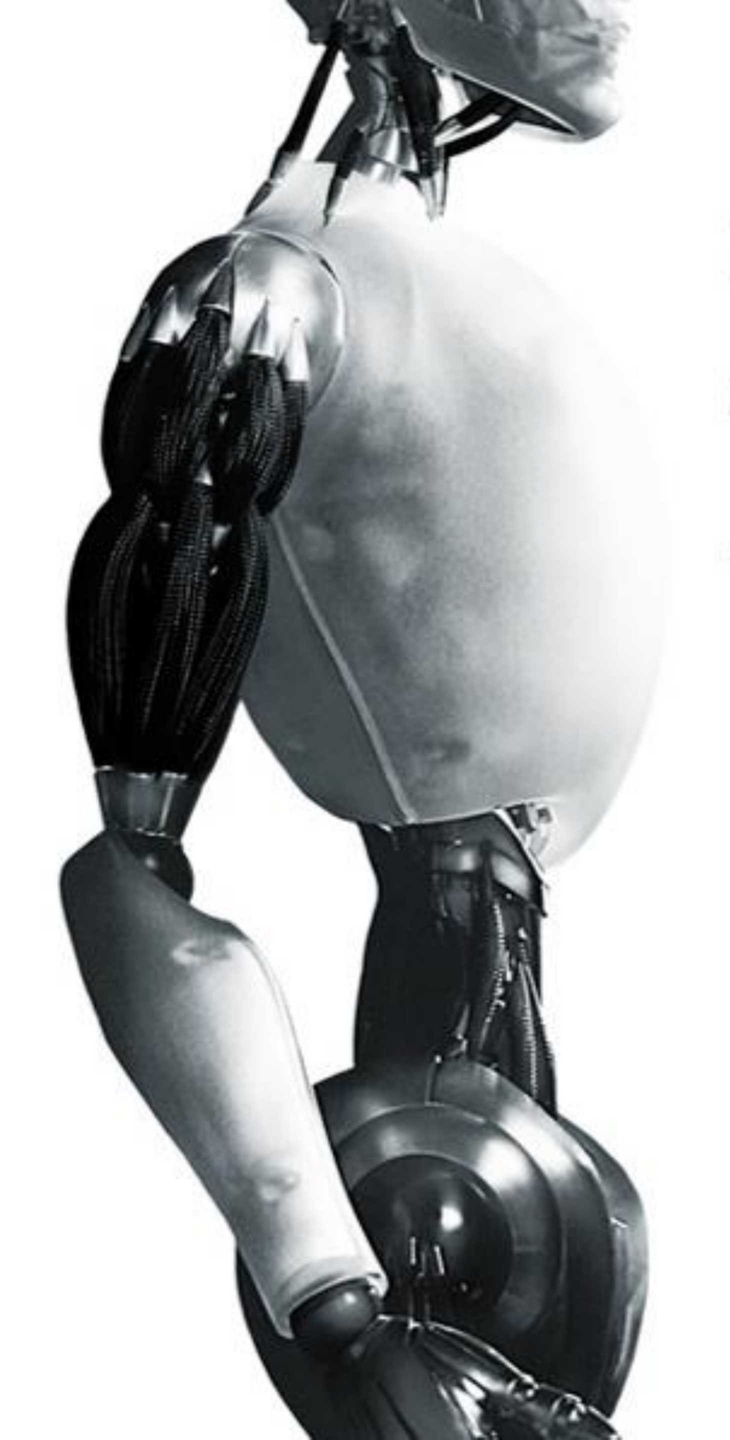


ZA-2203 Robotic Systems

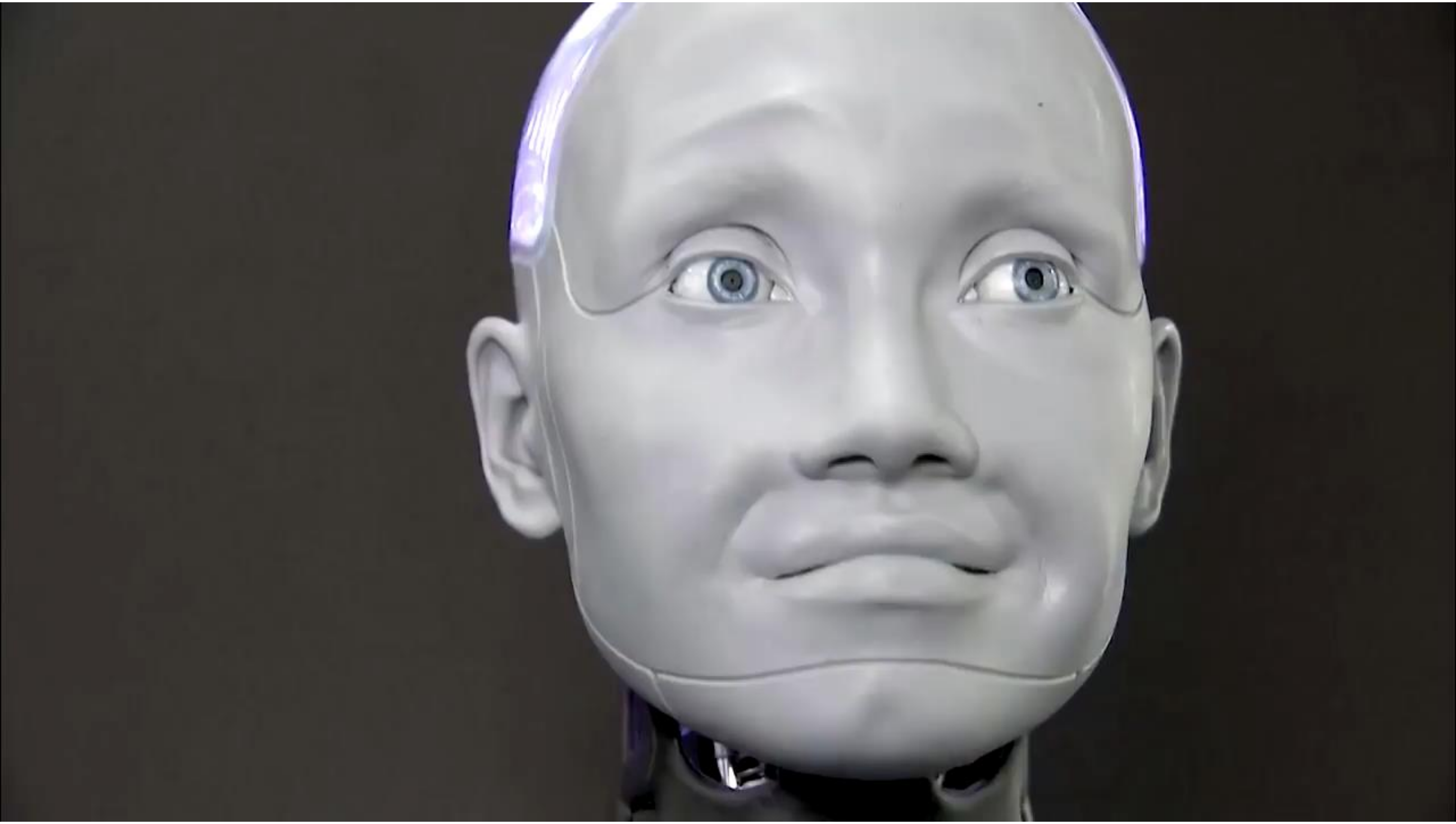
Lecturers:

Dr Ong Wee Hong

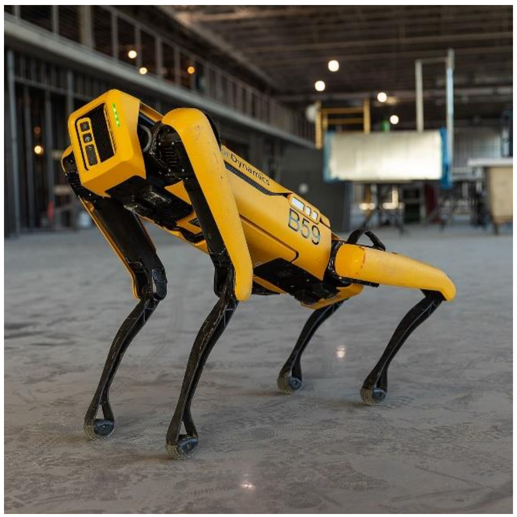
✉ weehong.ong@ubd.edu.bn, Office: SDS 2.43

