# Welcome Everyone to MECH 641/EECE 661 – Robotics

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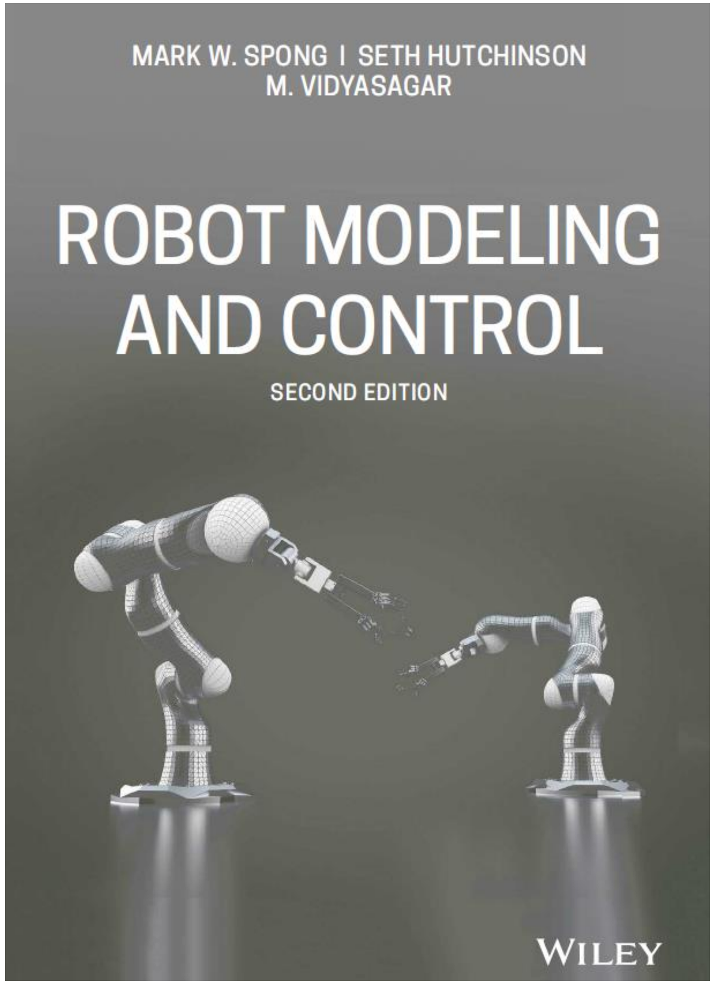
- **email:** hh224@aub.edu.lb
- **Office hours:** TR 13:00-15:00 - by appointment

**Unit of Study Description**

- **Classes**: 2 lectures, 1h 15m each
- **Time:** TR 15:30 - 16:45
- **Place:** Bechtel 208

- **Lab**: 1 session, 3h
- **Time:** TR 17:00 - 19:45
- **Place:** Oxy 402

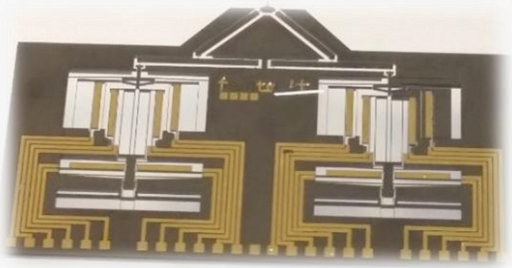
- **Pre- or Co-requisite**: Control systems



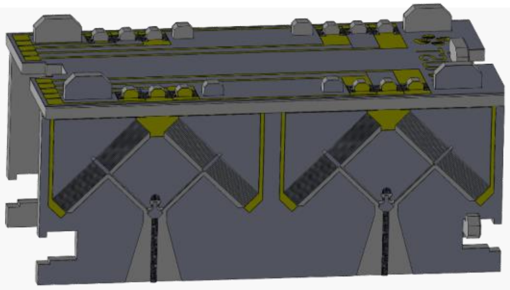
# My Journey


| | |
|---|---|
| **2007** | **Mechanical Engineering, Lebanon** |
| **2012** | **Master in Mechatronics, Compiegne, France** |
| **2015** | **PhD in Microsystems, Besancon, France** |
| **2017** | **Research Scientist, Lirmm, France** |
| **2019** | **Postdoc, Kaust, Saudi Arabia** |
| **2022** | **Assistant Professor, AUB, Lebanon** |
| **PRESENT** | |

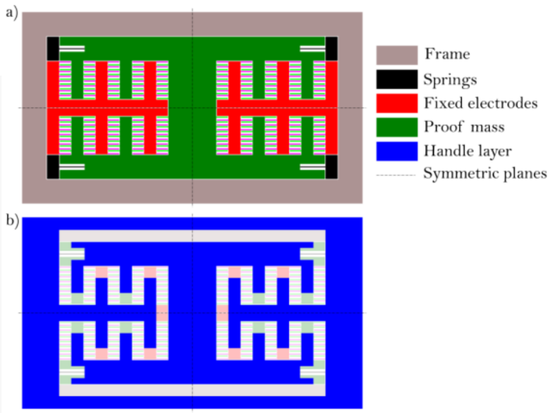
Digital microbotics



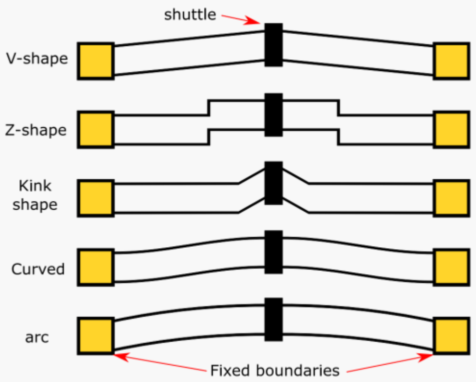
Mobile microbotics



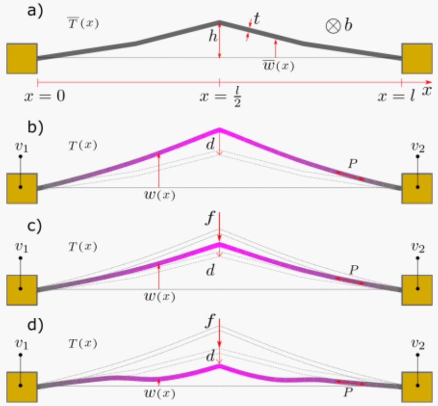
Accelerometer with high sensitivity



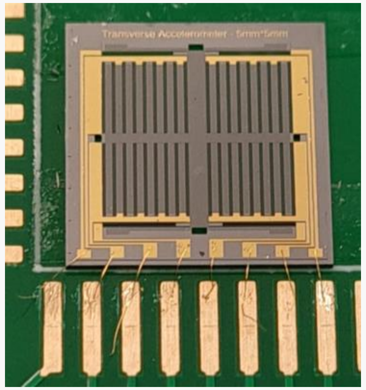

Bistable beams



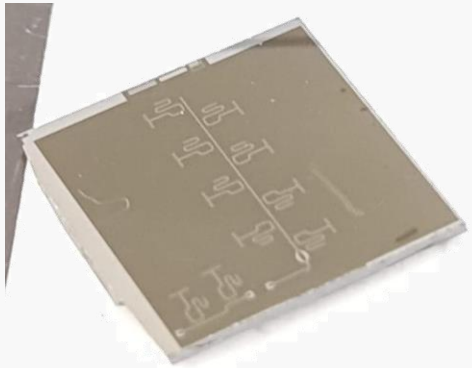

Electrothermal Actuators



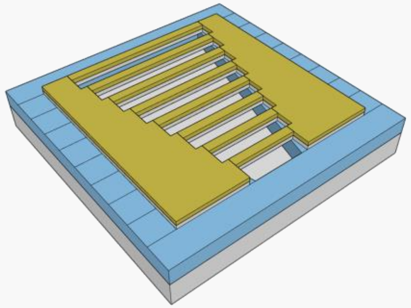

Accelerometer for oil exploration (with KFUPM and Aramco)



