

An Overview of Autonomous Robotic Systems

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Outline

- 1 Autonomous Robots
- 2 Agents
- 3 Environments
- 4 Agent types
- 5 Typical components
- 6 Example soccer robot
- 7 Example service robot
- 8 Acknowledgement



From automation...



Autonomous robots

Robot

A robot is a autonomous system which exists in the physical world, can sense its environment and can act on it to achieve some goals.

Autonomous robot

- An autonomous robot acts on its own decisions.
- It is not **directly** controlled by humans.
- Take an appropriate action for any given situation.

Robots

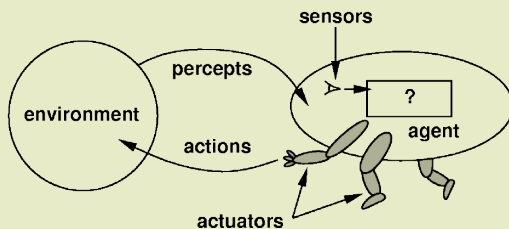
- **Situatedness**

Agents are strongly affected by the environment and deal with its immediate demands (not its abstract models) directly.

- **Embodiment**

Agents have bodies, are strongly constrained by those bodies, and experience the world through those bodies, which have a dynamic with the environment.

Agents and environments



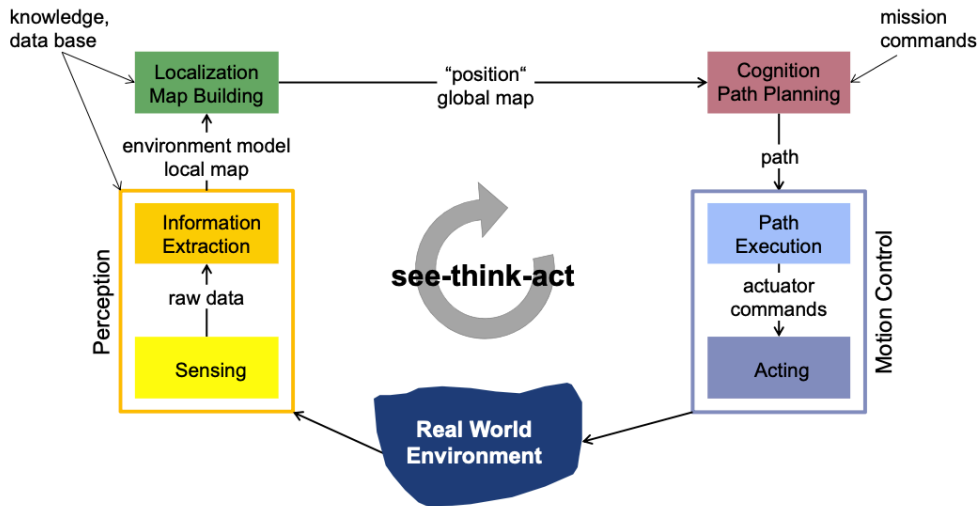
Agents interact with environments through sensors and actuators.

- Perception, perception sequences
- Agent function (abstract)
- Agent program (concrete)

Good behavior: rationality

- Rational agent
 - A rational agent is one that does the right thing...
 - First approximation, we will say that the right action is the one that will cause the agent to be most successful.
 - Problem: How and when do we decide whether or not the agent was successful?
- Performance measures
 - Subjective
 - Agent evaluates himself.
 - Objective
 - Evaluation done by observer: he defines standards for being successful in the environment.
 - Example: soccer agent.

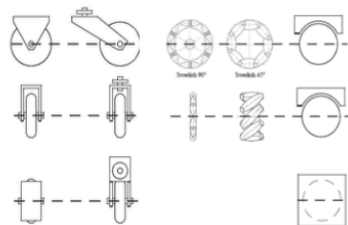
The see-think-act cycle knowledge



Source: R. Siegwart et al. 2015, ETH Zürich, Lecture series on Autonomous Mobile Robots

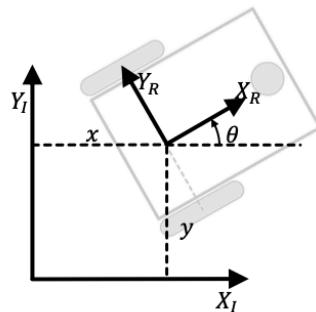
Motion control and kinematics

- Wheel types and its constraints
 - Rolling constraint
 - no-sliding constraint (lateral)
- Motion control

