

Outline

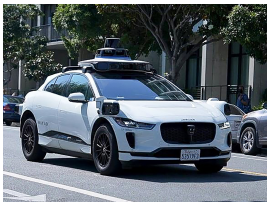
- 1 Autonomous robots
- 2 Agents
- 3 Environments
- 4 Agent types
- 5 Typical components
- 6 Example soccer robot
- 7 Example service robot



From automation...



...to autonomy



Waymo Autonomous Vehicle



Spot Robot



Adult Humanoids, RoMeLa, UCLA & NimbRo, U Bonn



Da Vinci Surgical Robot



Solo, 3D Robotics

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.

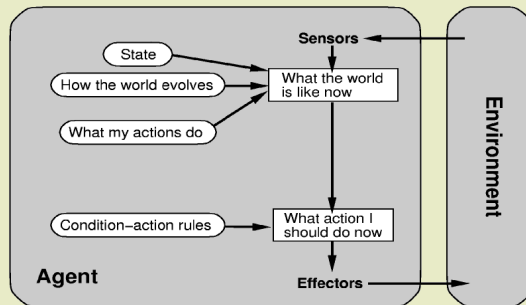
Typical components

Typical components

- Previous agent types from "S. J. Russell and P. Norvig. Artificial Intelligence: A Modern Approach."
- Focus so far on decision-making.
- Usually there are other parts in the architecture of an autonomous robot.

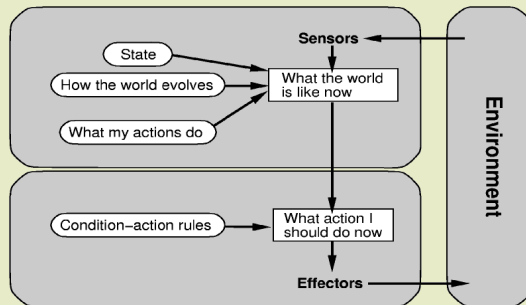
Typical components

The model-based reflex agent:

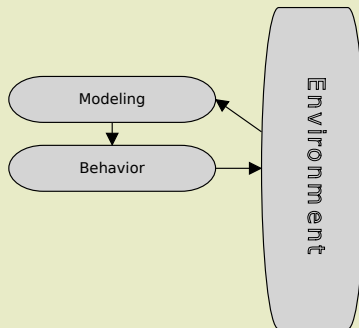


Typical components

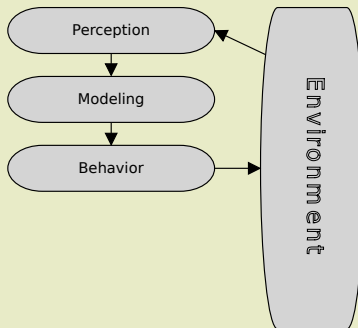
Split into a modeling and behavior:



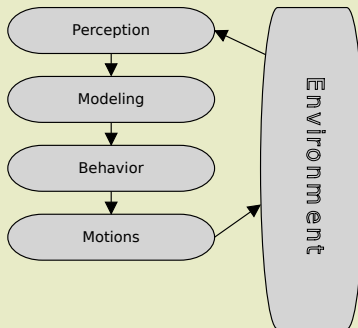
Typical components



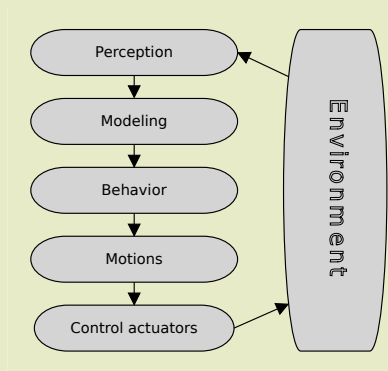
Typical components



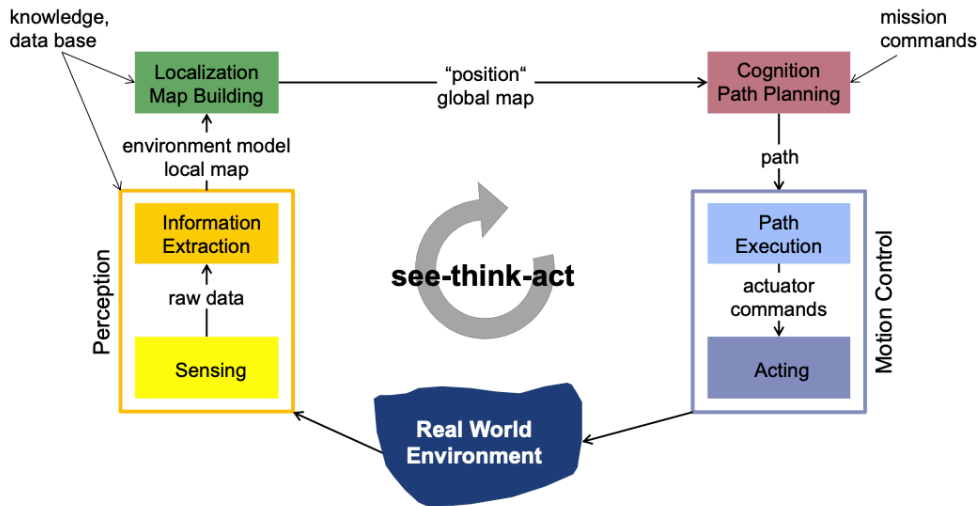
Typical components



Typical components



The see-think-act cycle knowledge

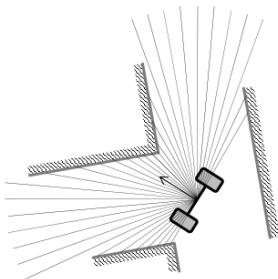


Source: R. Siegwart et al. 2015, ETH Zürich, Lecture series on Autonomous Mobile Robots

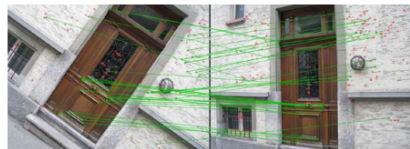
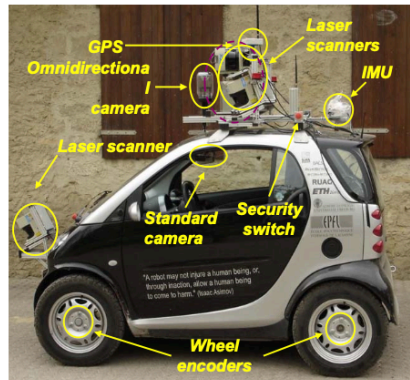
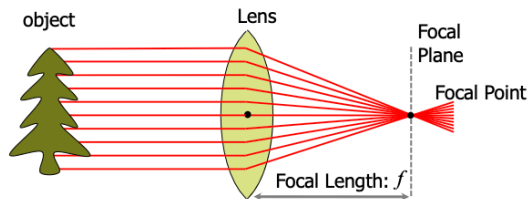
Sensing

■ Laser scanner

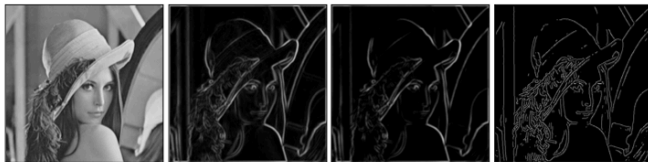
- time of flight



■ Camera



Information extraction



- Filtering / Edge Detection

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

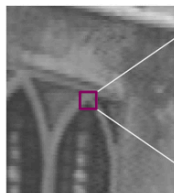
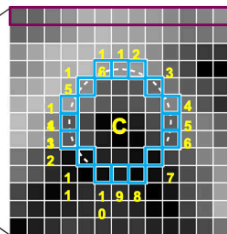