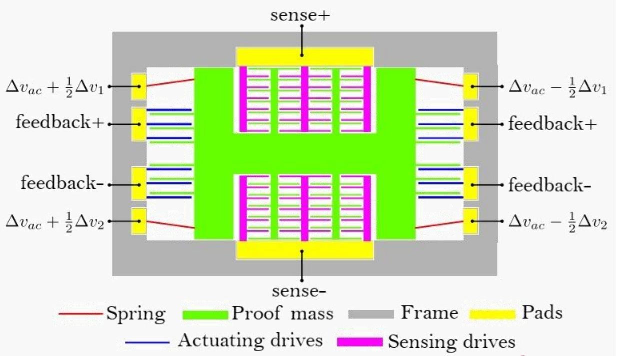
Quantum Computing elements (with KFUPM and UC Berkely)



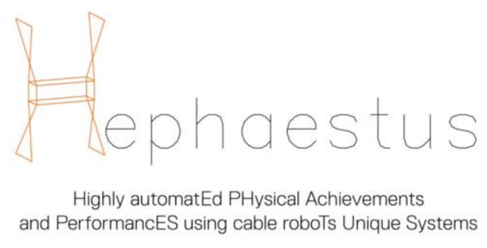
Electrothermal bimorph (with University of Washington)



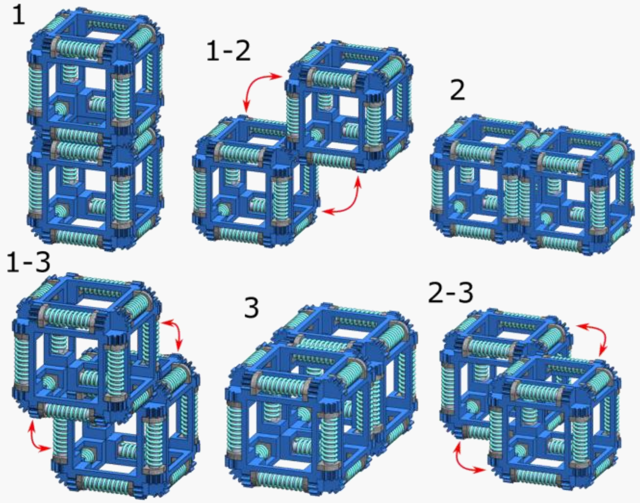
Accelerometer with tunable sensitivity (with KU Leuven)



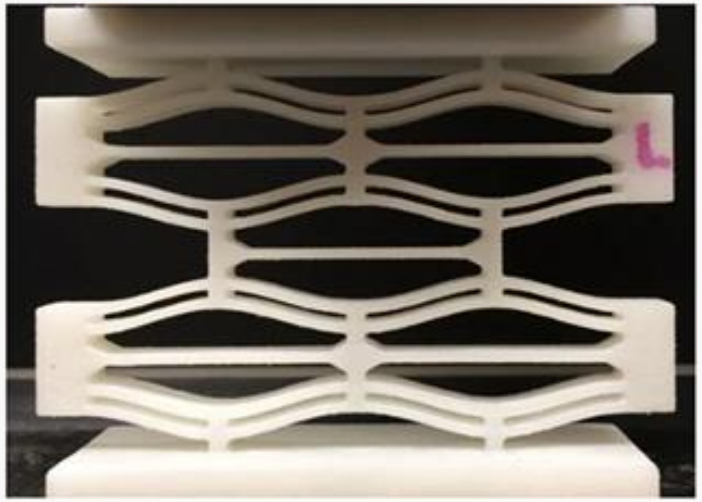
**Cable robotics**



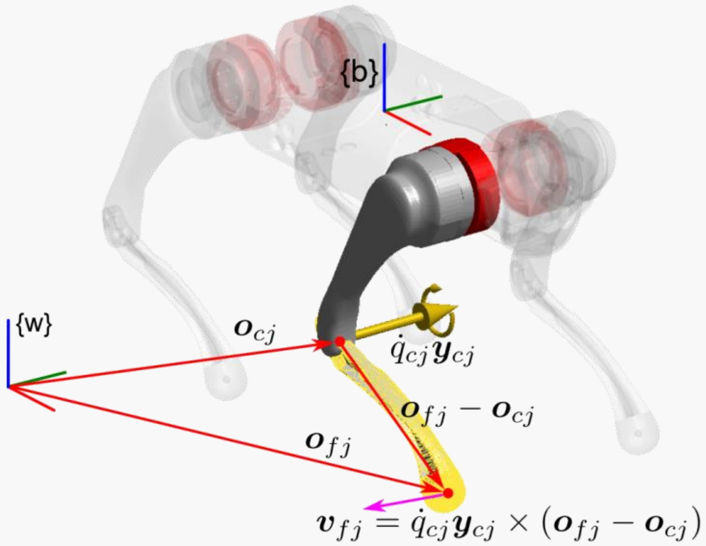

**Modular robotics**




**Metamaterials**



**Quadruped robotics**




**Mechanics, Mechatronics, and Microsystems**

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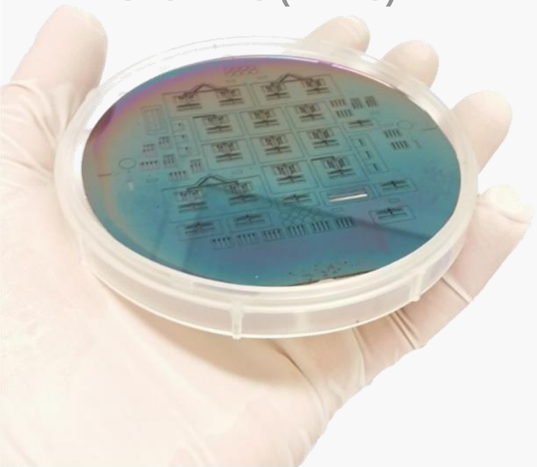
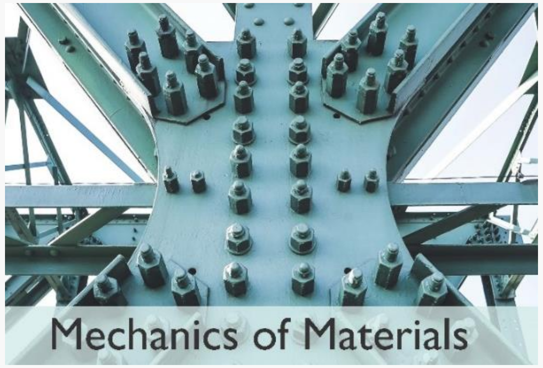
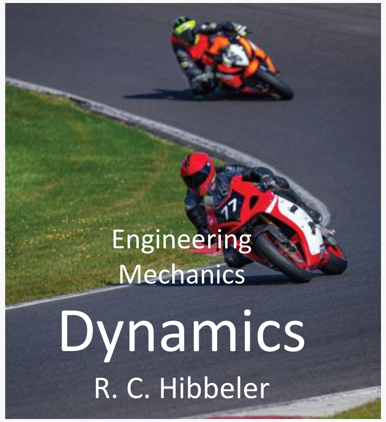
**FALL 22/23**
**MECH 631**
MICRO-ELECTO MECHANICAL SYSTEMS (MEMS)