Dr Ajaz Ahmad Bhat

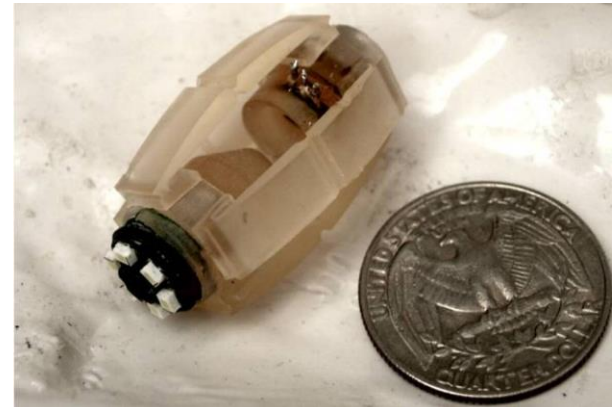
✉ ajaz.bhat@ubd.edu.bn, Office: SDS 2.48



Ameca robot   https://youtu.be/H_1x7OTowu0





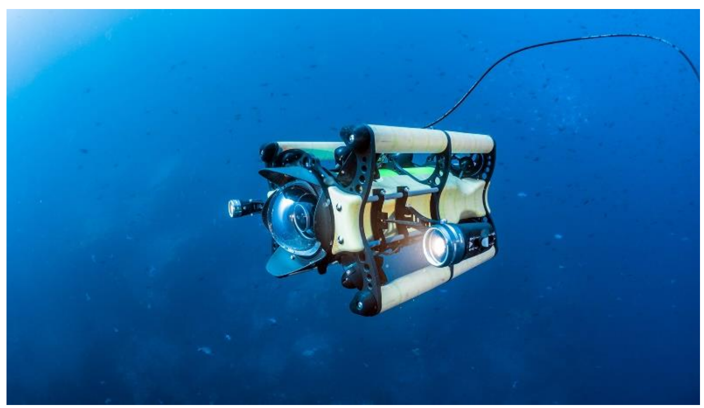
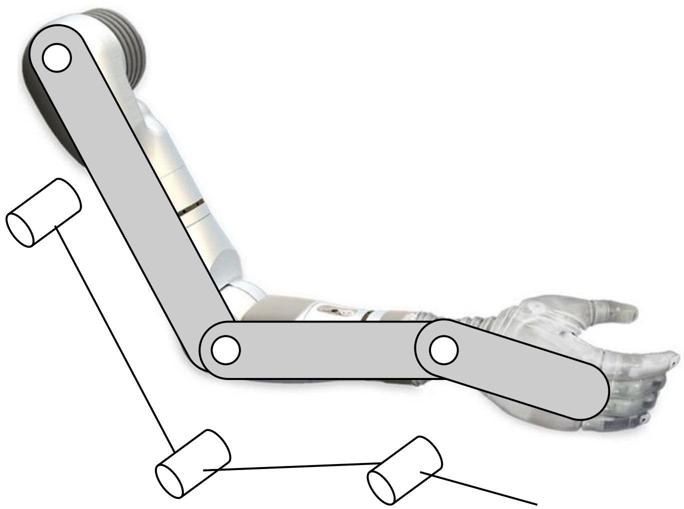
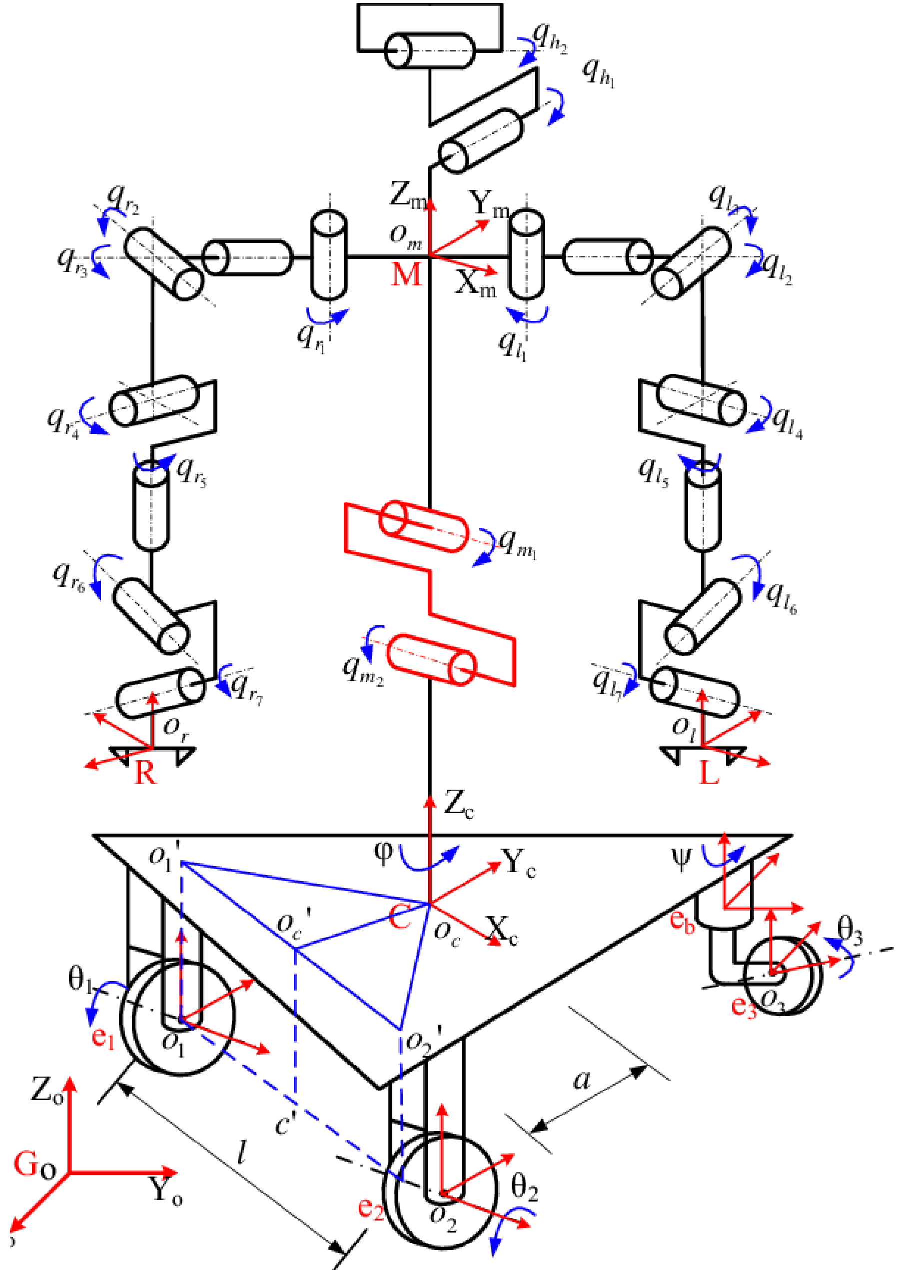