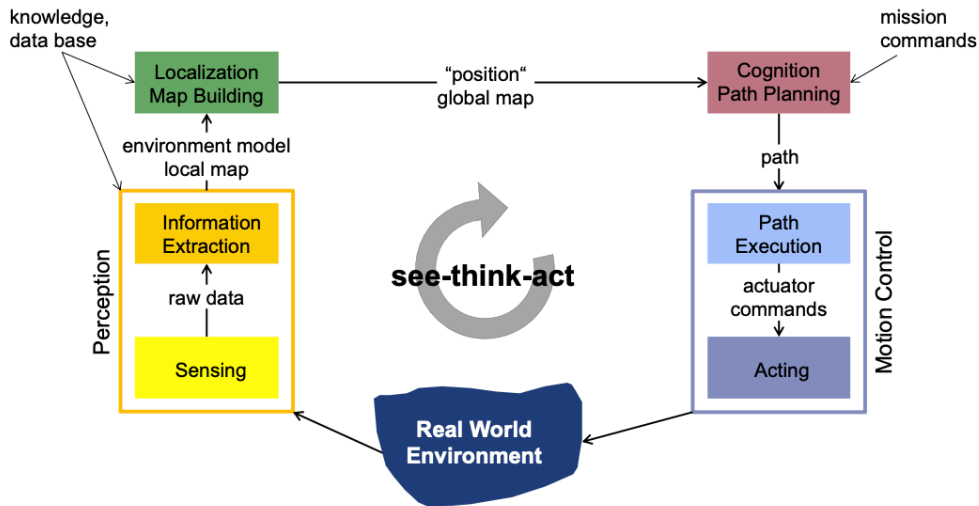
Image from [Rosten et al., PAMI 2010]