**SPRING 22/23 -/24 -/25 -/26**
**MECH 320**
MECHANICS OF MATERIALS

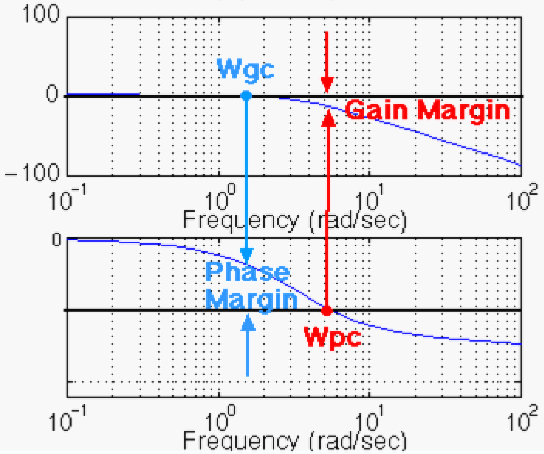



**FALL 23/24 - 25/26**
**MECH 230**
DYNAMICS




**FALL 23/24**
**SPRING 22/23 -/24 -/25 -/26**
**MECH 641/ EECE 661**
ROBOTICS

**FALL 25/26**
**MECH 436**
CONTROL



# Robotics

- A robot is a machine capable of carrying out a complex series of actions automatically

- Robotics is the interdisciplinary branch of engineering and science that deals with the design, construction, operation, and use of robots

- Imitation of manual actions by humans to replace it for highly repetitive tasks in the industry.

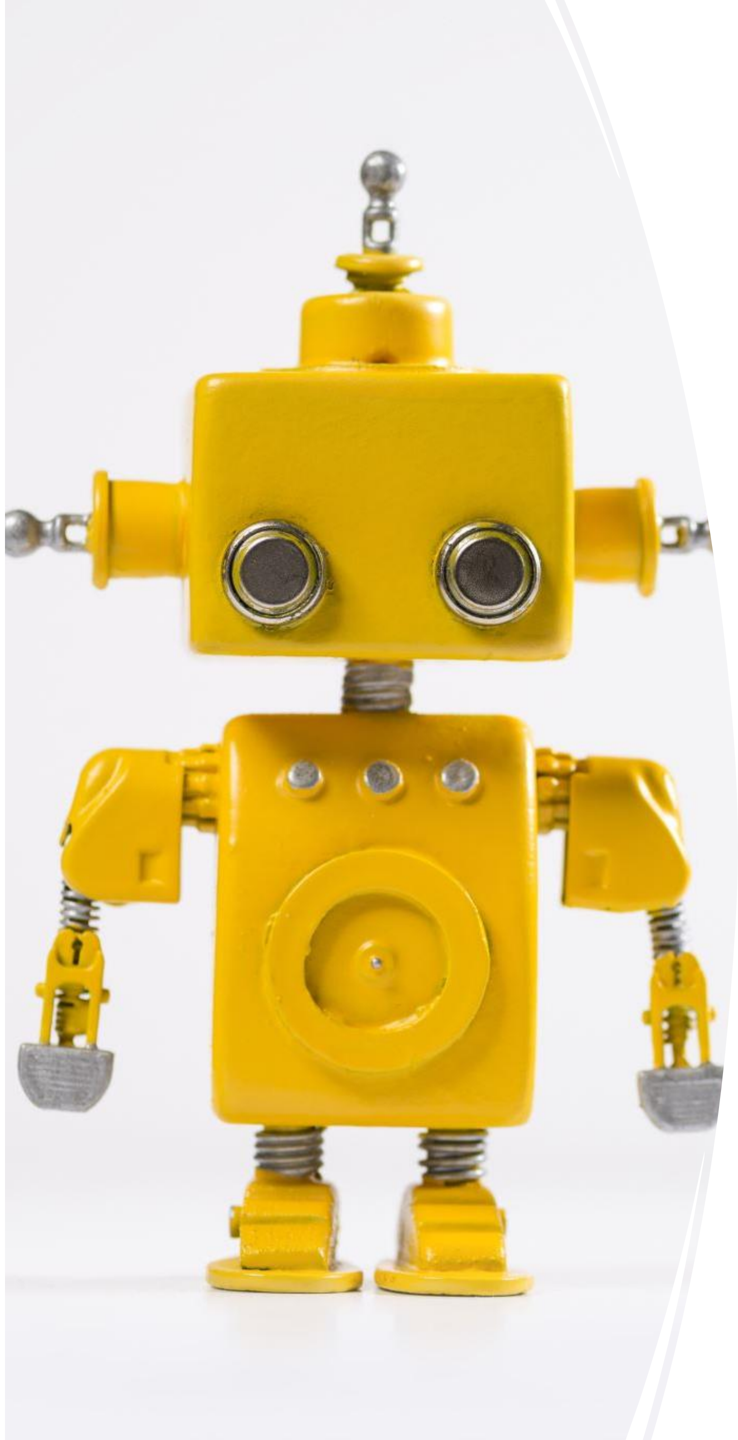
- Using of robots for automated tasks:
    - increased the human performance capacity
    - enhanced the cost, quality and delivery time for different tasks and products.

- Robotics investigates how robots can be used to:
    - automate tasks
    - improve efficiency in various industries such as manufacturing, healthcare, and transportation.




# Why robots?

- Robotics is the science of making machines do what humans used to do
- Robots are good for the 3 Ds: jobs that are dirty, dull, or dangerous.
- To date, robots have been used to:
  - replace or substitute for humans
  - Service
  - Medicine
  - assist humans
  - amuse.
- Robots are revolutionizing the way we approach everyday tasks.
- The possibilities of Robotics are endless, Robotics is the future!

