Exploration strategies for autonomous mobile robots

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Outline

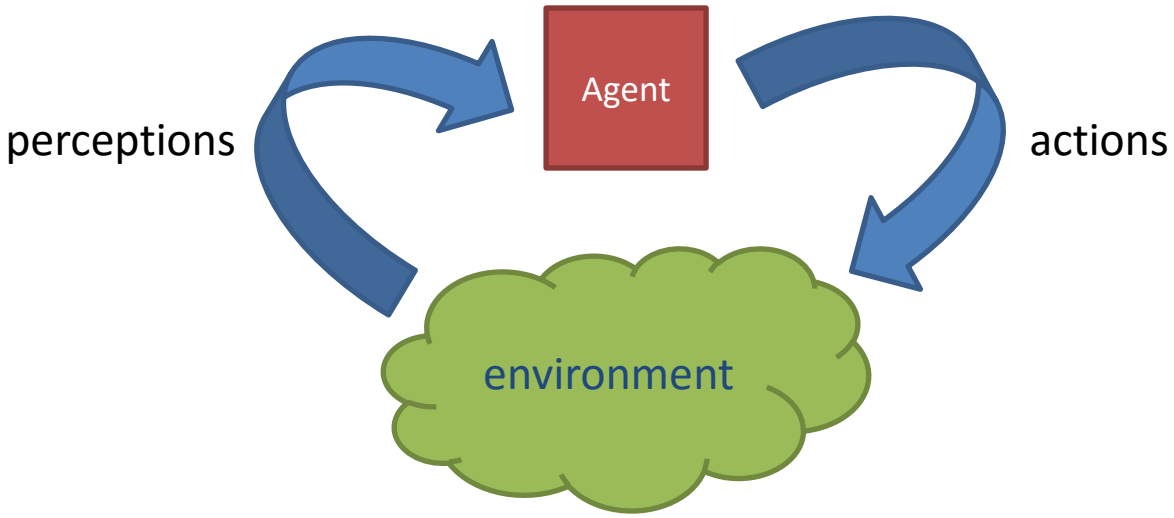
- Agents and Robots
- Exploration with a single robot
- Exploration with multiple robots under constraints

Agents

Agents

- *"[…] anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators." [Russel, Norvig 1995]*

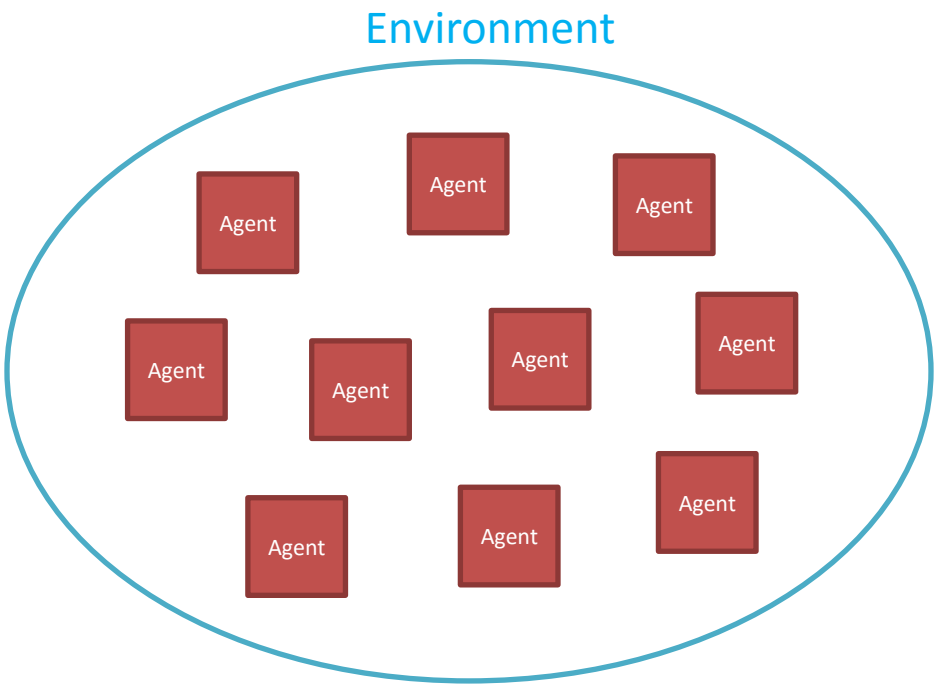
- *"[…] a computer system that is situated in some **environment**, and that is capable of **autonomous action** in this environment in order to meet its delegated objectives." [Wooldrige, 2009]*