- Keypoint matching
 - BRISK example

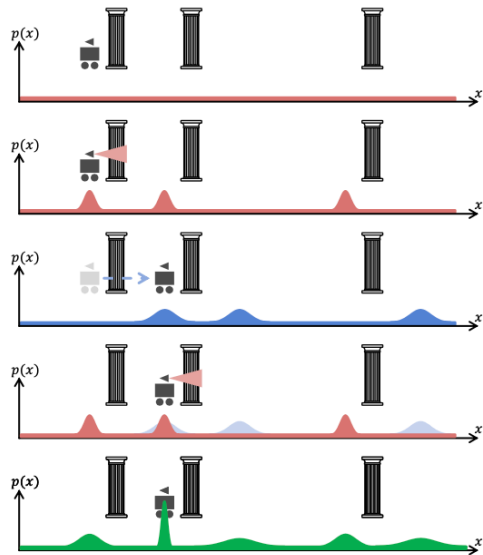


The see-think-act cycle knowledge

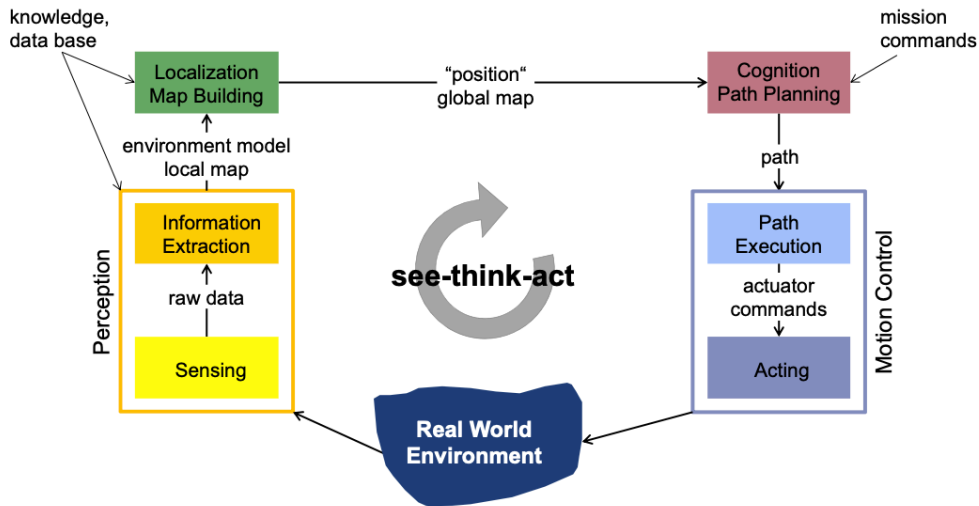


Localization

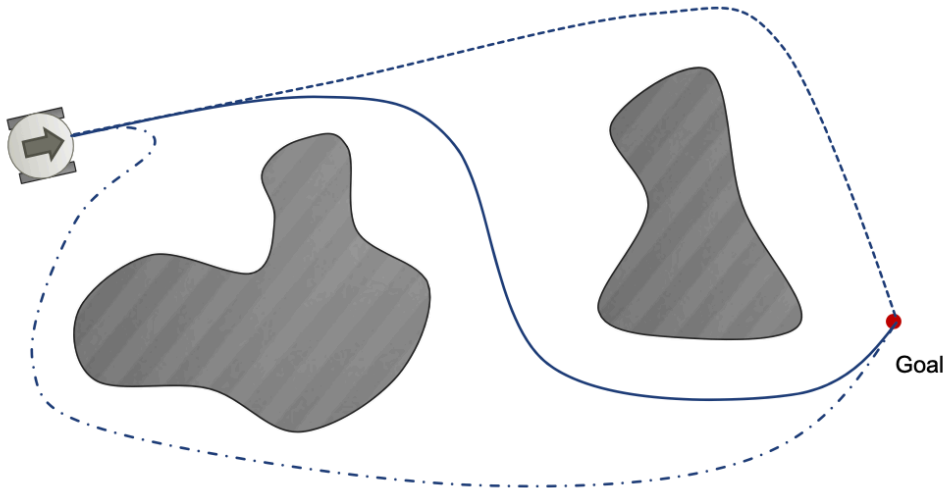
- **SEE:** The robot queries its sensors
→ finds itself next to a pillar
- **ACT:** Robot moves one meter forward
 - motion estimated by wheel encoders
 - accumulation of uncertainty
- **SEE:** The robot queries its sensors
again → finds itself next to a pillar
- **Belief update (information fusion)**



The see-think-act cycle knowledge

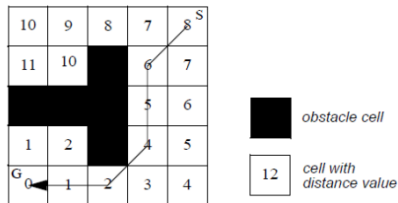


Cognition, where am I going, and how?

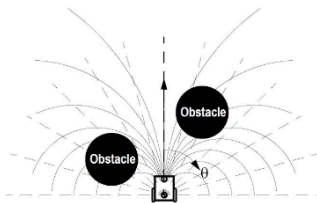


Cognition, where am I going, and how?

