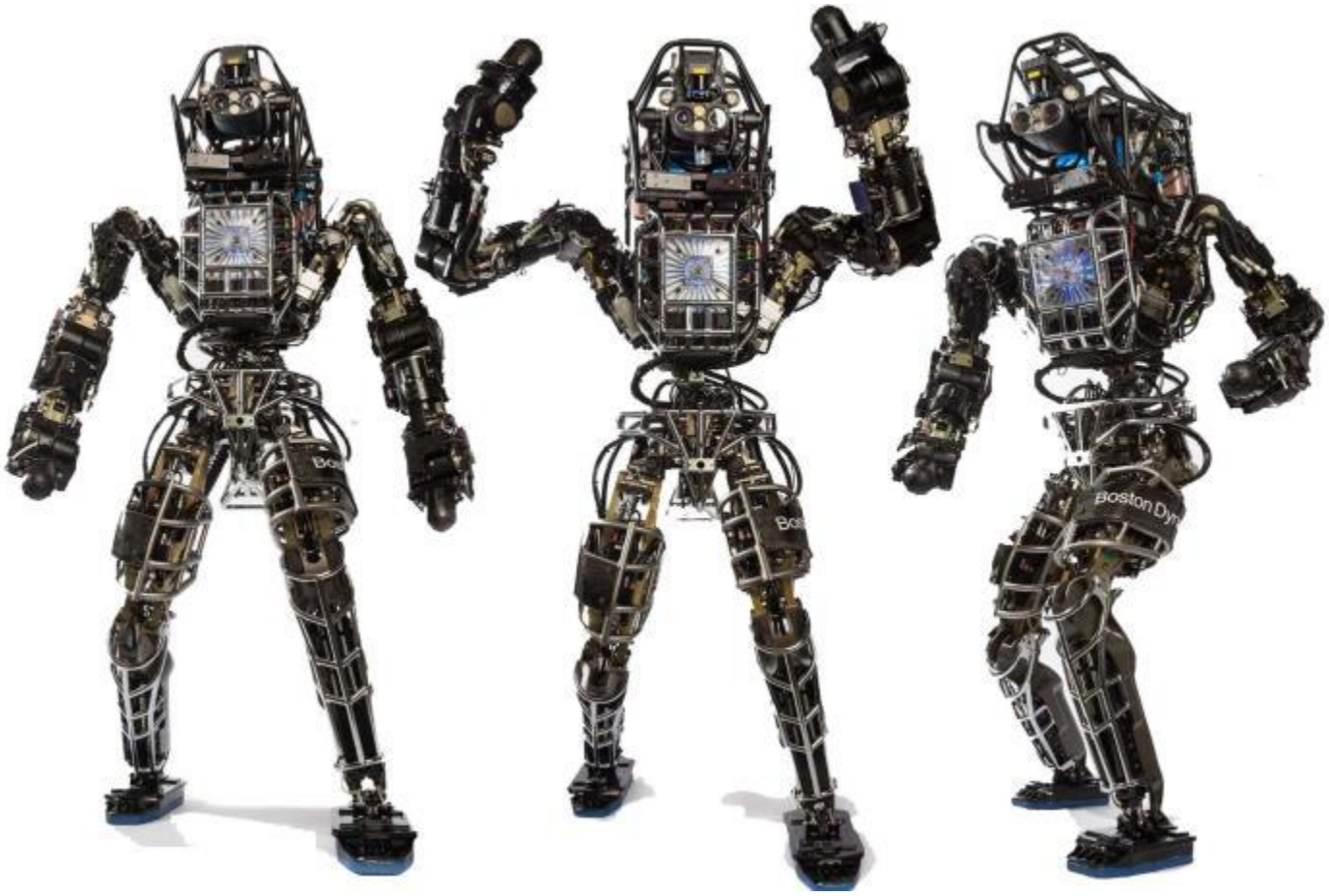
Examples – ancient

- Hero of Alexandria (c. 10 – 70 AD)
- Digesting Duck – Jacques de Vaucanson (1739)





Examples – humanoids



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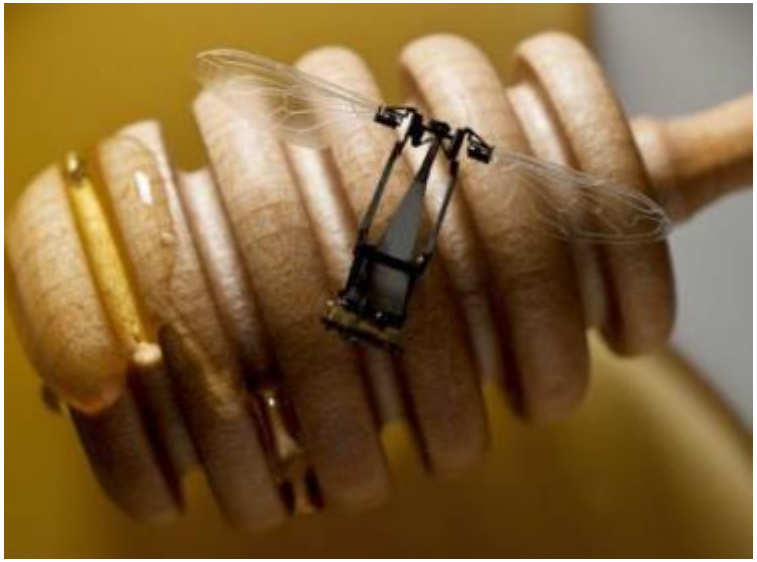
Examples – animals