Agents

- What features should characterize an intelligent agent?
- **Decisional autonomy**: given a set of objectives, find out how to carry out them

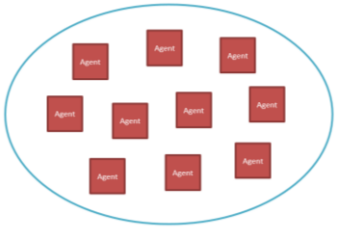
Multi-agent systems



A collection of agents interacting among each other and with the environment with the aim of carrying out a particular task

Multi-agent systems

- Synergies and connections with several disciplines
  - Distributed Systems
  - Artificial Intelligence and Robotics
  - Economics (both from mathematical and computational perspectives)
  - …

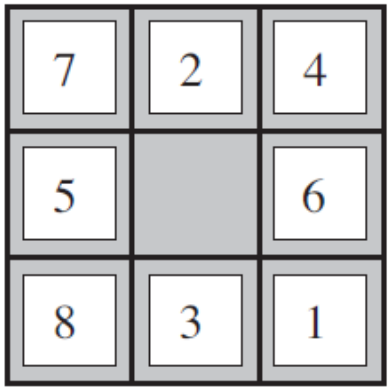


- MAS as an engineering paradigm
  - Viewing a problem and/or its resolution from a multi-agent stance can be convenient
  - *Example: computation as the result of interaction between software entities*

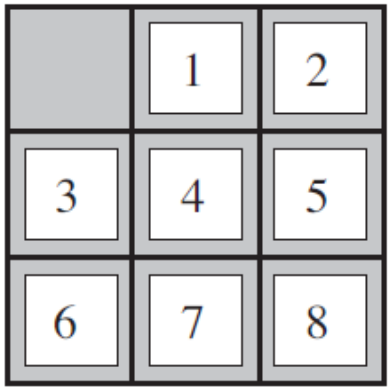
- MAS as a class of problems
  - Some real-world applications live in multi-agent settings and must be tackled as such
  - *Example: build a map of an environment with a team of cooperating autonomous mobile robots*

Planning

- What does it mean that agents have the capability of planning?
- Traditional sense: given a current (start) state and a goal state compute a sequence of actions (plan) to reach the goal state
- Classical example [Russel,Norvig]



Start State

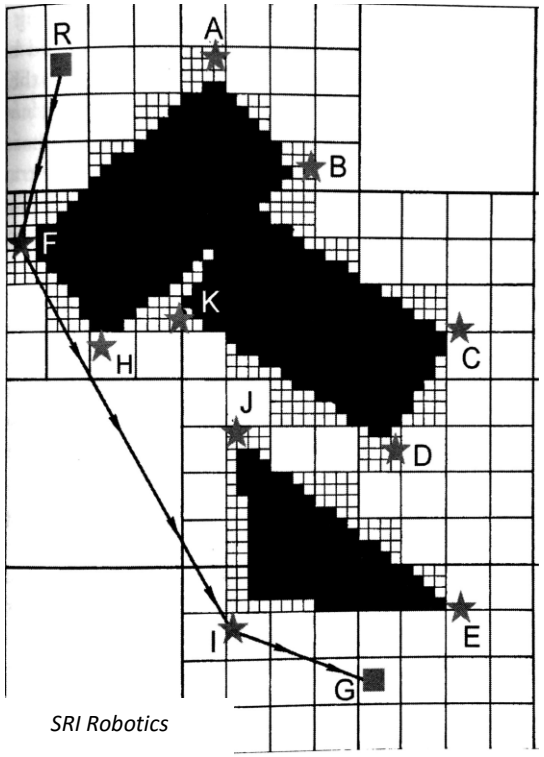


Goal State

Planning

- These traditional planning problems often take place in completely observable deterministic worlds and solved by search or reasoning

