AI Robotics

Week 1

Outline

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Instructor

- Kristian Fenech fenech@inf.elte.hu North Building 7.50
- Mark Domonkos domonkos@inf.elte.hu
- Office Hours: Friday 13:00 - 15:00

E-Learning/Canvas

- In-person teaching - All lectures and practical sessions will take place in person.
- Canvas eLearning: `https://canvas.elte.hu/courses/29540`
- Communication regarding the course will occur primarily via Canvas
- All homework, reports and other assessments will need to be submitted online via Canvas.
- Turn on course notifications in Canvas

Subject Goals

- Develop a comprehensive and up to date understanding of the fundamental knowledge in modeling and simulating robotic systems.
- Develop a theoretical understanding of the physical models used to describe the kinematics and dynamics of common robotic systems and experience in programming robotic systems in state-of-the-art simulation environments.
- Develop sufficient background knowledge, terminology and experience to communicate and interact with other researchers in the field of robotics.

Software and Tools

The following software and tools will be used throughout the course

- Python `https://www.python.org/downloads/`
- ROS `https://www.ros.org/`
- LaTeX `https://www.latex-project.org/get/#tex-distributions`

Lecture Schedule

The schedule for the lectures will be

1. Course Overview and History of Robotics
2. Robot Architectures
3. Perception, Sensing and SLAM
4. Spatial Descriptions and Configuration Space
5. Rigid Body Motion
6. Guest Lecture
7. Kinematics
8. Inverse Kinematics
9. Dynamics
10. Trajectory Generation
11. Control
12. Guest Lecture
13. Summary Lecture

Though these are subject to change

Practical Sessions

- Practical sessions will focus on problem solving. With some sessions involving demonstrations and problem solving, others will focus on solving a problem in ROS.
- Practical assignments will be scored out of 10 points. 7 points coming from the completed work and 3 point from the accompanying report
- Reports should be a minimum 1 page description of the problem, any theoretical background related to the result and finally a summary of the result including figures if relevant.
- 3 Practice assignments will be given.
- Practice assignments are worth 30% of the total grade.

Homework

- 5 problem sets will be given throughout the semester.
- Answers can be either hand-written or be typeset in LaTeX and submitted through Canvas. Note: You can also submit the physical copy if you wish

Quizes and Exam

- Each week there will be a short concept quiz available on Canvas to help reinforce the lecture material
- Quizzes will not be counted to the final grade but all quizzes need to be passed to attend the exam
- You may repeat the quizzes as many times as you like
- Due date for the quizzes is by the start of the final lecture
- Currently planned that there will be a written Exam
- Exam will make up 50% of the total mark

Grading

- Concept Quiz - Pass/Fail
- Homework - 20%
- Practical Sessions - 30%
- Exam - 50%

Prerequisite Topics

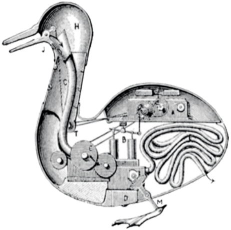
The following topics should be familiar to you.

- Linear algebra
- Differential equations
- Python

Outline

Early Era

- Machines and automata mentioned as far back as 1000 BC
- We will see that many of these early automata don't quite match our definition of robot



Modern Era 1920-1940

- The term 'Robot' was first used in the 1921 play Rosmun's Universal Robots by Czech playwright Karel Capek
- These robots were built to perform manual labor for their human creators
- Elektro introduced in 1939
  `https://www.youtube.com/watch?v=6HiRz-c3vBE`

Modern Era 1940-1960

- Issac Asimov introduces his three laws of robotics
- Elmer and Elsie `https://youtu.be/lLULRlmXkKo?t=41`
- Unimate
- George Devol and Joe Engleberger design the first programmable robot "arm" first industrial robot

Modern Era 1960-1980

- Heinrich Ernst develops the MH-1, a computer-operated mechanical hand. (1961)
- Wabot 1 first full-scale anthropomorphic robot introduced (1973)
- Programmable Universal Manipulation Arm Victor Scheinman (1975)
- PUMA developed by Unimation (1978)
- Stanford Cart developed by Hans Moravec (1979)
  `https://www.youtube.com/watch?v=ypE64ZLwC5w`

Modern Era 1980-2000

- PUMA 560 surgical arm used in procedure (1985)
- CyberKnife developed by John Adler (1992)
- Robo-Tuna developed by David Barrett and Michael Triantafyllou (1996)
- Honda develops the P-2 robot (1996)
  https://www.youtube.com/watch?v=FEXSqsW6rMM
- Sony Aibo canine robot (1999)

Modern Era 2000-2020

- Honda ASIMO released (2000)
- iRobot Roomba robot vacuum (2002)
- Boston Dynamics Big-Dog (2005)
- Robonaut 2 (2011)
- Sophia (2017)