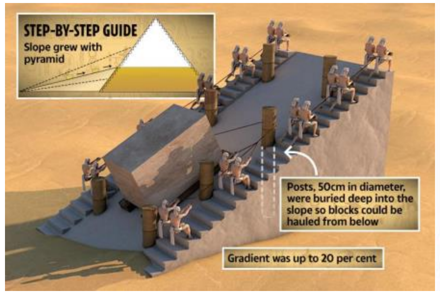


# A brief history of Robotics

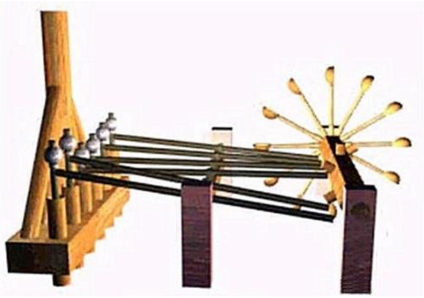
# A brief history of Robotics

- The word “robot” came into the popular consciousness on 1921, in Prague, with the first performance of Karel Capek’s play, R.U.R. (Rossum’s Universal Robots).
- The history of robotics can be traced back to ancient times, with the invention of simple machines such as the pulley and lever.
- 240-year-old drawing robots (Link)
- The modern robotics began to take shape in the 20th century with the advent of electronics and computers.
- In the 1940s and 1950s, scientists and engineers began to explore the idea of using machines to automate tasks that are traditionally done by humans.
- 1954: first patent for an industrial robot.
- 1961: the first industrial robot was installed in a General Motors factory.

R.U.R. performance, 1921




Pyramid construction
2550 BC



Taqi Al-Deen’s Pump
1551 AD


First industrial robot, 1961

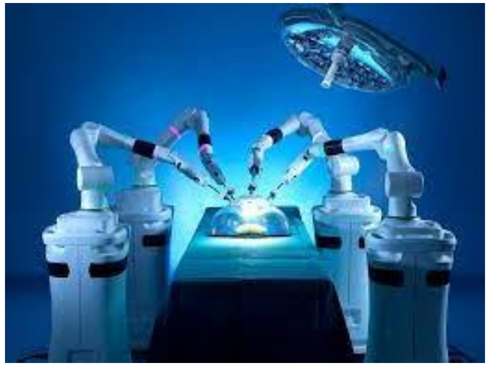
# A brief history of Robotics

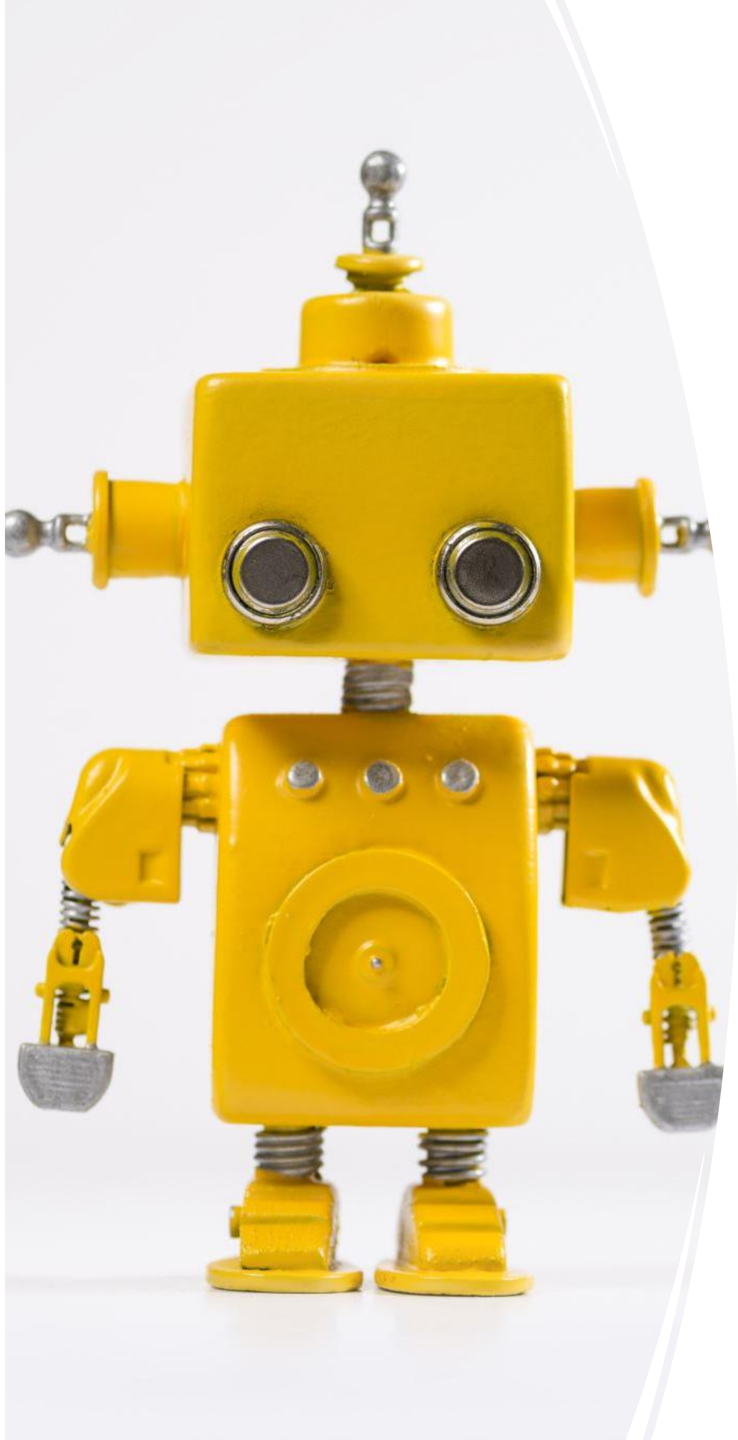
- In the 1970s and 1980s, robotics continued to advance
  - more sophisticated **sensors and control systems**.
  - Robotics began to be used in a wide range of industries, including manufacturing, agriculture, and construction.

- 1977, the first robot with six-axis of freedom was developed by Kawasaki Heavy Industries.

- In the late 1980s,
  - **mobile robots** began to emerge, with the development of robots that could move around in the environment.
  - first mobile robots were used in manufacturing and logistics, but they soon found applications in other fields such as mining, agriculture, and even space exploration.

- In the 1990s, robots began to be used in
  - more **advanced applications**, such as in surgery, where robotic arms were used to perform delicate procedures.
  - The use of robots in surgery has grown significantly and it's now considered the standard of care for many procedures.