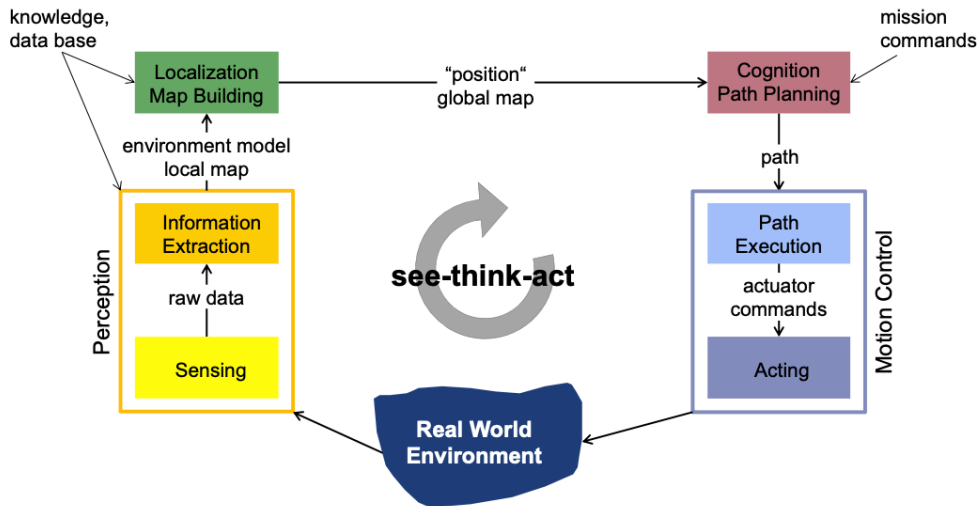


$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = f(\dot{\varphi}_1 \dots \dot{\varphi}_n, \theta, \text{geometry})$$

$$\begin{bmatrix} \dot{\varphi}_1 \\ \vdots \\ \dot{\varphi}_n \end{bmatrix} = f(x, y, \theta) \quad ?$$



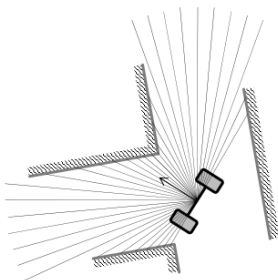
The see-think-act cycle knowledge



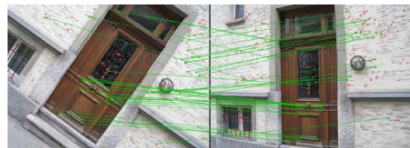
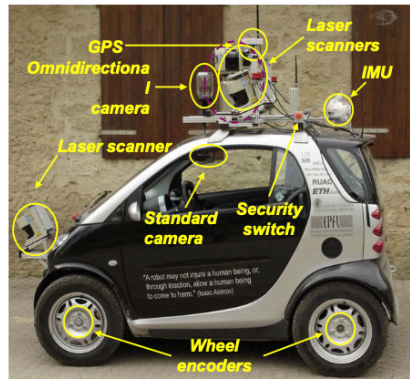
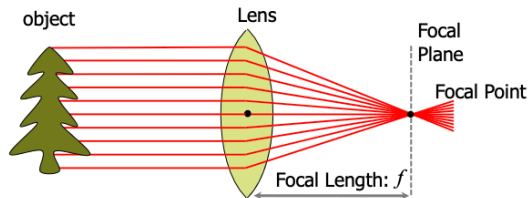
Sensing

■ Laser scanner

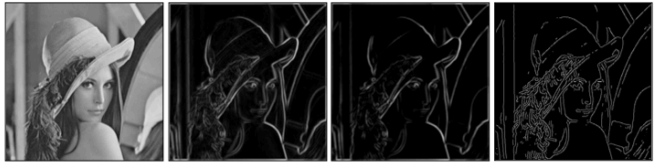
- time of flight



■ Camera



Information extraction



- Filtering / Edge Detection

- Keypoint Features
 - features that are reasonably invariant to rotation, scaling, viewpoint, illumination
 - FAST, SURF, SIFT, BRISK, ...

