



Introduction to autonomous robotics

ST5 Autonomous robotics

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Presentation

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- ▶ researcher in robotics
- ▶ Inria Nancy Grand-Est – Loria
- ▶ Larsen¹ team: long-term autonomy and interaction
- ▶ keywords: state estimation, mapping, navigation
- ▶ lectures, tutorials, lab works

Jérémy Fix

- ▶ associate professor
- ▶ CentraleSupélec – Loria
- ▶ Biscuit² team: unconventional computation models
- ▶ lab works

¹ <https://team.inria.fr/larsen> ² <https://biscuit.loria.fr>

Aim of the lecture

Introduction to autonomous robotics

- ▶ overview of robotics
- ▶ various aspects of autonomy
- ▶ implementation of simple techniques
- ▶ test in simulation and real robots

Aim of this session

- ▶ definition of robotics
- ▶ overview of autonomy

Organization

Lectures

- ▶ overview of a subject
- ▶ focus on a technique/algorithm

Tutorials

- ▶ theoretical exercises

Lab work

- ▶ implementation in Python using ROS (skeleton files)
- ▶ experimentation
- ▶ introduced by preparatory exercises

Exam

- ▶ main concepts (no document)
- ▶ some exercises (no code)

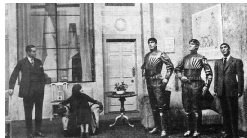
01

Robots and robotics

What is a robot?

Etymology

- ▶ Josef Čapek in R.U.R. from his brother Karel in 1920
- ▶ humanoids produced in a factory
- ▶ from the Czech “robota”: corvée, serf labor

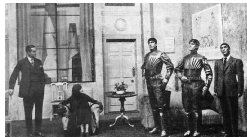


a scene from R.U.R.

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a scene from R.U.R.

Automaton

- ▶ mechanical device which moves alone
- ▶ powered by water, wind, spring, pendulum, ...
- ▶ able to perform sequences of motion



Leonardo da Vinci

What is a robot?

Definitions (en.wiktionary.org)

- ▶ “(chiefly science fiction) An intelligent mechanical being designed to look like a human or other creature”



i, Robot
(2004)

What is a robot?

Definitions (en.wiktionary.org)

- ▶ “(chiefly science fiction) An intelligent mechanical being designed to look like a human or other creature”
- ▶ “A machine built to carry out some complex task or group of tasks by physically moving, especially one which can be programmed”



i, Robot
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Fanuc welding
robot

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Definitions (en.wiktionary.org)

- ▶ “(chiefly science fiction) An intelligent mechanical being designed to look like a human or other creature”
- ▶ “A machine built to carry out some complex task or group of tasks by physically moving, especially one which can be programmed”
- ▶ In French: multi-function kitchen appliance



i, Robot
(2004)



Fanuc welding
robot



KitchenAid

What is an autonomous robot?

What is an autonomous robot?

Autonomous robot, for us:

- ▶ mechatronic device (mechanics, electronics, and software),
- ▶ which can perform a task by itself,
- ▶ in a non-dedicated environment,
- ▶ through the interaction between perception and action,
- ▶ with some decision autonomy.

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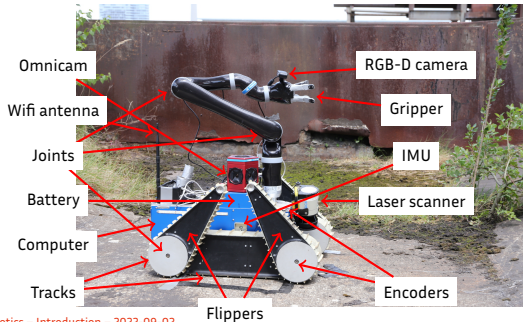
Tasks examples

- ▶ cleaning floor
- ▶ museum tour guide
- ▶ demining
- ▶ create a map of a place
- ▶ operate in human unfriendly environments

Robot anatomy

Components

- ▶ mechanical structure
- ▶ actuators (joints, wheels...)
- ▶ sensors (sonar, encoders...)
- ▶ electronics (power, communication bus, computers)
- ▶ software



Examples of autonomous robots

Industry

- ▶ removal of security cages
- ▶ cooperation with human operators
- ▶ quick and local issue solving
- ▶ fast learning of new tasks



Universal Robot UR5 at Atria



Baxter from Rethink Robotics

Examples of autonomous robots

Services

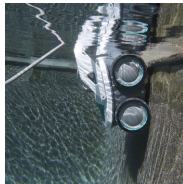
- ▶ cleaning (floor, swimming pool)
- ▶ logistics
- ▶ receptionist, tour guide



Rhino (1997)



iRobot Roomba



iRobot Mirra



Kiva Systems
(Amazon)



Softbank Pepper

Other examples in services



Lely Astronaut



AscTec Falcon 8



Packbot



Giraff

Robot research – Locomotion

Ground locomotion

- ▶ bipedal walk
- ▶ quadrupedal walk
- ▶ run
- ▶ wheels on challenging ground



Talos (PAL Robotics)



ANYmal (RSL, ETHZ)



Absalom/Nifti (Bluebotics)

Robot research – Locomotion

Groundless locomotion

- ▶ underwater
- ▶ boats
- ▶ planes, drones



LAUV (LSTS, Porto)



Kingfisher (Clearpath robotics)

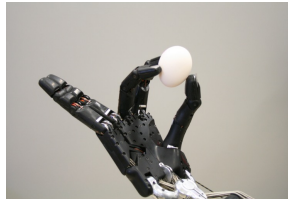


Atlantik Solar (ASL, ETHZ)