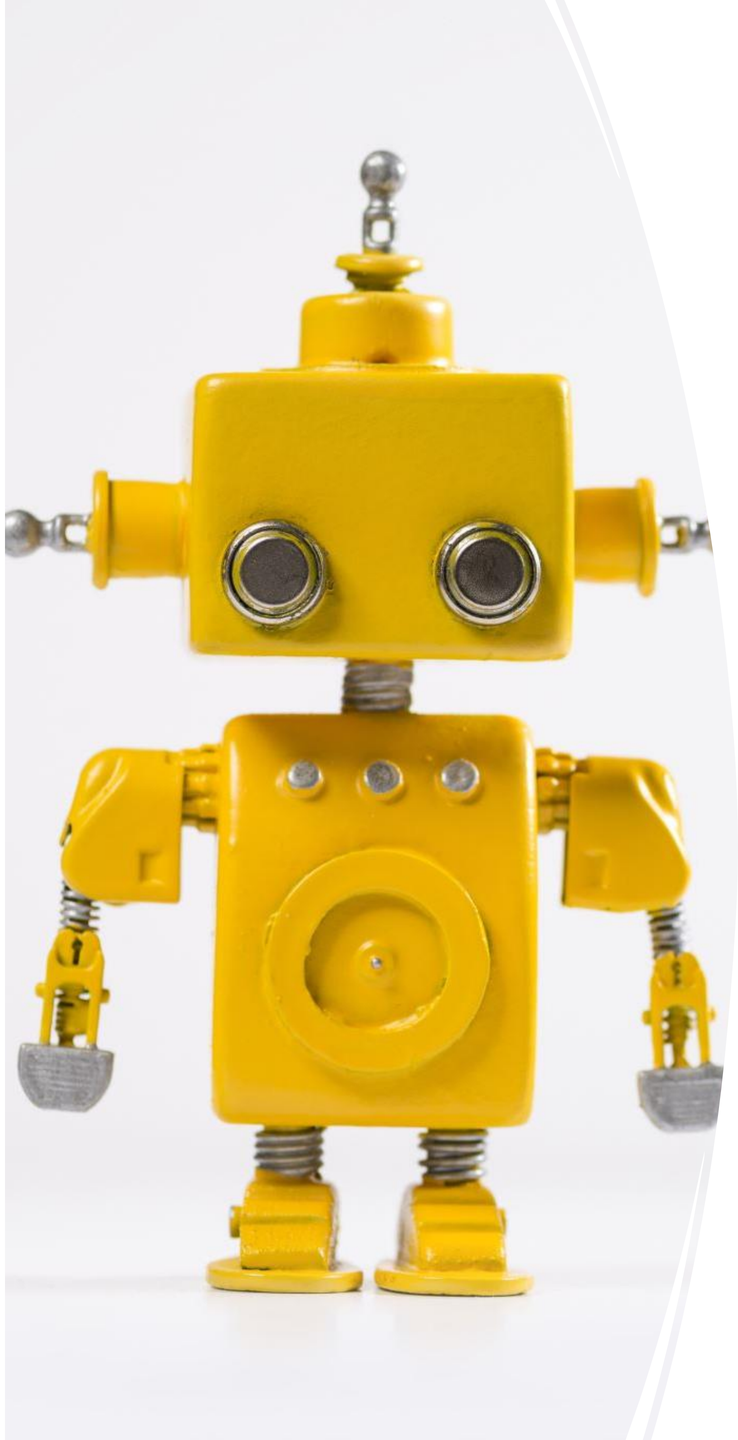


# Robotics in the $20^{th}$ century

Video Link

# A brief history of Robotics

- In the 21st century, Robotics has seen a **rapid development**, with the advent of advanced technologies like **artificial intelligence** and **machine learning**.
- Expanding **beyond the industry and factory**, with more and more robots being used in **healthcare**, **services**, and even in **domestic** environments.
- **More accessible and affordable**, with the rise of DIY robots and the development of low-cost robotic platforms.
- Robotics is now considered to be a key technology for the future and it is expected to play a major role in many areas of our lives.
- The field of Robotics is constantly evolving and advancing, and it's an exciting time to be a part of it.



# Robotics in the 21$^{th}$ century

Video Link

# Most common types of robots

**1 - Industrial robots**:

- used in **manufacturing**, **assembly**, and other applications.
- perform **repetitive tasks** with **high precision and speed**.
- **larger** and more **expensive** than other types and used in large factories or industrial settings.

**2 - Service robots:**

- interact with **people** and provide a **service**.
- found in **hospitals**, **hotels**, and **airports**.
- tasks such as **cleaning**, **security**, and **customer service**.

**3 - Mobile robots:**

- can **move around** in their environment
- wide range of applications, such as **logistics**, **agriculture**, **mining**, and **space exploration**.
- autonomous or teleoperated, and they can be either **ground-based**, in **water** or **aerial**.

**4 - Medical robots:**

- assist with **surgeries**, **therapy**, and other procedures.
- tasks such as performing **minimally invasive procedures**, assisting with **rehabilitation**, and **monitoring patients**.




# Most common types of robots

**5 - Social robots:**

- interact with **humans** in a **social manner**
- tasks such as **companionship**, **education**, and **entertainment**.

**6 - Drones:**

- **fly** and **navigate autonomously**
- tasks such as **delivery**, **surveillance**, **mapping**, and **inspection**.

**7 - Soft robots:**

- made of **soft and flexible materials**
- used in areas where **traditional robots can't go**, such as in **delicate environments**, or **interacting with humans.**

These are also many other specialized robots that are used in specific applications.

As technology continues to advance, the types of robots and the applications for them will continue to expand and evolve.


# Future of robotics

- The future of robotics is expected to be very exciting and dynamic.
  - development of **new technologies and applications**
  - potential to revolutionize the way we live and work.

- One of the most important areas of growth for robotics is in the field of **artificial intelligence** (AI). Advances in AI enable robots to perform tasks that were previously thought to be the exclusive domain of humans. This include things like natural language processing, image recognition, and decision-making.

- Another area of growth for robotics is in the field of **autonomous systems**, such as self-driving cars and drones, which have the potential to greatly improve efficiency and safety in transportation, logistics, and other industries.

- Robotics will also have a significant impact in the field of **healthcare**, with the development of new robotic surgical systems, telemedicine robots, and other assistive technologies that will help to improve the quality of care and the lives of patients.


# Future of robotics

- Robots and automation will continue to play an important role in **manufacturing and industry**, with the use of robots in factories, warehouses, and other industrial settings.

Overall, the future of robotics is very promising, with the potential to greatly **improve efficiency**, **safety** and **quality of life** in many industries.

It's an exciting time to **be a part of the field of robotics** and to see how it will continue to shape our world in the future