Image source: Internet, credit goes to original owners

Articulated rigid bodies





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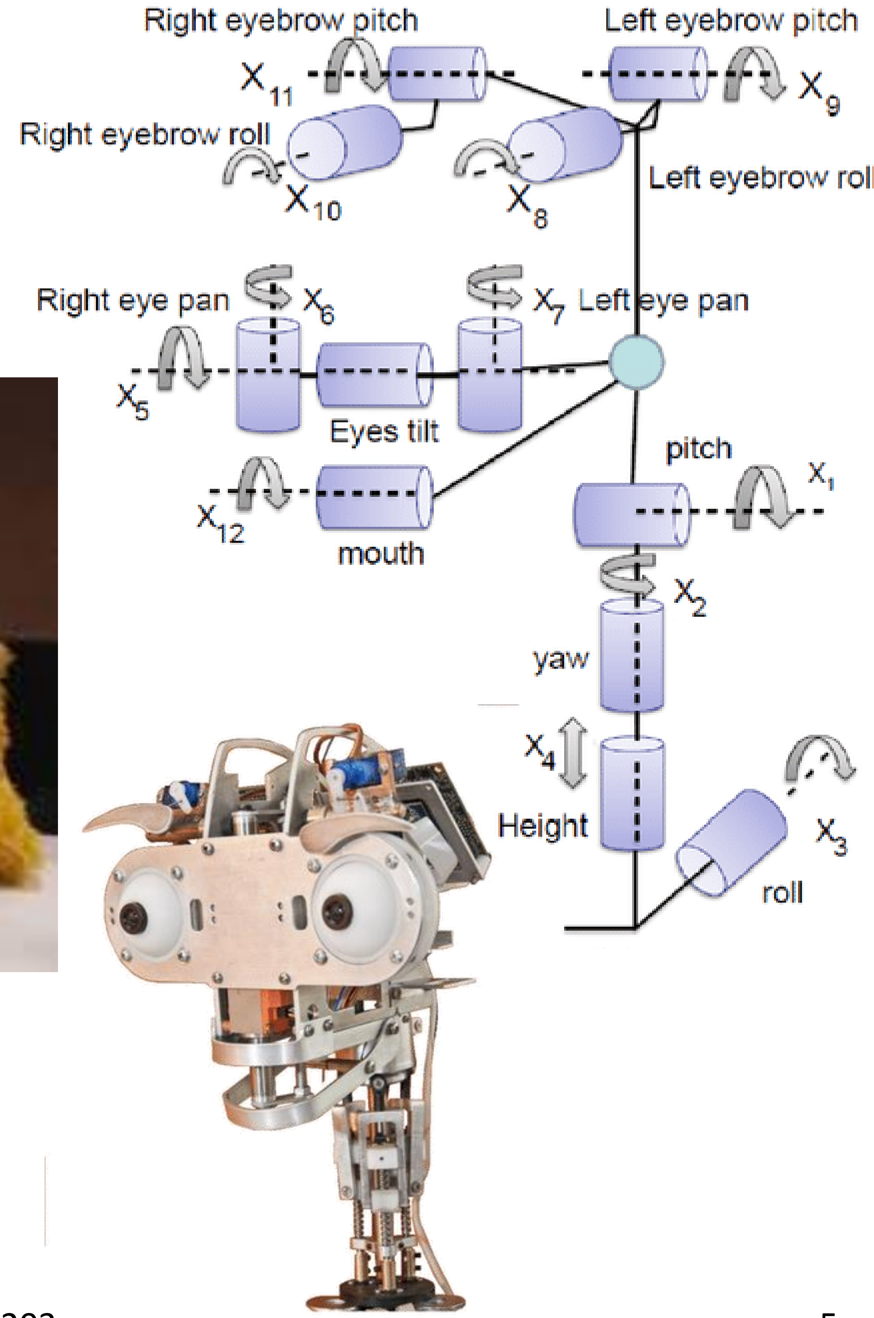
Under the skin



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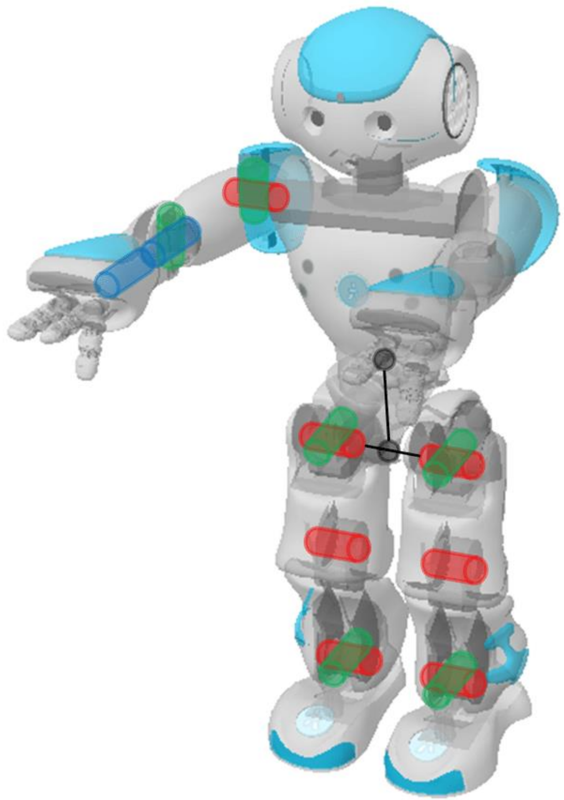
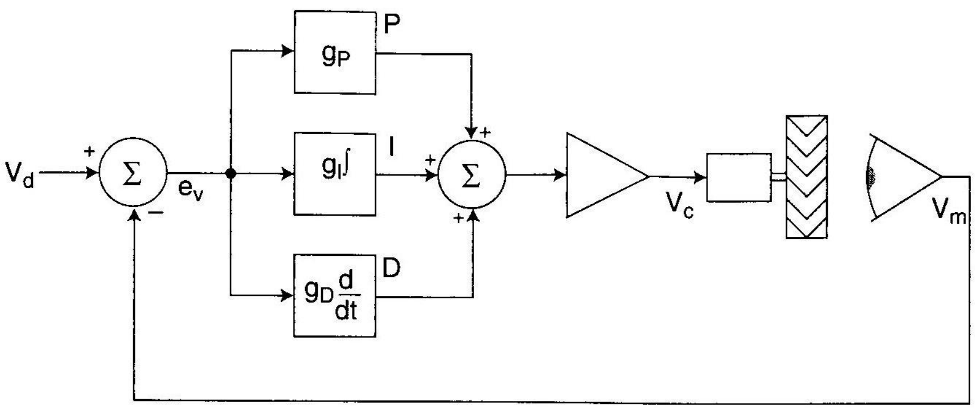




Source: Joseph L Jones, 2004

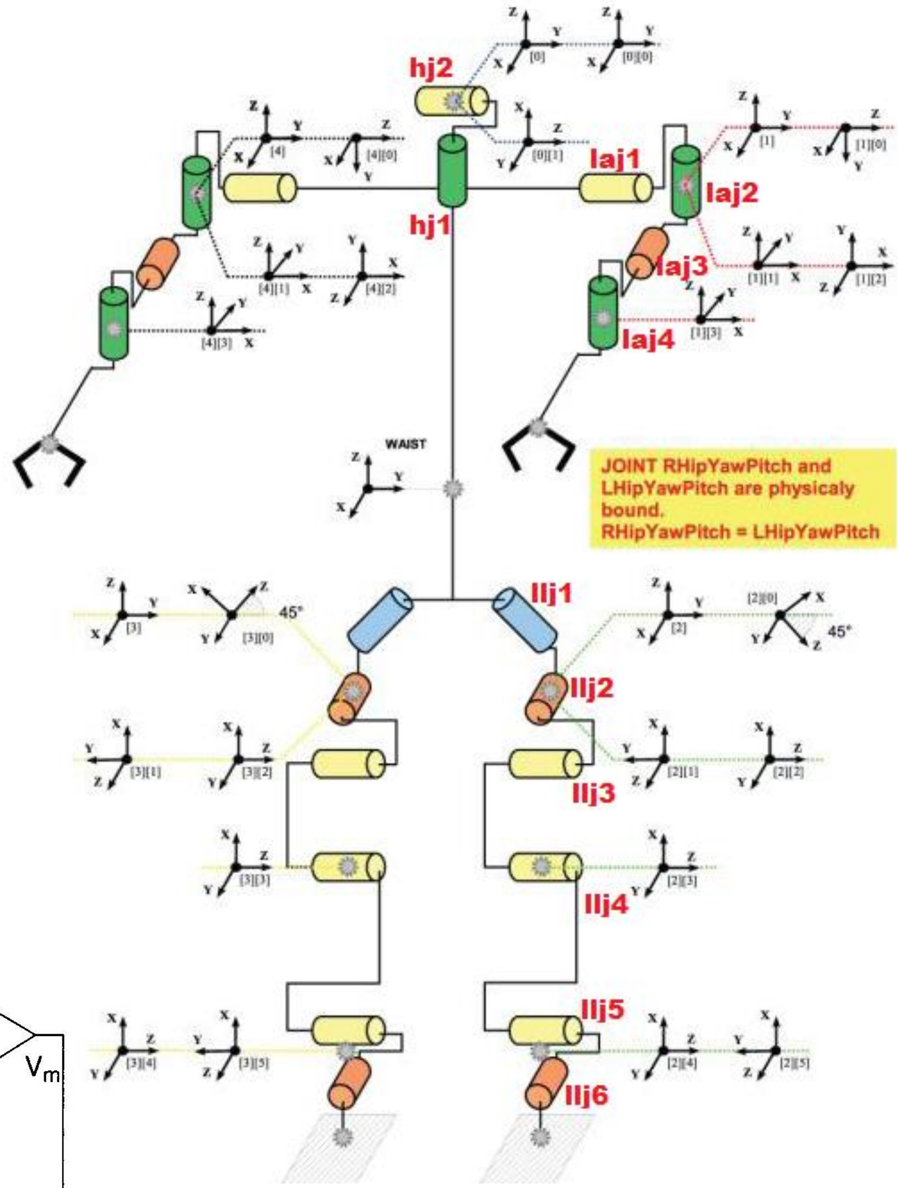


Image sources: Internet, credit goes to original owners

Course outline

- This module introduces to the students the basics of **modelling** and **control** of robot systems (their **mechanisms**) and train them to develop planning and **control** software modules for robots like manipulators.
- After successfully completion of this module, students will be able to:
  - Report different areas and **applications** of robotics
  - Describe different **components** of a robotic system
  - Design forward and inverse **kinematics** model for robot systems, primarily mechanical manipulators
  - Compute kinematics and **dynamics** of rigid bodies in task-spaces
  - Implement different **control** in robot systems using control theory and alternative approaches
  - Test robotic systems using robotic **simulators** and middleware

Course resources

- All course materials are available on **MS Teams**.
- All materials and assignments including files and announcements put up on the Teams are assumed to have reached you.
- All communications to your **UBD email address** or **MS Teams messages** are considered to have reached you.
- Please check the content and announcement on the Teams regularly.
- It is your responsibility to check your UBD emails and to check the Teams regularly.
- Please alert the lecturers if you are not added to the MS Teams of this module.