Outline


ASIMO

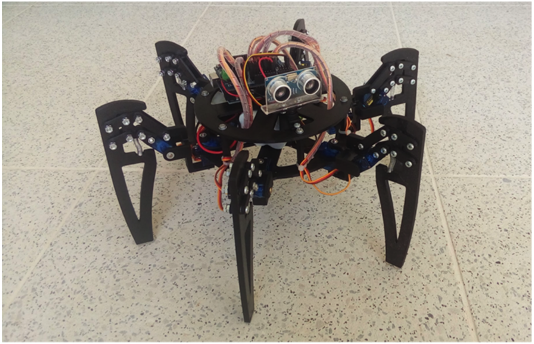

BostonDynamics

Defining a Robot

Definition

A physical system capable of acting autonomously, with the capacity to sense its environment, and act accordingly to achieve a goal.

- A physical robot is a construction made up of rigid-bodies (**links**) connected by **joints**, which are driven by **actuators** after processing the external world with **sensors** using on-board **computation**



Stationary vs Mobile

- Two main category of robot Stationary and Mobile
- While the the workspace is constrained for stationary robots, it is still important that the robot can sense and plan within its environment to deal with new obstacles safely
- Mobile robots require additional path planning and navigation. In some cases navigation can be constrained to less than 3 spatial dimensions

Joints

- Joints are components which provide the ability for one link to move relative to another
- These joints are categorized by the number of degrees of freedom (dof) which defines the number of independent directions which the joint can move.
- The possible degrees of freedom for a single joint can be 1, 2 or 3.

Joints

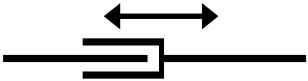
- The following are the most common joints for rigid bodies

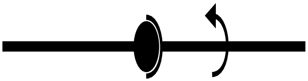
Joint Name	DOF	Notation
Revolute	1	R
Prismatic	1	P
Helical	1	H
Cylindrical	2	C
Universal	2	U
Spherical	3	S

- Robots can be identified by their joint configuration
- Example: A common multi-link robot is the RPR configuration

1-DOF Joints

- Three most common 1-DOF joints are the Revolute, Prismatic and Helical Joints



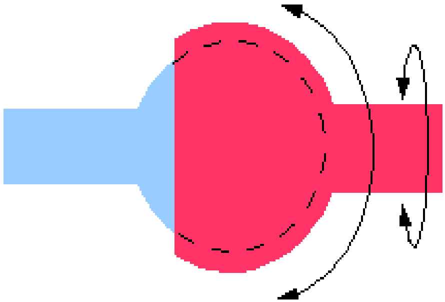


2-DOF Joints

- Common 2-DOF joints are the Cylindrical and Universal Joints
- Universal joint is made of two orthogonally connected revolute joints
- Cylindrical joint can be made by serially connecting a prismatic and revolute joint

3-DOF Joints

- The spherical joint is also known as the ball and socket joint



End-Effectors

- The actuating element which allows a robot to manipulate and move around in its environment and achieve its goal
- End-effectors for manipulation include
  - Grippers
  - Suction
  - Welding tools
- Effectors for motion include
  - Wheels
  - Tracks
  - Legs

Actuators

- Any device which produces motion
- Motion can be linear or rotary
- Can be powered Electrically, Pneumatically or Hydraulically. Primarily Electrically
- Most common actuator is the electric motor

Sensors

- Senors are essential for the autonomous operation of a robot
- Sensing allows the robot to measure its internal state (position, joint angles, velocity, etc) and the external state (locations of objects, walls, etc)
- Proprioceptive sensors provide internal measurement and exterioceptive sensor provice external measurement

Proprioceptive Sensors

- Provide measurement of the internal states
- Position sensors (GPS, GNSS) provide a coordinate reference
- Inertial sensors (Gyroscopes) can provide a relative location for when absolute position is unavailable
- Encoders can measure joint angle, velocity
- Current and Voltage sensors
- Accelerometers
- Force Sensors

Exterioceptive Sensors

- Provide measurement of the external states
- Vision sensors
  - Monocular RGB
  - Stereo RGB (also rangefinding to an extent)
- Rangefinding sensors
  - Ultrasonic
  - LIDAR
  - RADAR
- Contact sensors

Exterioceptive Sensors

- Provide measurement of the external states
- Environmental Sensors
  - Gas sensors
  - Magnetic field sensors
  - Light sensors

Computation

- All robots need a brain
- For most hobby and simple robotic projects modern ARM microprocessors such as those in the RaspberryPi, Arduino are suitable
- For most industrial usage PLC (Programmable Logic Controller) are used

Summary

- Covered the administration of the course, contact information, schedule, assignments and expectations
- A brief history of key developments in the history of robotics
- Defined a robot as: A physical system capable of acting autonomously, with the capacity to sense its environment, and act accordingly to achieve a goal.
- Introduced the physical components which allow a robot to move, manipulate and sense its self and its environment. These components are links, joints, actuators and various sensors

- Next Lecture
  - Robot control paradigms