- Another classical example: path-finding



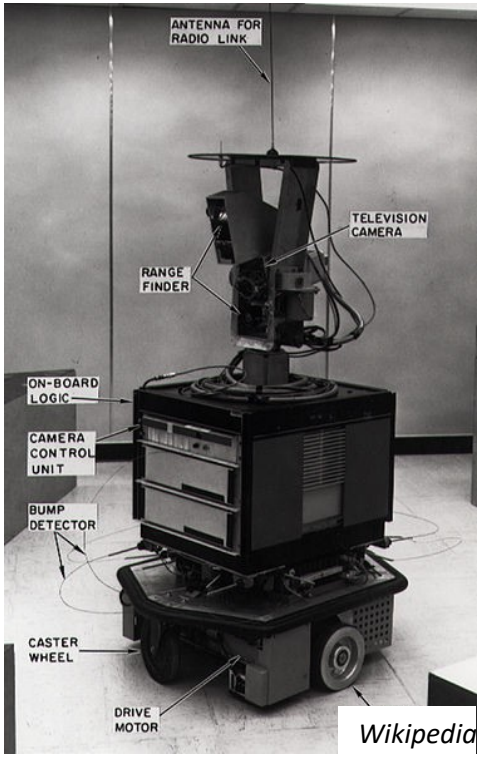
SRI Robotics

- An agent starting from point R must reach point G without bumping into obstacles

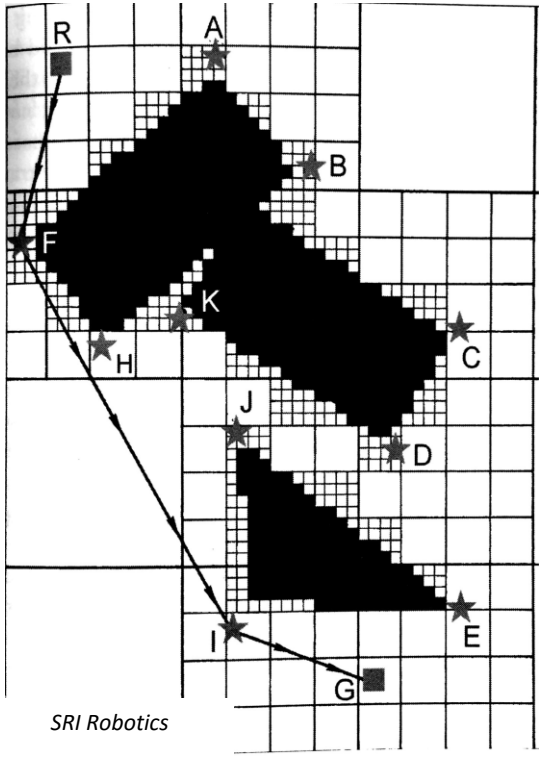
- We'd like to it to travel the shortest possible distance

Planning

- This is the problem that, in 1968, Nilsson, Hart, and Raphael had to face for Shakey's navigation (the ancestor of today mobile robots)



Wikipedia



SRI Robotics

- The solution they come up with is today known as A*

Decision-theoretic agents

- This notion of planning can capture only “ideal” goal-oriented decisional tasks
- Need for higher level of autonomy: can the agent set its own goals?
- A more general framework is needed:
  - Goal: entails a binary evaluation scheme (yes/no)
  - Deterministic and fully observable worlds

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    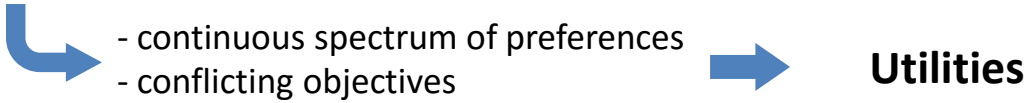

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    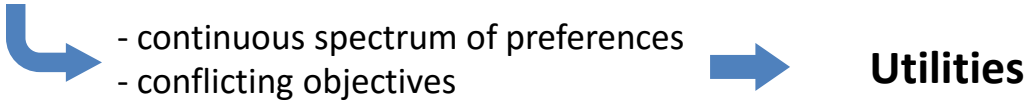

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    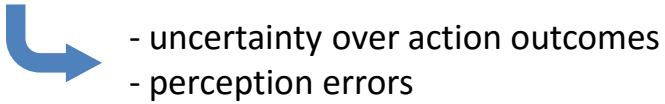

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    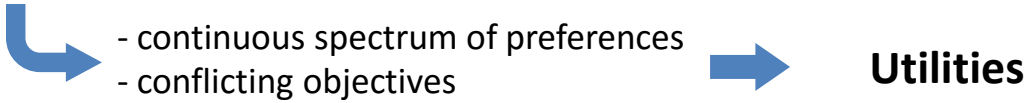