Books

- This course mainly follow below this textbook:
  - Kevin M. Lynch and Frank C. Park, "Modern Robotics: Mechanics, Planning, and Control", Cambridge University Press, 2017, ISBN 9781107156302 (video lectures)
- Other good reference books:
  - Mark W. Spong, Seth Hutchinson, M. Vidyasagar, "Robot Modeling and Control, 2nd Edition", Wiley, ISBN: 978-1-119-52404-5
  - Peter Corke, "Robotics, Vision and Control Fundamental Algorithms in Matlab, 2nd Edition", Springer, ISBN: 978-3-319-54412-0
  - Richar M. Murray, Zexiang Li, S. Shankar Sastry, "A Mathematical Introduction to Robotic Manipulation", Taylor & Francis, ISBN: 978-0-8493-7981-9
- There are other helpful resources, and you are encouraged to find further references online to enhance your understanding
  - CS223A - Introduction to Robotics by Professor Oussama Khatib at Stanford University
  - QUT Robot Academy video lectures by Professor Peter Corke at Queensland University of Technology

Course schedule

- Learning activities (subject to alternative arrangements)
  - **14:10-16:00, Tuesday**, SDS G.38
  - **14:10-16:00, Friday**, SDS G.38
  - Please use your **own laptop** for the lab works.
- Assessment scheme: **70% Coursework, 30% Examination**
  - One class test (10%), one lab test (15%)
  - Two assignments (20%), project (25%)
  - Examination (30%)

Schedule

Week		Tuesday (14:10-16:00, SDS G38)	Friday (14:10-16:00, SDS G38)	Notes:
1	8-Jan	L1 Introduction	L2 Configuration Spaces	
2	15-Jan	L3 Rigid Body Motions	L3 Rigid Body Motions	
3	22-Jan	Tutorial 1 - C-Spaces and Motions	L4 Forward Kinematics	
4	29-Jan	L4 Forward Kinematics	Tutorial 2 - Forward Kinematics	
5	5-Feb	L5 Velocity Kinematics	L6 Inverse Kinematics	Assignment 1 Out
6	12-Feb	L6 Inverse Kinematics, Tutorial 3 - Inverse Kinematics	Tutorial 4 - Inverse Kinematics	
7	19-Feb	Class Test (L1-L6)		Assignment 1 Due
8	26-Feb	Mid Semester Break		
9	4-Mar	Lab 1 - Robotic Systems Simulation and Middleware	Lab 2 - Webots and Transformation	
10	11-Mar	Lab 3 - RTB: Forward Kinematics	Lab 4 - RTB: Inverse Kinematics	Project Out
11	18-Mar	L7 Dynamics of Rigid Bodies, Task-Space Dynamics	L7 Dynamics of Rigid Bodies, Task-Space Dynamics	
12	25-Mar	Tutorial 5 - Dynamics	Lab 5 - Dynamics	Assignment 2 Out
13	1-Apr	Lab Test (Lab 1 - Lab 5)	L8 Trajectory Generation	
14	8-Apr	L9 Control Theory, Feedback and Force Control	Tutorial 6 - Control Theory	Assignment 2 Due
15	15-Apr	L10 Alternative Approaches to Optimal Control	Lab 6 - Control Theory and Trajectory Planning	Project Due
16	22-Apr	Revision Week		
17-18	29-Apr	Examination Week		

Dr Hong: L1 to L6
Dr Ajaz: L7 to L10, Labs

Today's menu

- Introduction
  - What is a Robot?
  - Properties of Robots
  - Components of Robots
  - Challenges in Robotics
- Applications of Robots
- Types of Robots
- Robotics in SDS

Let’s get started by knowing the main terms …

WHAT IS A ROBOT?

The definition

- The term “Robot” has different definitions from different sources. There is no one definition that satisfies everyone.

- *“A robot is a **machine**—especially one **programmable** by a computer—capable of carrying out a complex series of actions **automatically**. A robot can be guided by an **external** control device, or the control may be **embedded** within.”* - Wikipedia

- *“A robot is an **autonomous** system (agent) which exists in the **physical** world, that can **sense** its environment (including its own internal state) and **act** on its environment to achieve some **goals**.”* - Maja J Mataric

Properties of robots

- Robots will usually have the following properties:
  - Can **sense** its environment, i.e. have inputs
  - Can **manipulate** things in its environment, i.e. have outputs (**act**)
  - Have some degree of **intelligent** - programmed by human (**think**)
  - Appear to have **intent** or **agency**, i.e. they have their purpose

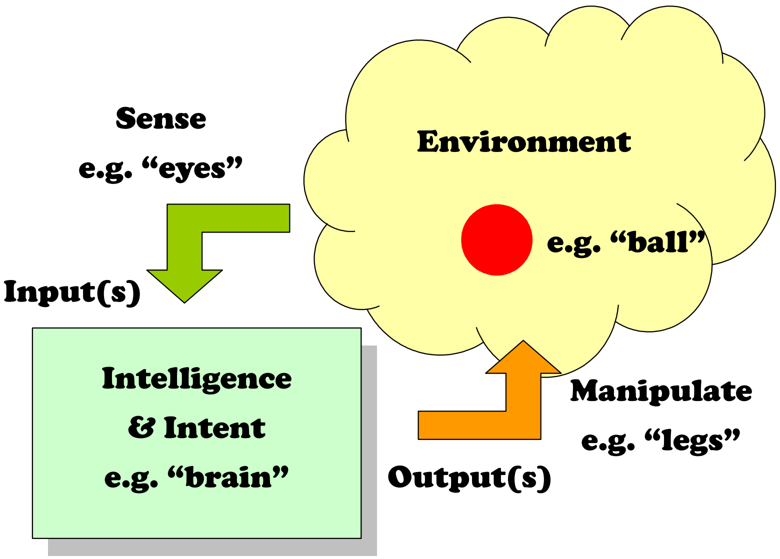
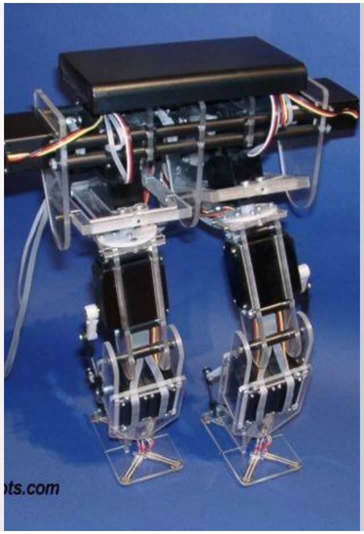
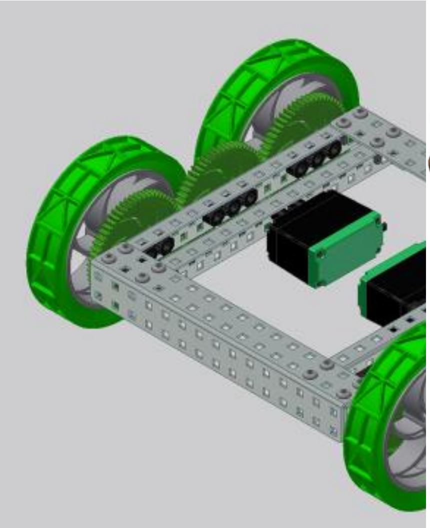


Image source: Internet, credit goes to original owners (Robot dog)