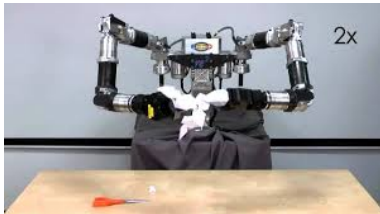
Robot research – Manipulation

Manipulation

- ▶ dexterous manipulation
- ▶ bimanual manipulation
- ▶ non-rigid objects
- ▶ dynamic manipulation



HYFLAM (UHAM)



HDMS (Re²)



PR2 Willow Garage)

Autonomous robots

Deployed autonomous robots

- ▶ industry: collaboration with humans
- ▶ services: cleaning, logistics, or reception

Research robots

- ▶ locomotion: on ground or not
- ▶ manipulation

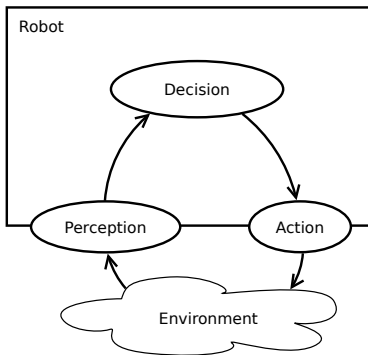
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Autonomy

Functions of an autonomous robot

Main functions

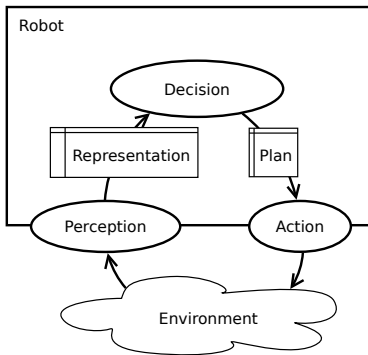
- ▶ perception and representation of the environment
- ▶ motion and action
- ▶ decision and planning



Functions of an autonomous robot

Main functions

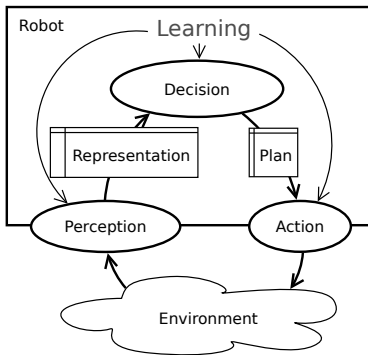
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Functions of an autonomous robot

Main functions

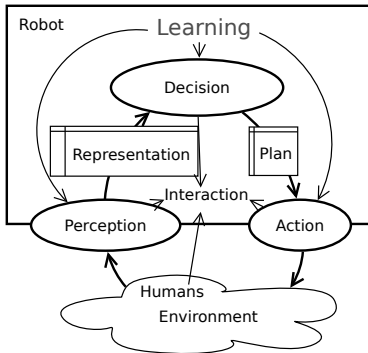
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- ▶ motion and action
- ▶ decision and planning
- ▶ learning



Functions of an autonomous robot

Main functions

- ▶ perception and representation of the environment
- ▶ motion and action
- ▶ decision and planning
- ▶ learning
- ▶ communication and interaction



Perception

Perception

- ▶ interpretation of the sensor values
- ▶ inference on the environment
- ▶ inference on the state of the robot
- ▶ building of an internal representation

Implementation

- ▶ sensors
- ▶ representation space
- ▶ sensor models

Motion

Action

- ▶ achievement of a given motion
- ▶ control of an actuator

Implementation

- ▶ actuators
- ▶ control space
- ▶ actuator model
- ▶ loop closing with a sensor

Decision

Decision and planning

- ▶ choice of actions to achieve a given goal
- ▶ definition of a plan
- ▶ simulation of the consequences of actions

Implementation

- ▶ current representation
- ▶ planning domain
- ▶ action model

Learning

Machine learning

- ▶ model optimization
- ▶ definition of new models
- ▶ for perception, action, or decision

Implementation

- ▶ training data
- ▶ generic model

Interaction

Communication and interaction

- ▶ sharing information
- ▶ joint performing a task
- ▶ with humans or other robots

Implementation

- ▶ model of the others
- ▶ model of the interaction

03

Conclusion

Conclusion

Autonomous robotics

- ▶ variety of robots, environments, and tasks
- ▶ different functions:
 - ▶ perception
 - ▶ action
 - ▶ decision
 - ▶ learning
 - ▶ interaction

Program

Lectures

- ▶ L1: intro (done)
- ▶ L2: introduction to ROS
- ▶ L3: Bayesian inference
- ▶ L4: sensors and state estimation
- ▶ L5: localization
- ▶ L6: mapping and SLAM
- ▶ L7: path planning
- ▶ L8: navigation
- ▶ L9: architecture and interaction

Tutorials and lab work

- ▶ LW1: ROS, simulation, and real robot
- ▶ TU1: state estimation
- ▶ LW2: state estimation
- ▶ TU2: localization
- ▶ LW3: localization
- ▶ LW4: mapping and SLAM
- ▶ LW5: path planning
- ▶ LW6: navigation
- ▶ LW7: integration on a real robot

Bibliography

Robotics books

- ▶ Latombe, *Robot Motion Planning*, Kluwer Academic Publishers, 1991.
- ▶ Thrun et al., *Probabilistic Robotics*, MIT Press, 2005.
- ▶ Lavelle, *Planning Algorithms*, Cambridge University Press, 2006.
- ▶ Siegwart et al., *Introduction to Autonomous Mobile Robots*, MIT Press, 2011.
- ▶ Siciliano et al., *Springer Handbook of Robotics*, 2nd ed., Springer, 2016.

Other books

- ▶ Bishop, *Pattern Recognition and Machine Learning*, Springer, 2007.
- ▶ Russel and Norvig, *Artificial Intelligence: A Modern Approach*, 3rd ed., Pearson, 2009.



Thanks for your attention
Questions?