# Robots at AUB

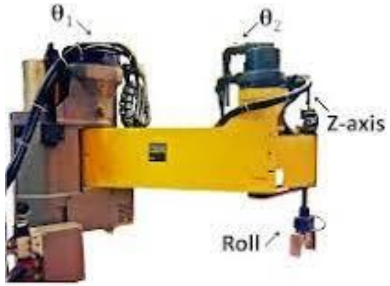
Dr Robot X80

Exofabulatronixx 5200

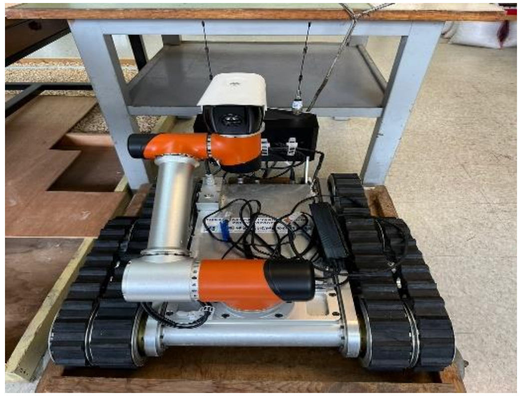
BMW AG

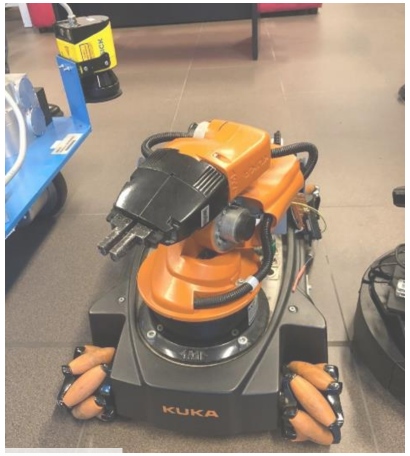
Robotis Premium

Mindstorms EV3




IBM SCARA 7540






Kuka Youbot

Nao Robot

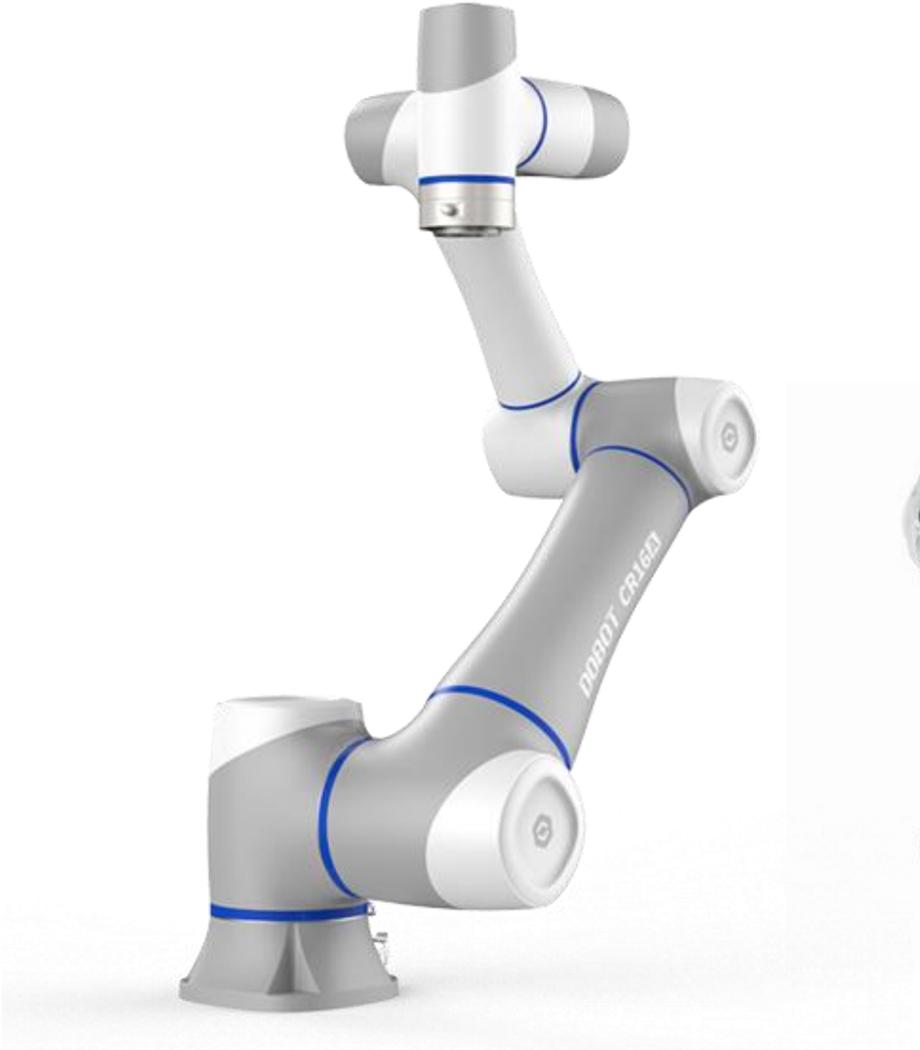

Kobuki

Rhino

Husky

Unitree Go1


Unitree Go2





# Robots for the Robotics lab
# Dobot CRA10 and Unitree Go1 & Go2

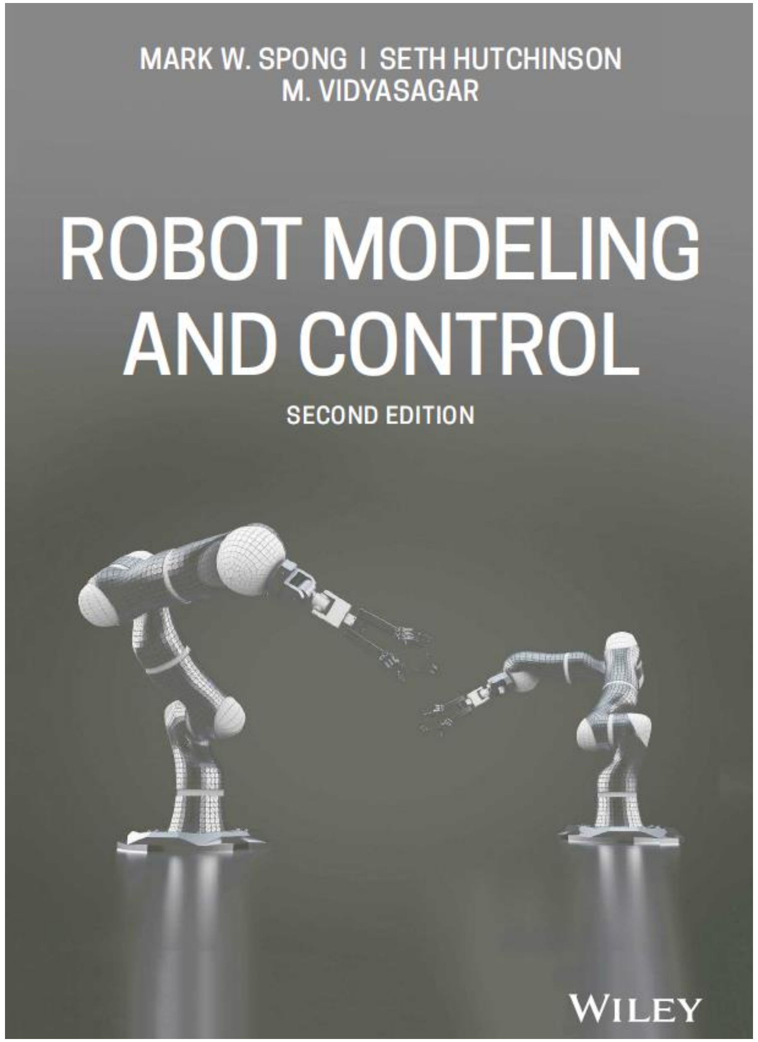
# Syllabus

- **Textbook**
  - M.W. Spong, S. Hutchinson and M. Vidyasagar. *"Robot Modeling and Control"*, John Wiley, Second edition, 2018

- **Class Meetings and Office Hours**

| | | | |
|---|---|---|---|
| **LEC:** | TUE & THU | 3:30 pm – 4:45 pm | BECHTEL 208 |
| **LAB:** | TUE or THU | 5:00 pm – 7:45 pm | IOEC 402 |
| **OH:** | TUE & THU: | 01:00 pm – 03:00 pm | BECH 503 |