Components of robots

- **Controller** (control, intelligence | analogy: brain) – Computing
- **Body** (mechanical construct) – Mechanical
- **Actuators**, **effectors** (mechanism and drive train | analogy: limbs, mouth, skin) – Mechanical, Electronics
- **Sensors** (perception| analogy: eyes, ears, skin) – Electronics, Mechanical
- **Power Source** (battery | analogy: food) – Electronics





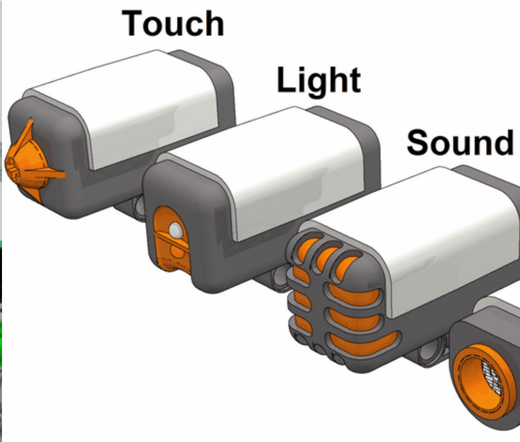


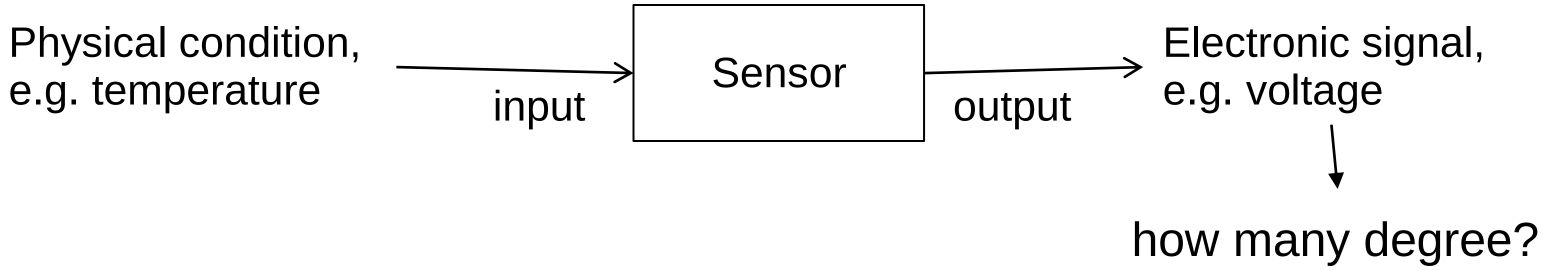
Image sources: Internet, credit goes to original owners

Intangible components

- **Arts**
  - Creativity in making a robot fun and appealing in its look is an important skill to mention. Robotics can be an art too.
- **Behavioral**
  - Communication ability
  - Understanding of human emotion while interacting with human
  - Expression of emotion while interacting with human
- **Safety**

Sensors

- **Sensors** are devices that can sense and measure physical properties of the environment.
  - They convert physical quantities into electronic signals.
  - E.g. Temperature, luminance, resistance to touch, weight, size, etc.
- The key phenomenon is **transduction**.
  - Transduction (engineering) is a process that converts one type of energy to another.
- They deliver low-level information about the environment the robot is working in.
  - Return an incomplete description of the world.
  - Require correct interpretation of the information - **perception**.



Types by source

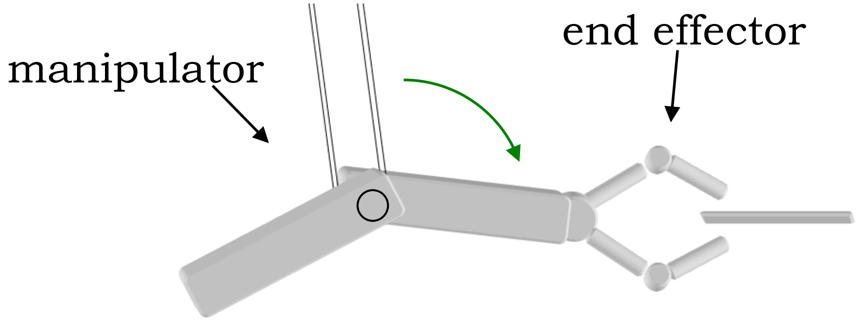
- **Proprioceptive sensors**: senses robot's internal state, i.e. monitor the robot itself.
  - E.g. Positions of the wheels (sensor: encoder), direction the head is facing (sensor: accelerometer).
- **Exteroceptive sensors**: senses robot's external state, i.e. monitor the environment.
  - E.g. Light levels (sensor: light), distances to object (sensor: ultrasonic), sound (sensor: microphone).
- Proprioceptive sensors and exteroceptive sensors together constitute the **perceptual system** of a robot.

More ways to classify sensors

- Active versus Passive
  - **Passive**: does not require "power supply". Has detector only, e.g. light sensor.
  - **Active**: require "power supply". Has detector and emitter, e.g. radar.
- Classification by **functions**.
  - E.g. Vision sensors, audio sensors, touch (tactile) sensors, range (distance) sensors.
- Classification by modes of **operation**.
  - E.g. Contact versus non-contact.

Effectors

- Effectors
  - The parts of a robot that interact with the environment and have an **effect** on the environment.
  - Three types:
    - Physical effects (main focus in robotics):
      - **Manipulators**, e.g. arms.
      - **Mobile**, e.g. wheels, legs.
    - **Perceptual**, e.g. speaker, light bulb.
- End-effectors
  - The tool, gripper or other device mounted **at the end** of a manipulator or mobile effector.



Actuators

- Actuators
  - Mechanisms or devices that **drives the effectors** to produce their effect in the environment, e.g. motors, spring, artificial muscle.
- Two types
  - **Passive**: uses potential energy in the effectors, and its interaction with the environment without active power consumption.
  - **Active**: consumes energy from power source. Most commonly used.
  - E.g. gliding (passive) vs jet engine (active).

Robotics: All-in-1 solution

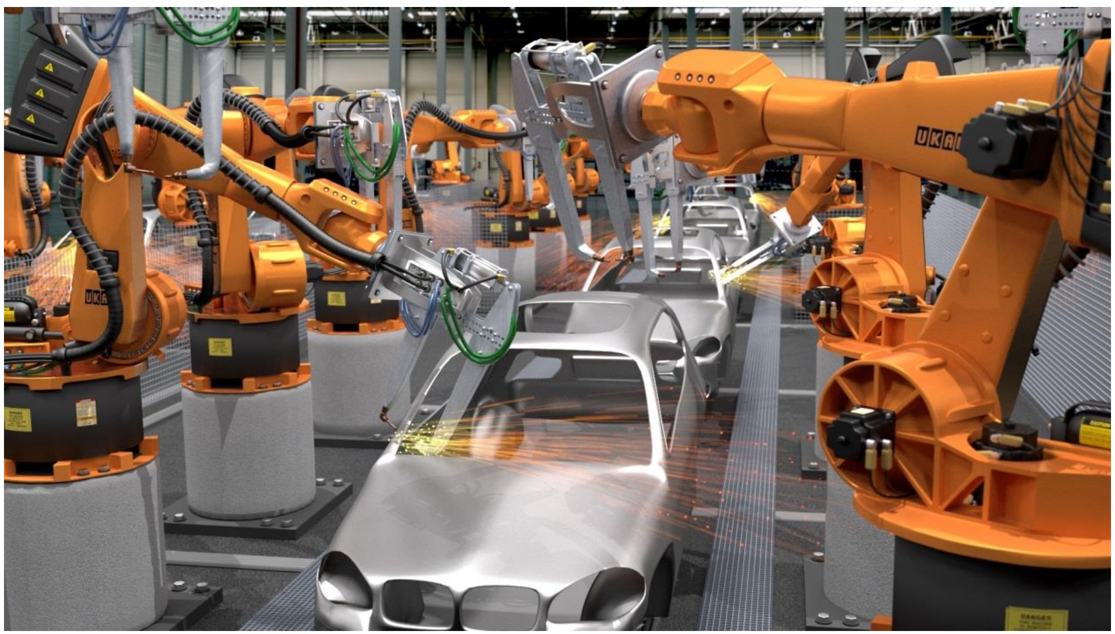
- The term “**Robotics**” refers to the science and technology of robots: their design, manufacture and applications.
- Robotics is a **fusion** of a wide variety of science and technologies encompassing mechanical, electronics, control, instrumentation, communication, information, internet, artificial intelligence, audio and visual, embedded systems, and many more including non-technical aspects such as psychology and art.
- This not only makes Robotic very **interesting**, but also makes robotic a **versatile** solution to wide variety of problems.

Let the robots do the **dull**, **dirty** and **dangerous**: 3D jobs.