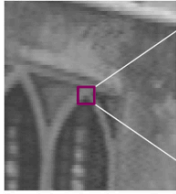
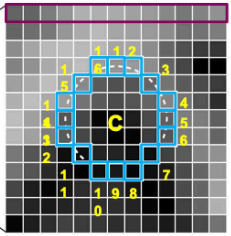


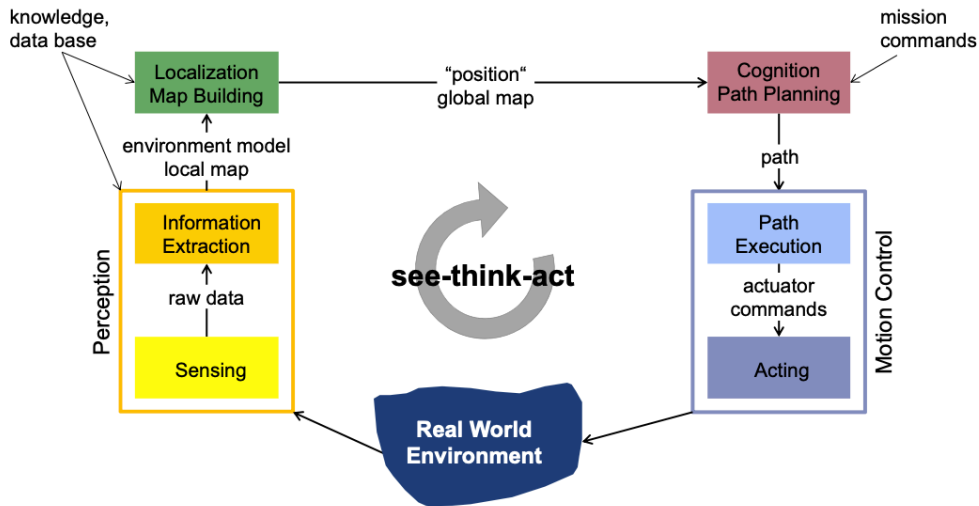
Image from [Rosten et al., PAMI 2010]