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    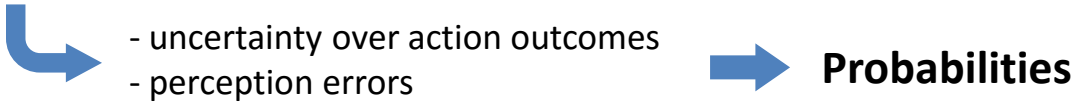

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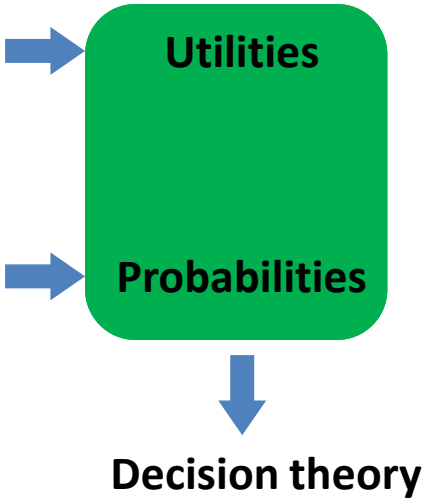
    - continuous spectrum of preferences
    - conflicting objectives
  - Deterministic and fully observable worlds
    - uncertainty over action outcomes
    - perception errors



Decision-theoretic agents

- Decision theoretic framework: agents combine preferences and beliefs to compute decisions (policies)
- Interactive decision theory: agents can cooperate or compete (strategies)
- Examples:
  - An agent
  - Search and rescue: find victims locations in a partially known environment

Mobile robots

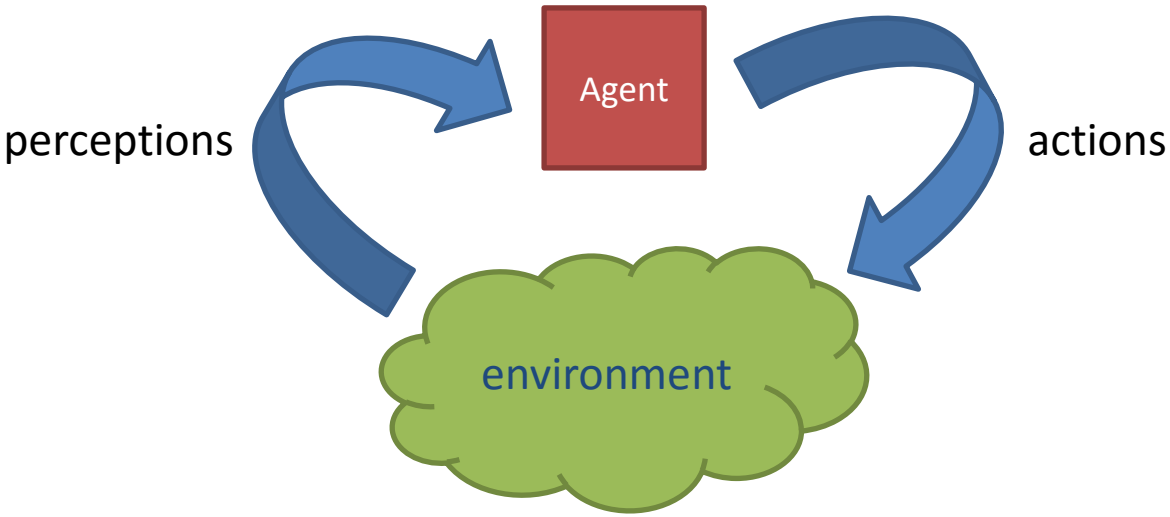
Mobile Robots

- Robots with locomotion capabilities that can move within an environment

http://www.turtlebot.com/

- Mechanics, kinematics, control theory, signal analysis, information theory, probability theory, artificial intelligence, …