- Global path planning
 - Graph search

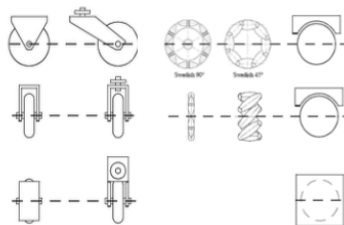


- Local path planning
 - Local collision avoidance



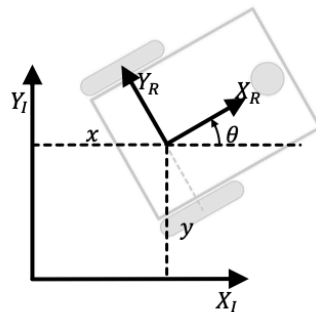
Motion control and kinematics

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

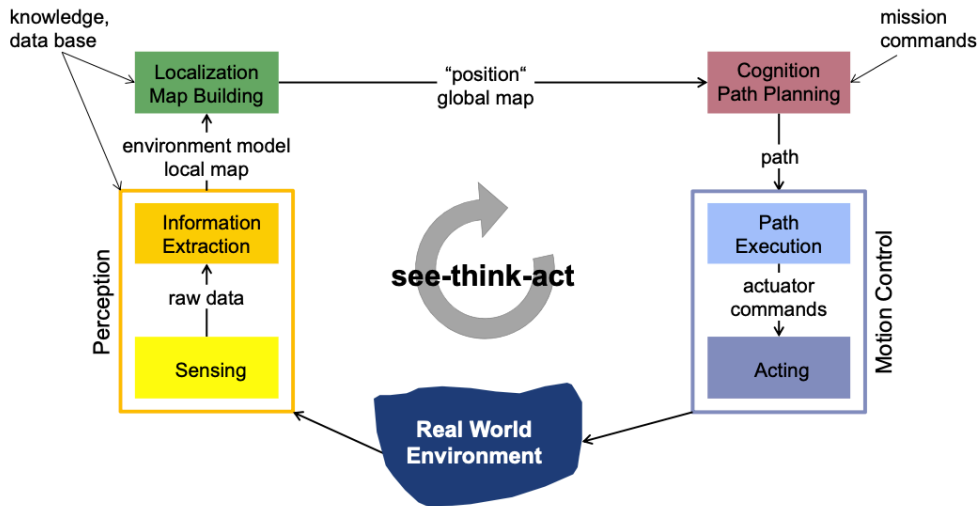


$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = f(\dot{\phi}_1 \cdots \dot{\phi}_n, \theta, geometry)$$

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



The see-think-act cycle knowledge



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.?
 - ...

Example soccer robot

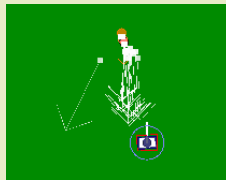
Example soccer robot



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

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")

Motion & control

- Motion:
 - Walking, kick, stand-up, ...
 - Set an angle for each joint.
 - Calculate trajectories, inverse kinematics, balancing, ...
 - Execute static angle sequences.
- Control
 - Move joints to the target positions.

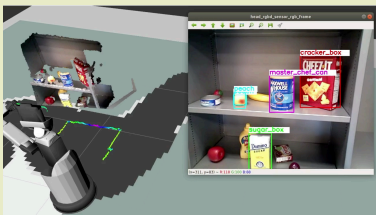
Example service robot

Example service robot, HSR TMC



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

Perceptions



From image processing:

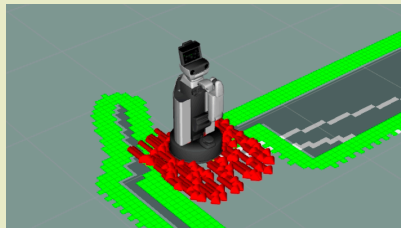
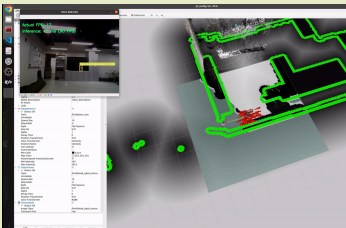
- household objects
- categorization (kitchen items, food items...)
- maps
- environment segmentation

Other:

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

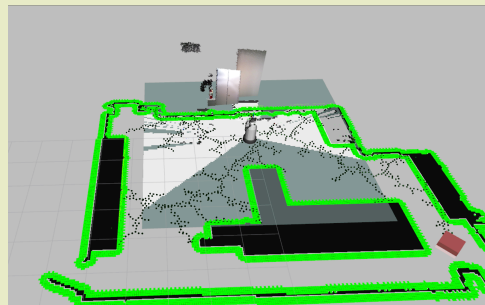
Modeling

- 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/>.