- Keypoint matching
 - BRISK example

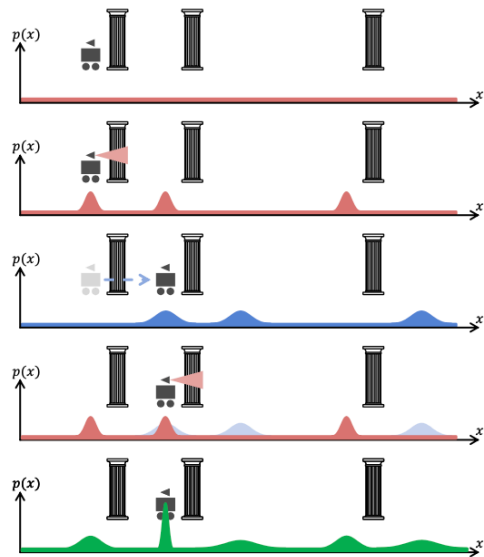


The see-think-act cycle knowledge

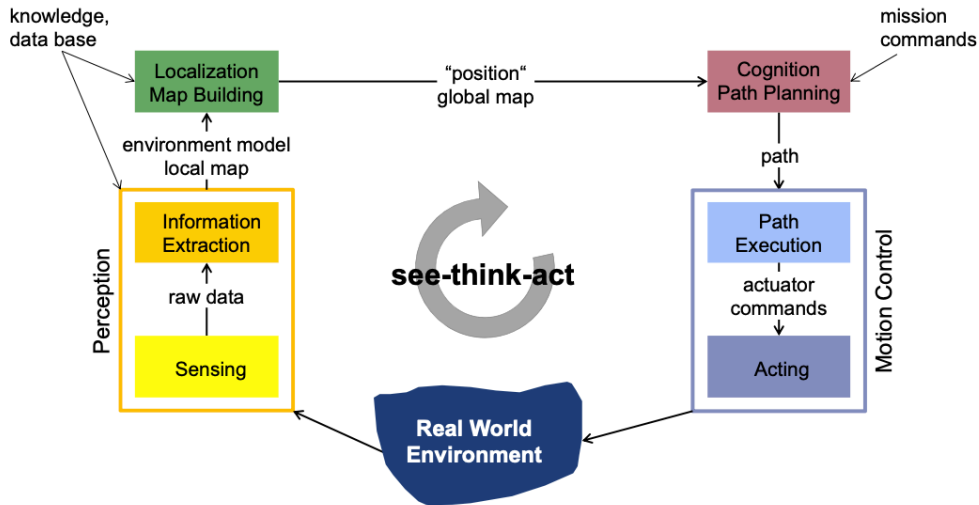


Localization

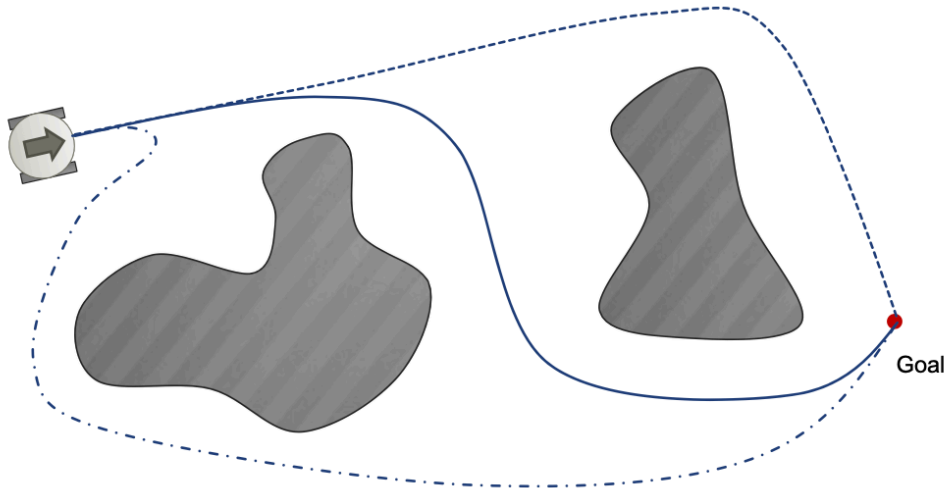
- SEE:** The robot queries its sensors
 → finds itself next to a pillar
- ACT:** Robot moves one meter forward
 - motion estimated by wheel encoders
 - accumulation of uncertainty
- SEE:** The robot queries its sensors
 again → finds itself next to a pillar
- Belief update (information fusion)**



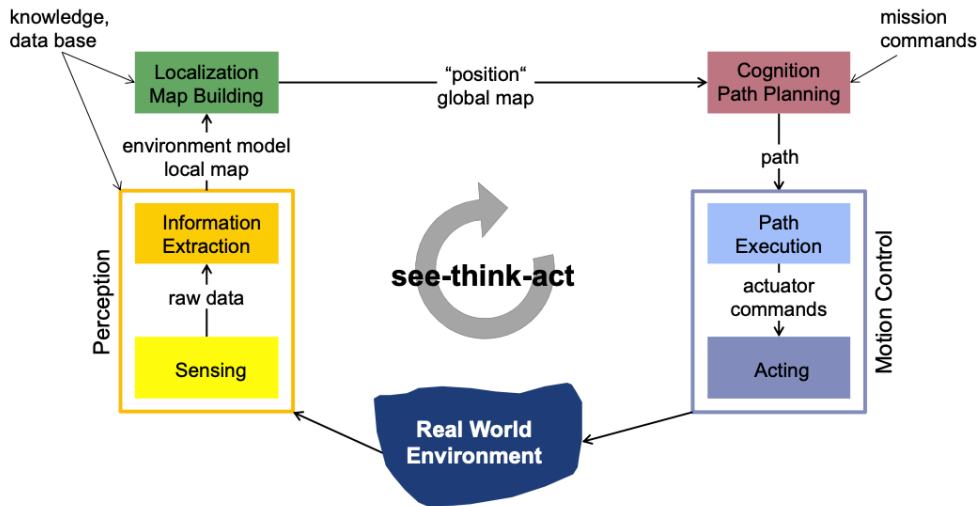
The see-think-act cycle knowledge



Cognition, where am I going, and how?



The see-think-act cycle knowledge



Environments

PEAS for a Service Humanoid Robot

PEAS Element	Service Humanoid Robot
Performance Measure	Safe operation, task success, balance, efficient assistance, reliable manipulation, and natural human interaction.
Environment	Homes, hospitals, offices, classrooms, hallways, kitchens, and other indoor spaces shared with people and objects.
Actuators / Effectors	Arms, hands or grippers, legs, torso, head, speakers, display, and possibly a hybrid mobile base.
Sensors	Cameras, depth sensors, LiDAR, IMU, encoders, force sensors, tactile sensors, microphones, and foot contact sensors.



Robots and uncertainty

- Uncertainty is a key property of existence in the physical world.
- Physical sensors provide limited, noisy, and inaccurate information.
- Physical effectors produce limited, noisy, and inaccurate action.
- The uncertainty of physical sensors and effectors is not well characterized, so robots have no available a priori models.