APPLICATIONS OF ROBOTS

Industrial robots: automation

- The most extensive use of “real” robots are in the industry: factories.
- These robots are usually fixed in place – making their operations easy to automate. They do **3D** jobs: **Dull, Dirty, Dangerous**.



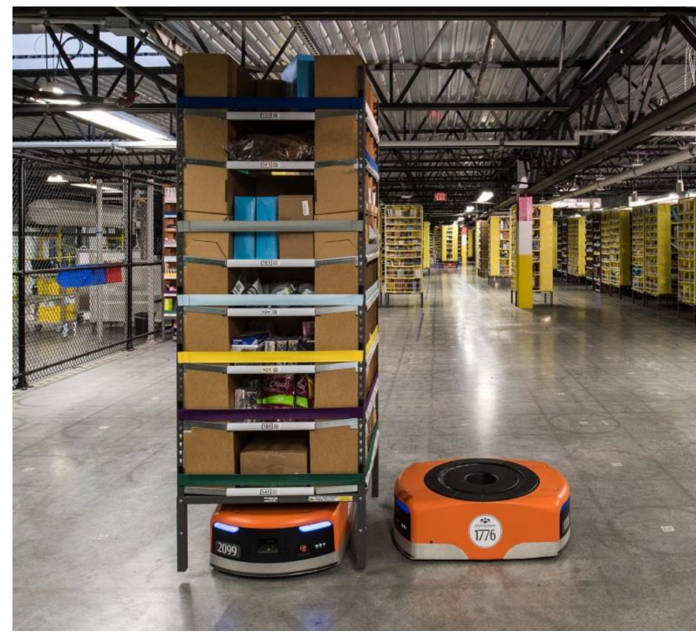
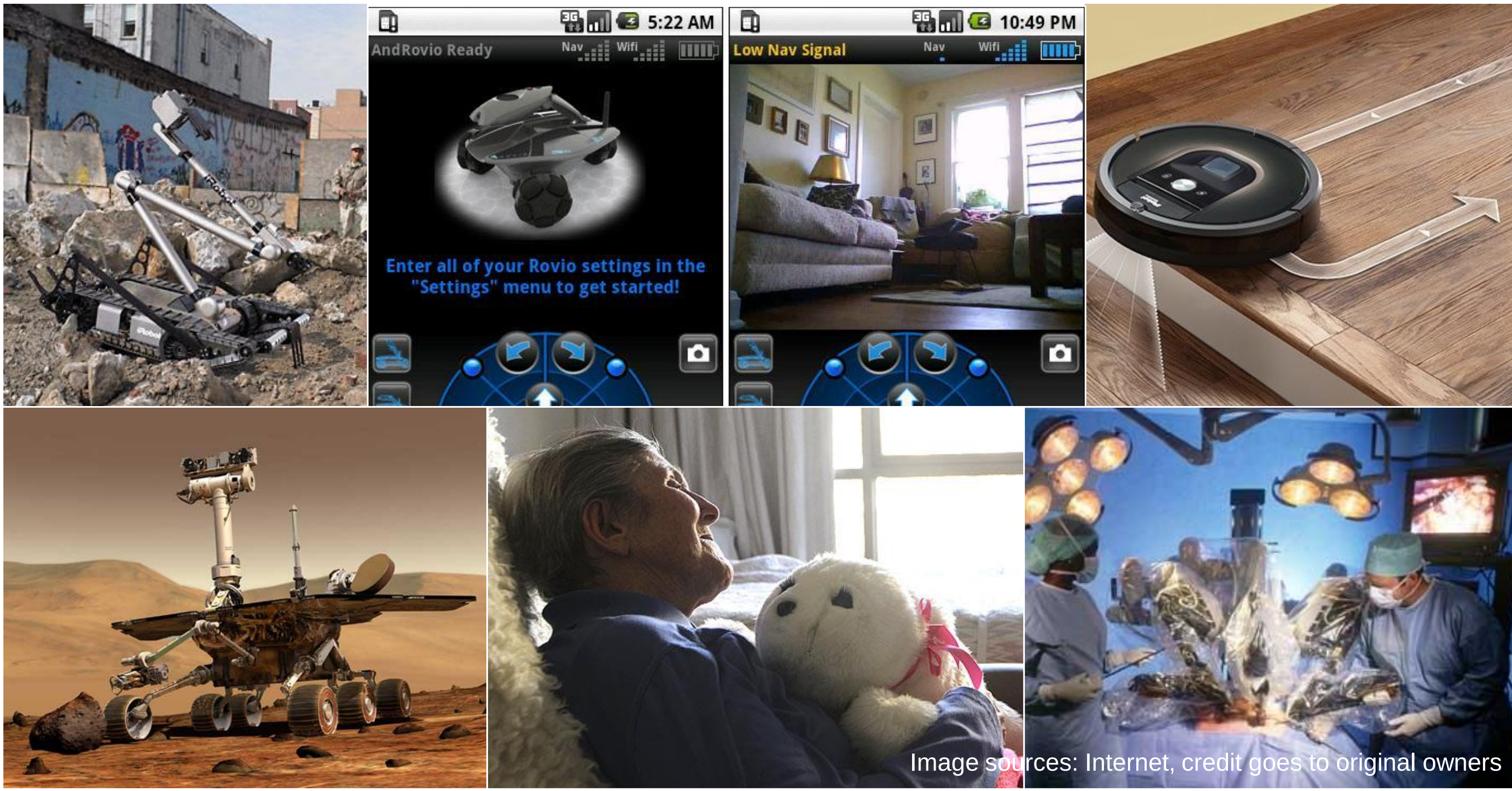


Image sources: Internet, credit goes to original owners

Out of the factories

- Real robotic applications started prominently in the factories. But, that has changed …



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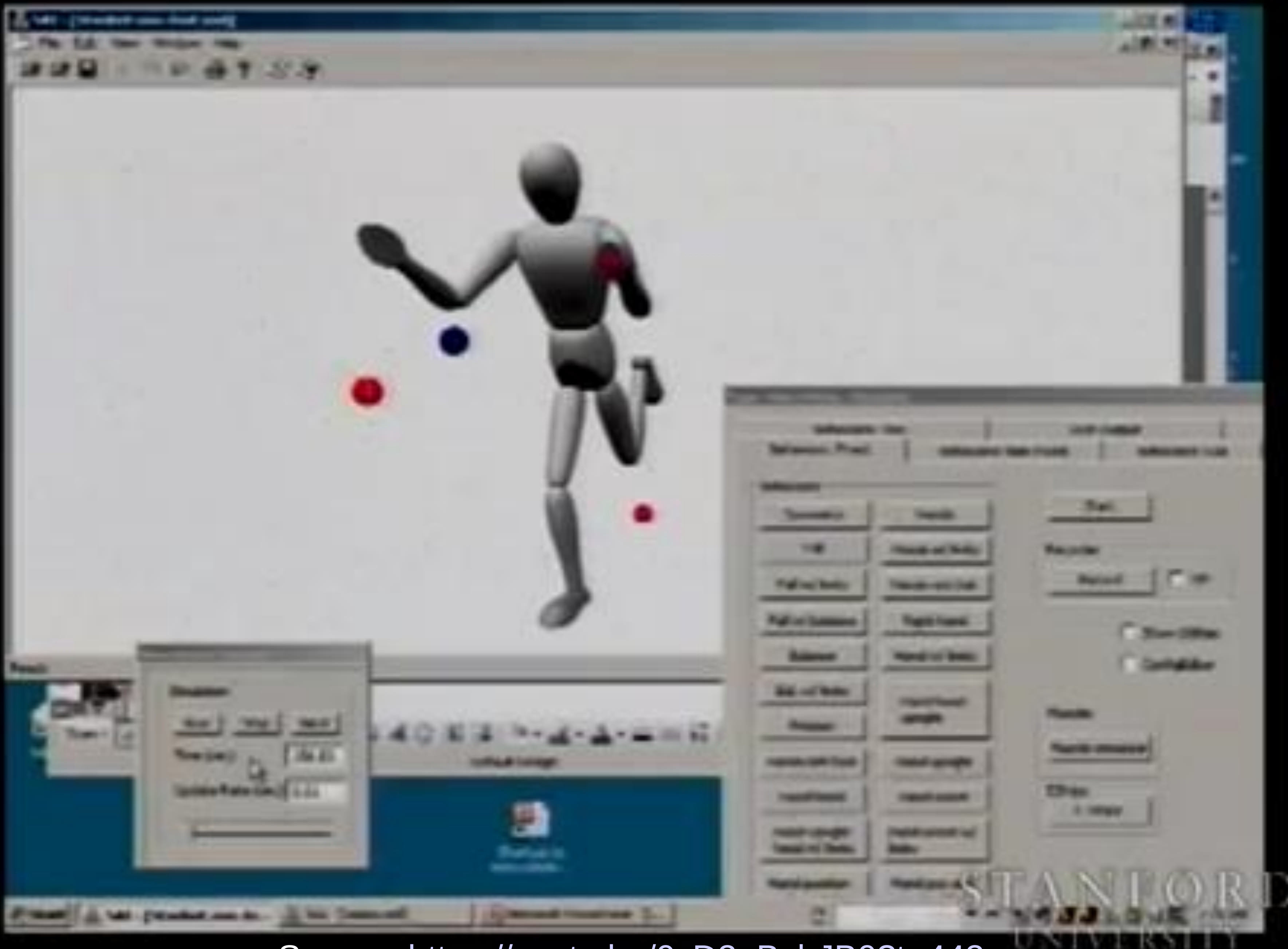


Source: https://youtu.be/0yD3uBshJB0?t=443

Why is robot control hard?