- **Personnel**
  - **Lecturer:** Hussien Hussein (Bechtel 503–hh224@aub.edu.lb)
  - **Lab instructor:** Samer Bou Karam (IOEC 411–sb137@aub.edu.lb)



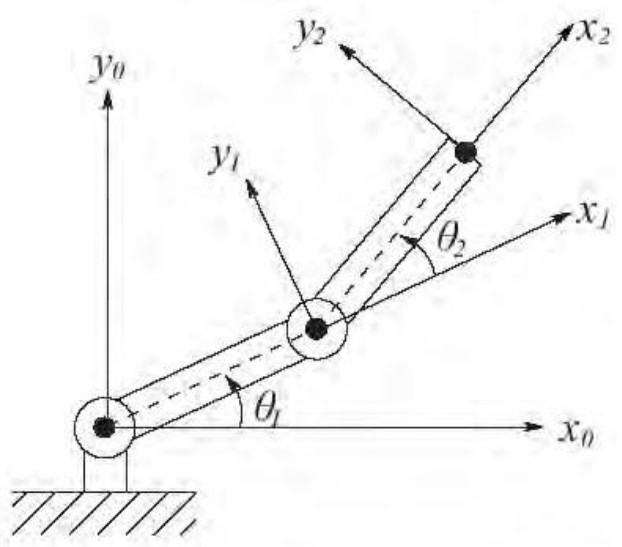
## What is this course about?

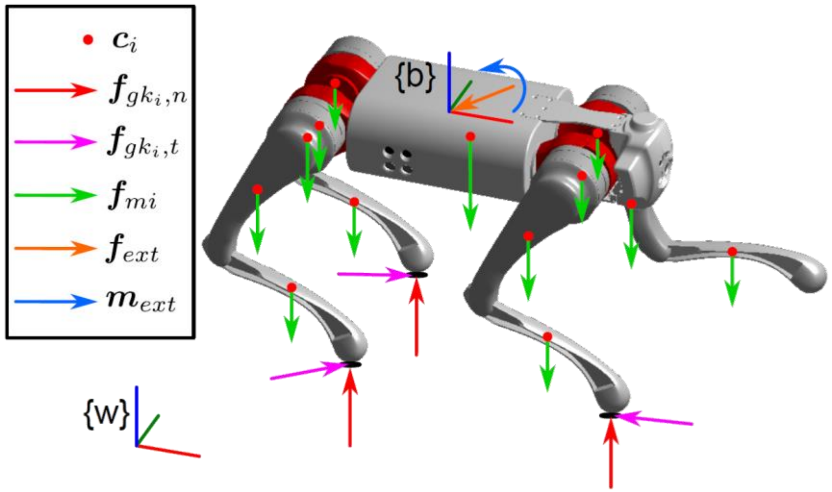
- We want robot arms (typically serial manipulator) do some desired task. To accomplish this, one needs to be well versed in the following topics

- **Robot modeling**
  - Kinematics
  - Dynamics
- **Planning**
  - Motion planning
  - Trajectory generation
- **Control**
  - Traversing a trajectory
  - Motor controller for joints

# Robot modeling

- **Kinematics:** is the study of motion without a regard to forces.
  - Knowing the geometry of the links and the type of the joints are enough to locate any point on the robot

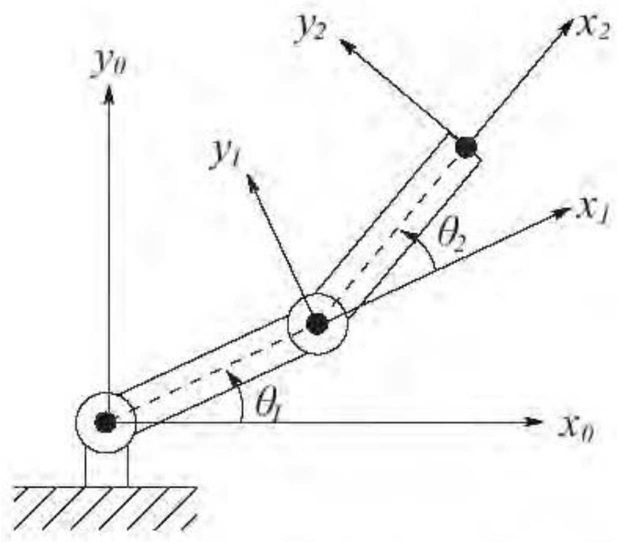



- **Dynamics:** is the study of motion considering the effect of forces on a mechanical system
  - Knowing the mass and inertia of the links, the motion of the robotic system can be described provided that one knows the external forces acting on the robot.

# Planning

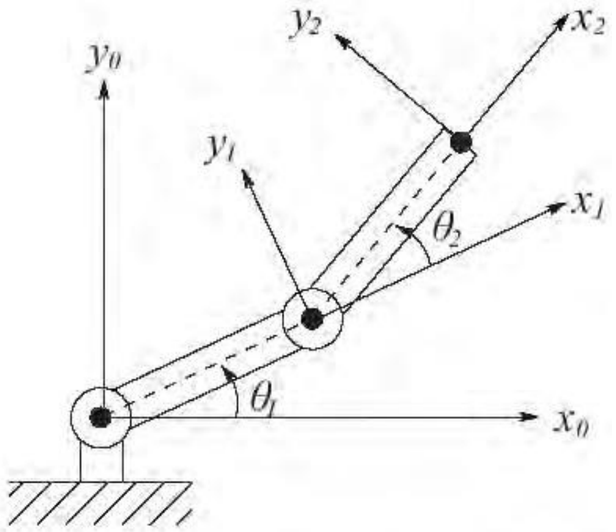
- **Motion planning: path**
  - Formalizing the task of the robot, such as, going from a start to a goal location (fastest time, least control energy, etc.)




- **Trajectory generation: path + schedule**
  - Formalizing how to connect two configurations, how the robot should proceed from a start to a goal

# Control

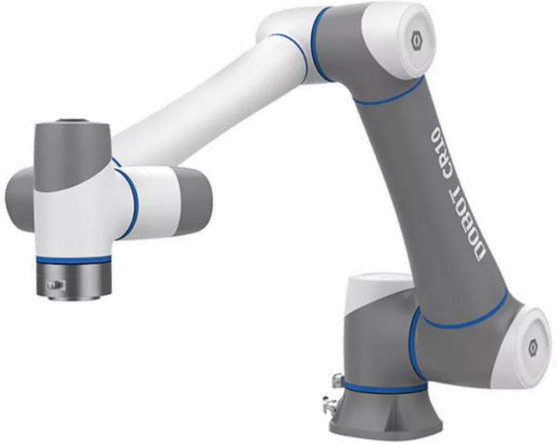
- **Traversing a trajectory:**
  - Finding the motor angles that make the end effector or a robot traverse a trajectory




- **Motor controller for a joint:**
  - Finding the motor input that makes a motor angle maintain a certain value or follow a prescribed function of time.