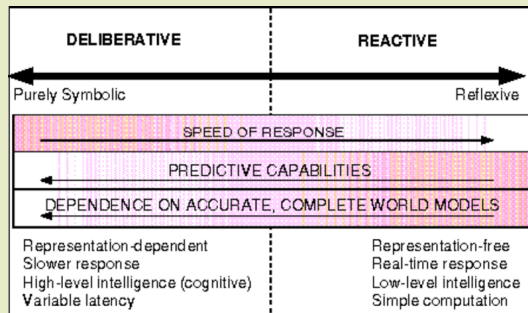
Robots and uncertainty

- A robot can not accurately know the answers to the following:
 - Where am I?
 - Where are my body parts, are they working, what are they doing?
 - What did I just do?
 - What will happen if I do X?
 - Who/what are you, where are you, what are you doing, etc.?
 - ...

Agent types

Agents types

Spectrum of robot control:

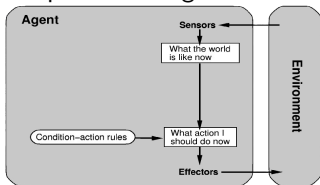


From "Behavior-Based Robotics" by R. Arkin, MIT Press, 1998

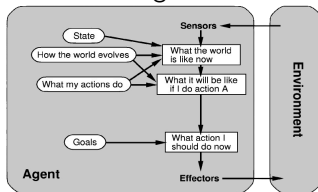
Agent Program Types

Four basic kinds of agent programs that embody the principles underlying almost all intelligent systems:

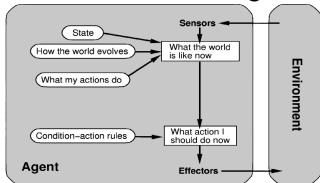
- Simple Reflex Agents



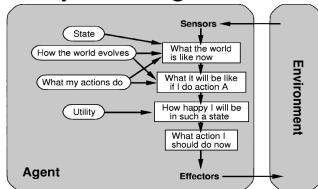
- Goal-based Agents



- Model-based Reflex Agents



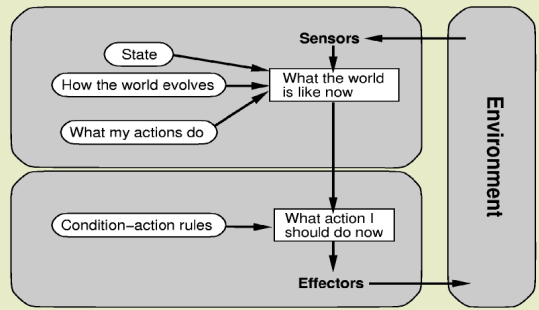
- Utility-based Agents



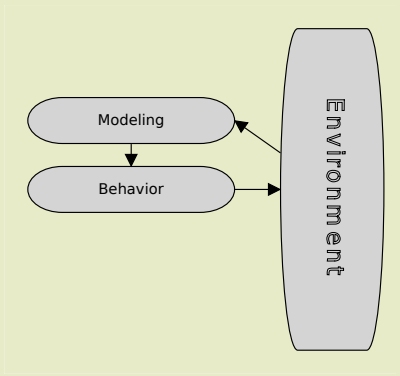
Typical components

Typical components

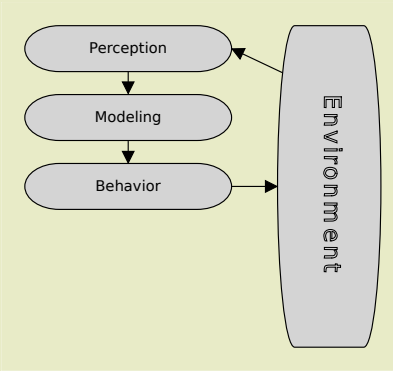
Split into a modeling and behavior:



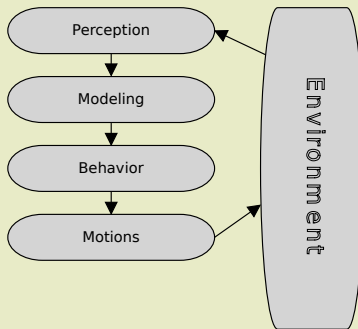
Typical components



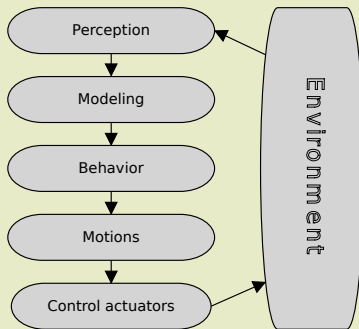
Typical components



Typical components



Typical components



Example soccer robot

Example soccer robot



- What do these robots do?
- Same categories:
 - Perception
 - Modeling
 - Behavior
 - Motions
 - Control