- High-level, complex goals
  - Impossible to “formulate” solution.
  - E.g. chasing a cat versus solving an equation.
- Dynamic (changing) and realtime (events don’t wait) environment
- Robot has mechanical constraints of its own (e.g. can’t turn fast enough, too bulky)
- Sensor noise and uncertainty
- Unexpected events (collisions, dropped objects, etc.)
- Perception is difficult: vision, speech

Robots can be categorized by different characteristics.

TYPES OF ROBOTS

Modes of control

- Not all robots are "fully" autonomous.
  - E.g. robots that are remotely controlled.
- A robot can be **autonomous** or **manipulators**.
  - **Autonomous** robots are robots that can act on their own without human intervention, while **manipulators** are manipulated or controlled by human (with some degree of autonomy).
- **Teleoperated** robots are robots controlled by a human in a remote location.
- **Augmenting** robots are connected directly to the human's body, and controlled by human movements.
- Depending on the definition adapted, manipulators may not be considered as robots.

Asimo: autonomous

Kuratas: manipulated

Image sources: Internet, credit goes to original owners

Areas of application

- Industrial robots
- Domestic robots, personal robots
- Medical robots
- Service robots
- Military robots
- Entertainment robots
- Space robots
- Hobby and competition robots

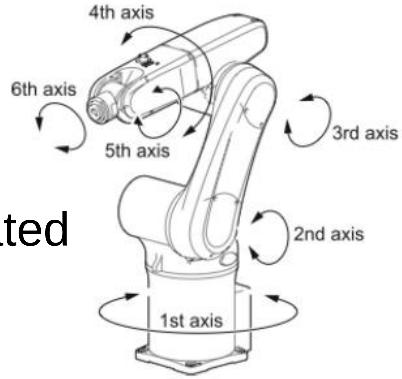
Fields of operation

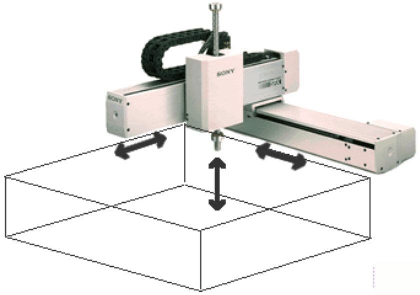
- **Stationary** robots are fixed in one place and cannot move.
- **Ground** robots operate on the ground surface.
- **Underwater** robots, often called Autonomous Underwater Vehicles (AUV), operate underwater.
- **Aerial** robots, often called Unmanned Aerial Vehicles (UAV) fly in the air.
- **Microgravity** robots operate in low-gravity environments, such as earth orbit.

Industrial robots

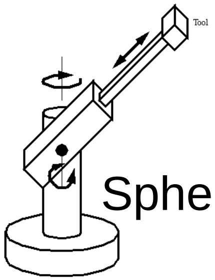
- They are mainly **stationary** robots.
- They are categorized by the design of their **moving** parts:
  - **Articulated**: with joints and links similar to an arm.
  - **Cartesian**: with linear movements similar to gantry.
  - **Cylindrical**: with rotary joint at the base.
  - **Polar** or **spherical**
  - **SCARA**
  - **Parallel**: e.g. delta.

Articulated

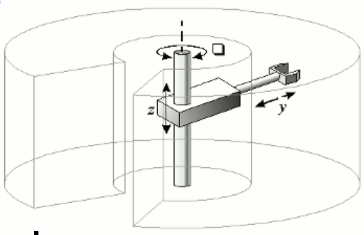




Cartesian



Spherical



Cylindrical

SCARA

Delta

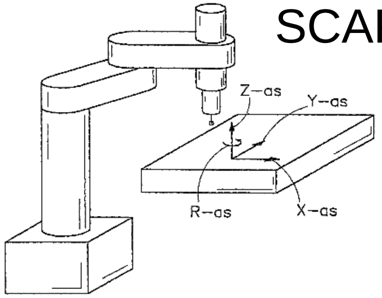


Image sources: Internet, credit goes to original owners

Mobile robots

- They can move. Often used to refer to ground robots.
- Robots can be categorized by its mode of **movements** (locomotion):
  - **Wheeled** robots: single wheel, two-wheeled, more wheels.
  - **Tracked** robots
  - **Rolling** robots
  - **Legged**, or walking robots: bipedal (humanoid), tripedal, quadrupedal, hexapod, more legs.
  - **Swimming** robots.
  - **Flying** robots.

ROBOTICS IN SDS

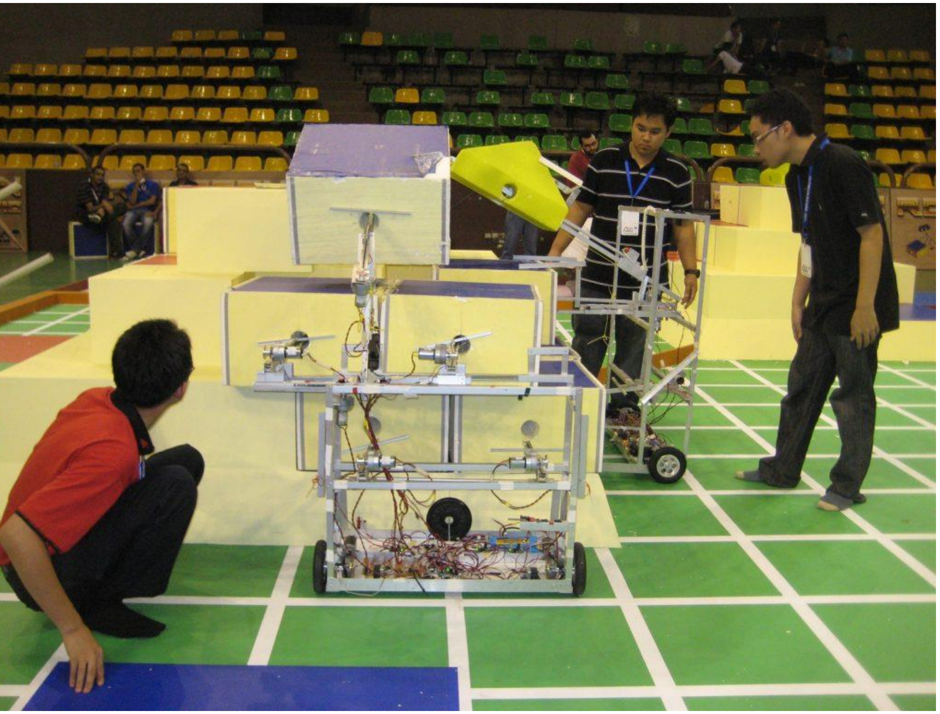
Robotic labs

Robotics and Intelligent Systems Lab (ISB B2-14/15)