Agents as mobile robots



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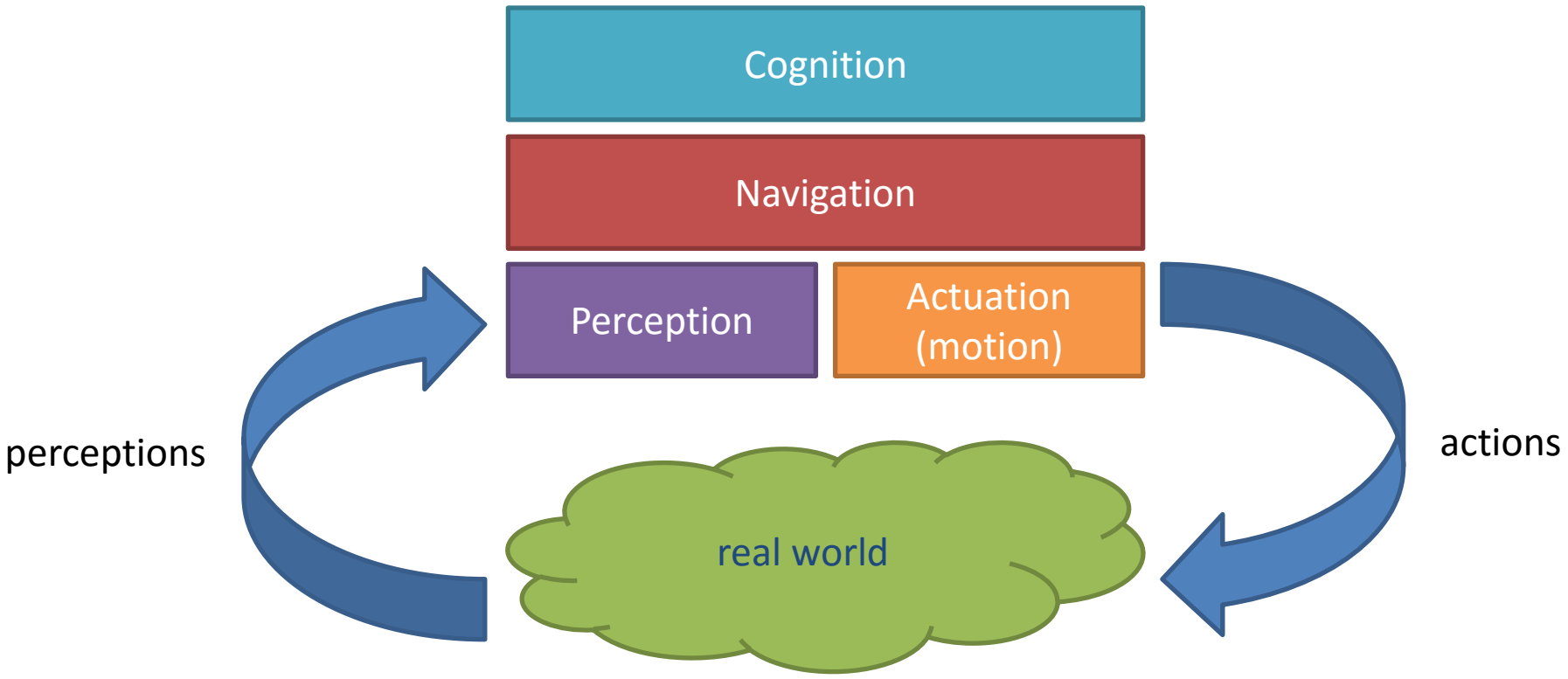
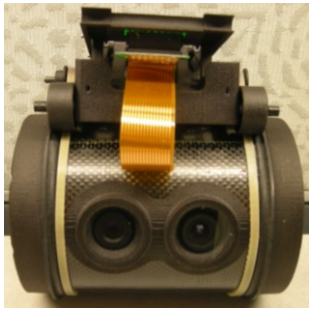


Perception

Sensors:

- Proprioceptive: speed, battery level, …
- Exteroceptive: distance, images, chemicals, …
- Passive: sense energy
- Active: emit and sense energy

Laser range scanner



Camera

Tasks:

- Characterize performance and errors
- Data interpretation and fusion

…

Navigation

- The most important problem in navigation is to answer the following question: “Where am I?”
- In many robotic application we are not interested in an absolute localization but, instead, in a relative one

Localization
(“where am I?”)

Mapping
(maintain a map of the known environment)

These are two sides of the same problem: SLAM

- It’s a difficult problem: integrating noisy and heterogeneous sensor readings to maintain a probabilistic description of the environment
- One popular approach is Kalman filtering

Navigation

- One popular example…

Navigation

- One popular example…

VSLAM:

- Acquires images
- Extracts features, keeps track of them
- Combines such data with odometry to build a map and simultaneously estimate its position

Cognition

- It's the control module in charge of **decisions**
- It must coordinate perception and navigation to **effectively** achieve some task or mission
- We are going to discuss some examples, the first is **autonomous exploration**