Perceptions



From image processing:

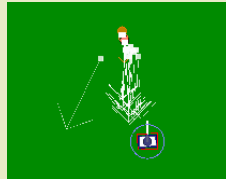
- ball
- goalposts
- field lines
- parts of other robots

Other:

- current joint angles
- battery state
- accelerometer
- ...

Modeling

- Self-localization
- Estimate orientation of the robot (standing/lying)
- Ball tracking
- Opponent tracking



Behavior

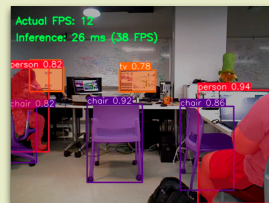
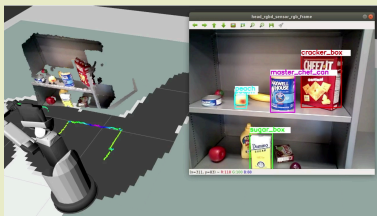
- Decide what to do based on
 - current world model,
 - team communication,
 - role,
 - current plan,
 - internal state,
 - ...
- Select actions (e.g. "walk forward", "left kick")

Example service robot, HSR TMC



- What does this robot do?
- Same categories:
 - Perception
 - Modeling
 - Behavior
 - Motions
 - Control

Perceptions



From image processing:

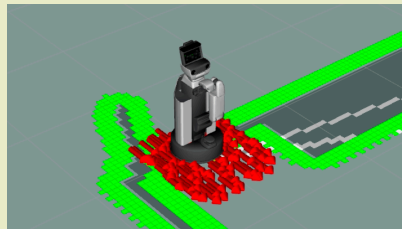
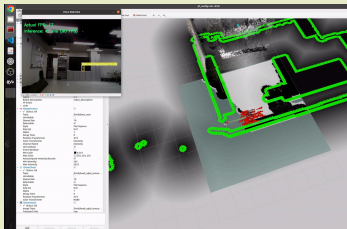
- household objects
- categorization (kitchen items, food items...)
- maps
- environment segmentation

Other:

- current joint angles
- battery state
- IMU
- ...

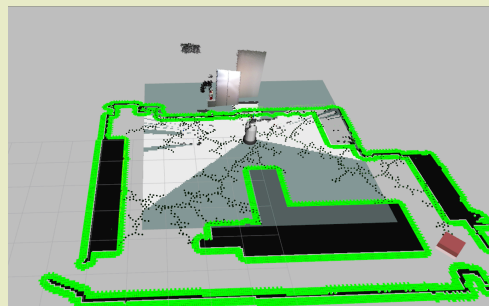
Modeling

- Self-localization
- Estimate orientation of the robot (standing/lying)
- Object tracking
- Human tracking



Behavior

- Decide what to do based on
 - current world model,
 - team communication,
 - role,
 - current plan,
 - internal state,
 - ...
- Select actions (e.g. "move forward", "pick-and-place mustard bottle")



Motion & control

- Motion:
 - Moving using wheels, pick-and-place, interact with humans...
 - Set an angle for each joint.
 - Calculate trajectories, inverse kinematics, balancing, ...
 - Execute static angle sequences.
- Control
 - Move joints to the target positions.

Acknowledgement

Acknowledgement

Some of the slides for this course have been prepared by Andreas Seekircher. I took some material from the ASL Lab at ETH Zürich <https://asl.ethz.ch/>.

CSC 398 - Introduction to Autonomous Robots

**CSC 398 - Topics in CS
Fall 2026**

**Lec: TuTh 11:00 pm - 12:15 pm
Lab: Tu 5-7pm
UB 305**

Introduction to Autonomous Robots

Autonomous robotic systems integrate techniques from AI, robotics, machine learning, image processing, signal processing, and more. We use the RoboCup@Home environment in simulation with NVIDIA's Isaac Sim and reality. We'll employ Toyota's state-of-the-art research service robot (HSR). Topics include controls, kinematics, machine learning, perception, cognition, reasoning, and HRI.



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