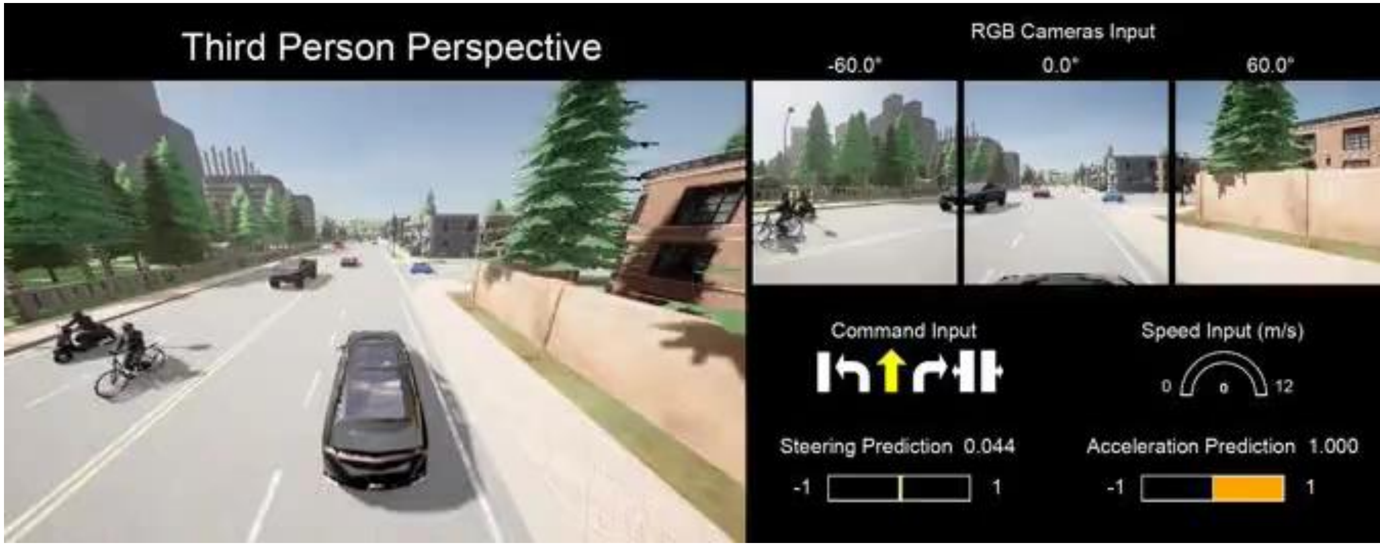
Cyber-physical Systems Lab (SDS G38)

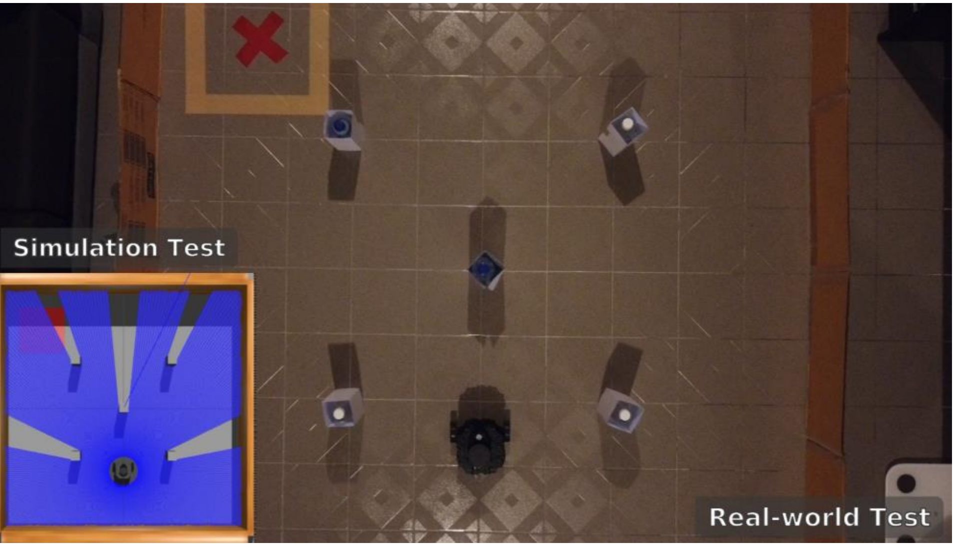
Robotic systems

Robotic competitions

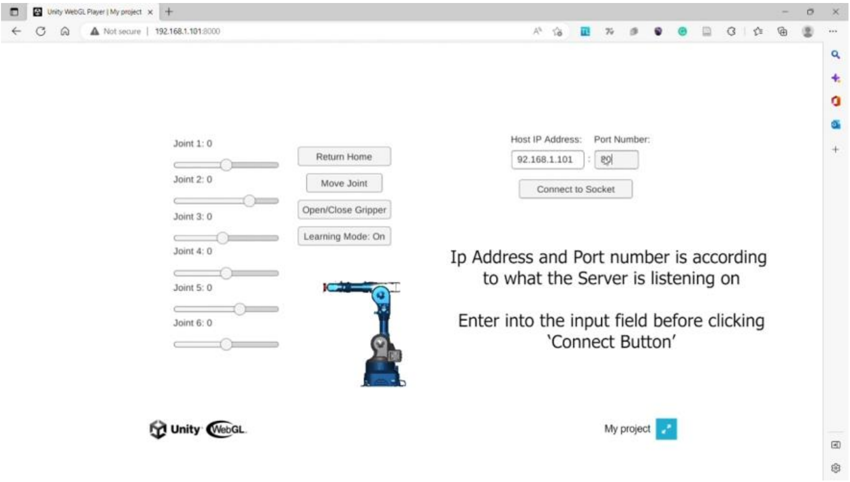


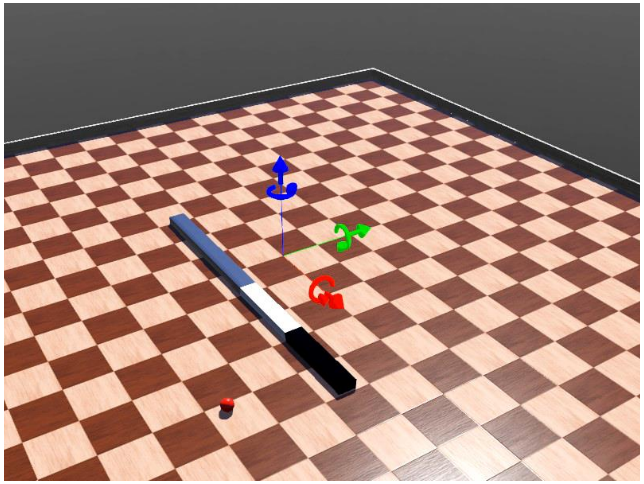
Robotic projects





Source: https://ailab.space/projects/


Joint 1: 0
Joint 2: 0
Joint 3: 0
Joint 4: 0
Joint 5: 0
Joint 6: 0
Return Home
Move Joint
Open/Close Gripper
Learning Mode: On
Host IP Address:
Port Number:
92.168.1.101
Connect to Socket
Ip Address and Port number is according to what the Server is listening on
Enter into the input field before clicking 'Connect Button'
Unity
WebGL
My project




SCIENTIFIC
AMERICAN

Summary

- Robots **integrate multiple technologies** to make it highly potential to become useful in real physical world.
- They are already delivering their potential in many **real applications**: especially in the industry.
- Robotic applications have extended beyond the industry and gone into our **personal living domain**.
- There are various **types** and **designs** of robots.
- Robot **properties**: can sense, think, act, and has agency
- Robot **components**: controller (brain), body, actuators & effectors (limbs, etc), sensors (eyes, etc), power source (food).
- **Applications** everywhere.
- Robotics is **challenging** especially the physical aspects.
- Different **types** of robots.

Advise

- Mathematics refreshers – Trigonometry, Linear Algebra, Calculus (Files, Khan Academy)

- Weekly: CS223A (1-2 hrs) -> Lecture (4 hrs) -> Reading (2-4 hrs) -> (Coursera) (1 hr) -> Exercises (2-4 hrs)

Reading list

- A Robot in Every Home by Bill Gates on Scientific American
  - This article was more than a decade ago but we are yet to see the realization of such vision …
  - Somehow, Microsoft seems to have ceased its development in robotics.
- On history of robotics:
  - RobotShop: http://www.robotshop.com/content/PDF/timeline.pdf.
  - MegaGiant Robotics: http://robotics.megagiant.com/history.html.
  - Science Kids: http://www.sciencekids.co.nz/sciencefacts/technology/historyofrobotics.html.
  - Industry tap: http://www.industrytap.com/brief-history-robots/29235.

To Do list

- Watch below videos:
  - WRC 2023 - China's largest robot exhibition | Robots and technologies at the exhibition in China (youtube.com)
  - ICRA 2023: The best robots that will change the world! | Robots of the future | Pro Robots (youtube.com)
  - From Toys to Space
- What is your impression of the progress in robotics comparing the latest state-of-the-art in the first two videos with Professor Oussama Khatib's video we watched earlier about 17 years ago?
- Check out the terms: **cyborgs** and **androids** (robot). What are their differences?
- What robot(s) would you like to develop/make?