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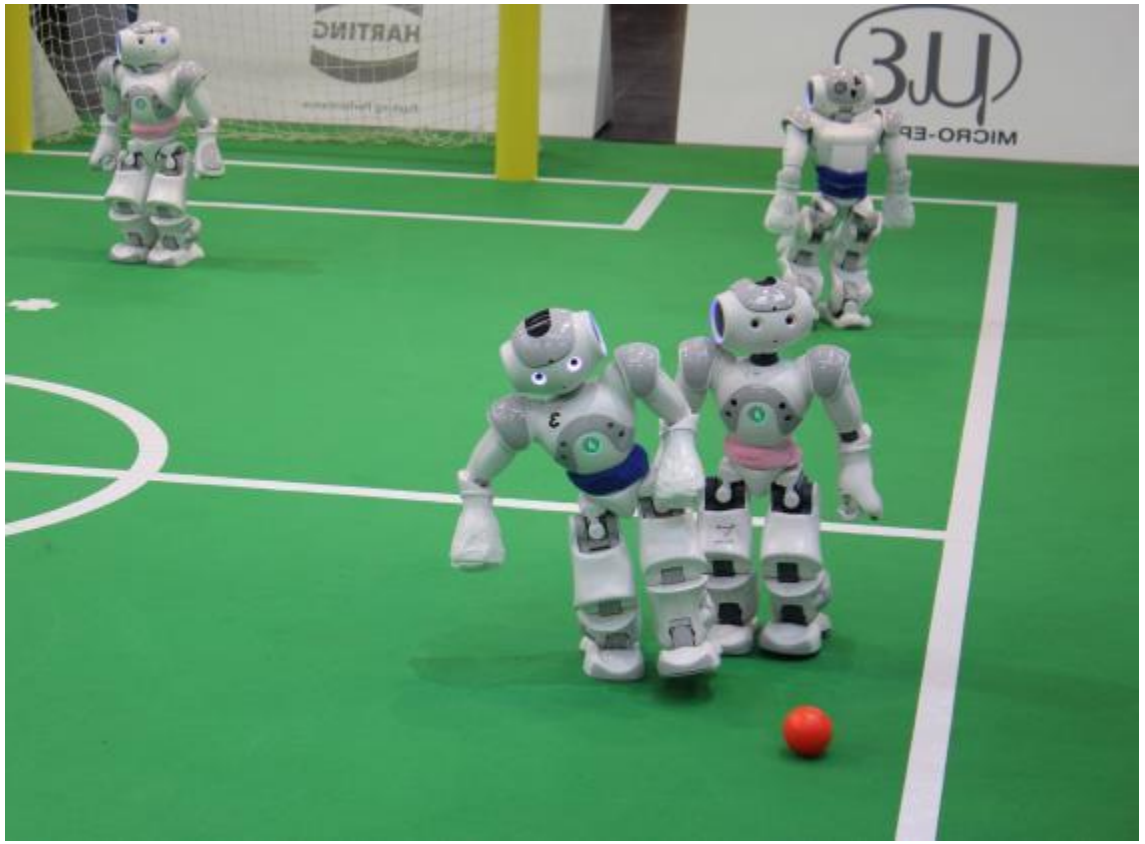
Examples – multipurpose platforms

Examples – other

Examples – RoboCup



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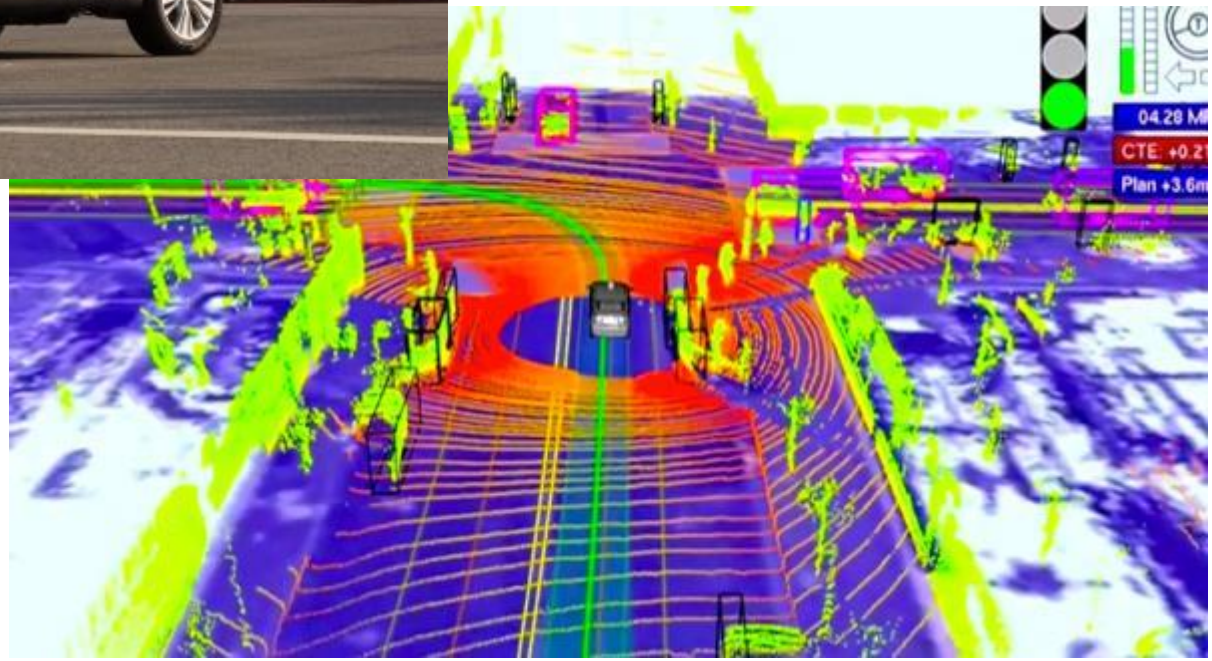
Examples – autonomous driving



Thank you!

Questions?