# Lab sessions

- **Labs span topics such as:**
  - Working with Ros 2 on Ubuntu
  - Building functional Ros applications
  - Using Ros packages (Rviz, gazebo)
  - Advanced project including application of the student solutions on the robotic arm platform and Unitree Go1 and Go2
  - Use LLM for robots decision making

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TOM TAILOR


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| Topic | Learning Activities | Due Dates |
|---|---|---|
| Introduction to Robotics (Chapter 1) | Lecture | 1 week |
| Rigid Motions (Chapter 2) | Lecture, Homework | 2 weeks |
| Forward Kinematics (Chapter 3) | Lecture | 2 weeks |
| Jacobians (Chapter 4) | Lecture | 3 weeks |
| Inverse Kinematics (Chapter 5) | Lecture | 1 week |
| Dynamics (Chapter 6) | Lecture, Homework | 2 weeks |
| Motion Planning and Trajectory Generation (Chapter 7) | Lecture, Homework | 1 week |

| Topic | Due Dates |
|---|---|
| Lab Project 1: ROS Nodes to control a Robot | Half of the semester |
| Lab Project 2: Control robots in Ros for a cooperative application | End of the semester |

# Grading

**Assessment**

| | |
|---|---|
| Team quizzes and activities | 10% |
| Midterm | 20% |
| Lab project | 25% |
| Final | 45% |

**<u>Midterm</u>: Chapters 2, 3, and 4**
**<u>Final</u>: DH + Chapters 4, 5 and 6**

- **Forum**
- **Presentation/Video Segment**
- **Matlab-based assignments and exams**
- **Team assignments and quizzes**

| weeks | Tuesday | Thursday |
|---|---|---|
| 1 | 13-Jan | 15-Jan |
| 2 | 20-Jan | 22-Jan |
| 3 | 27-Jan | 29-Jan |
| 4 | 3-Feb | 5-Feb |
| 5 | 10-Feb | 12-Feb |
| 6 | 17-Feb | 19-Feb |
| 7 | 24-Feb | 26-Feb |
| 8 | 3-Mar | 5-Mar |
| 9 | 10-Mar | 12-Mar |
| 10 | 17-Mar | 19-Mar |
| 11 | 24-Mar | 26-Mar |
| 12 | 31-Mar | 2-Apr |
| 13 | 7-Apr | 9-Apr |
| 14 | 14-Apr | 16-Apr |
| 15 | 21-Apr | 23-Apr |
| 16 | 29-Apr | |

**Team formation**
- 2-3 members per team
- Choose your teams on Moodle

**Grading**
- Grades will be over 10 pts
- First 3 teams will have 1,2 and 3 extra points on the total

# Office hours

| | MONDAY | TUESDAY | WEDNESDAY | THURSDAY | FRIDAY |
|---|---|---|---|---|---|
| 08:00 - 09:00 | | | | | |
| 09:00 - 10:00 | | Mechanics of Materials | | Mechanics of Materials | |
| 10:00 - 11:00 | | | | | |
| 11:00 - 12:00 | | | | | |
| 12:00 - 13:00 | | | | | |
| 13:00 - 14:00 | | Office Hours | | Office Hours | |
| 14:00 - 15:00 | | | | | |
| 15:00 - 16:00 | | Robotics | | Robotics | |
| 16:00 - 17:00 | | | | | |

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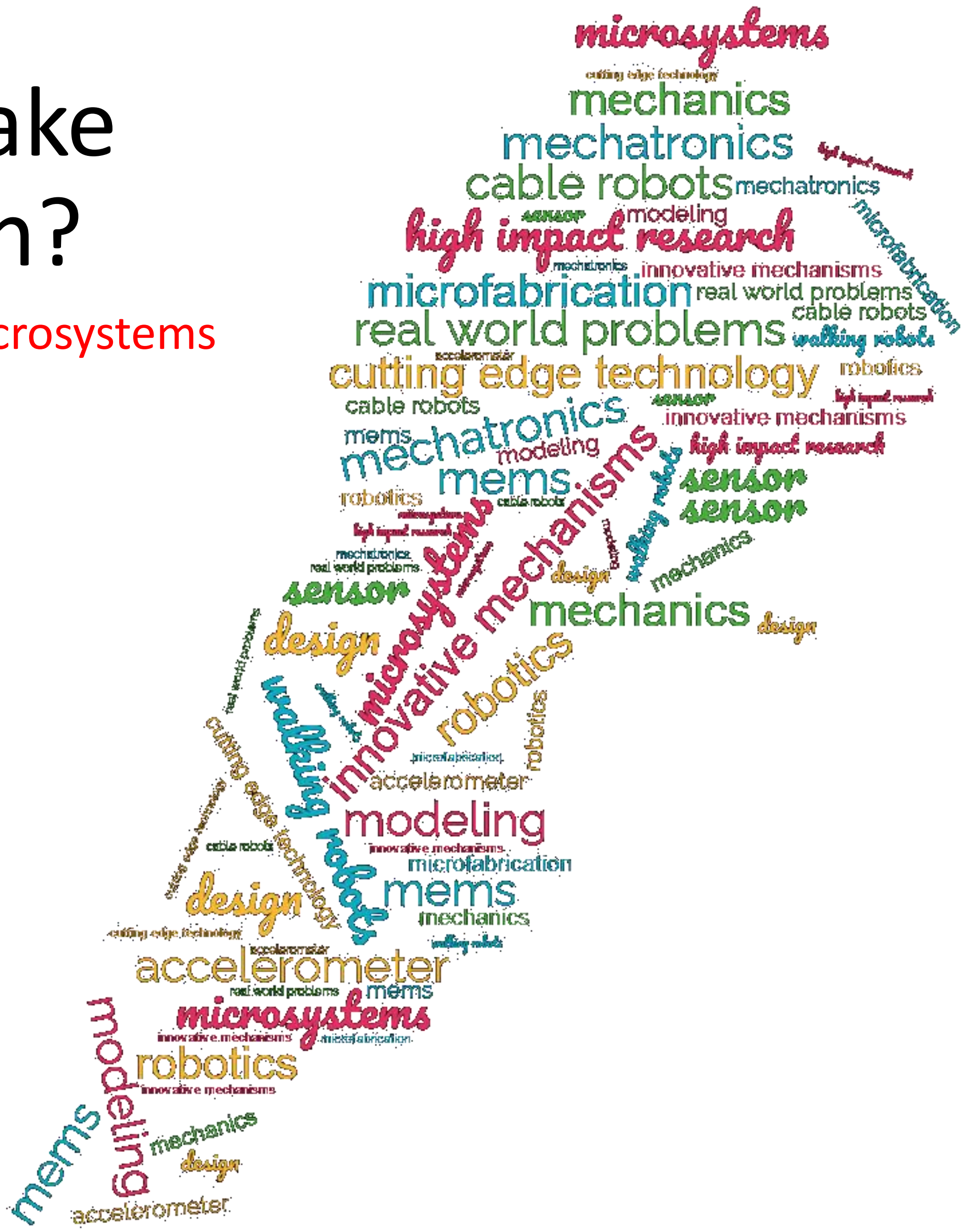
# Do you want to make some nice research?

In Mechanics, Mechatronics, and Microsystems




## Hussein Hussein

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