

#### Probabilistic Robotics Overview

MSc course Artificial Intelligence 2018

https://staff.fnwi.uva.nl/a.visser/education/ProbabilisticRobotics/

Arnoud Visser & Emiel Hoogeboom Intelligent Robotics Lab Informatics Institute Universiteit van Amsterdam A.Visser@uva.nl

Illustrations courtesy of Sebastian Thrun, Wolfram Burghard, Dieter Fox, Michael Montemerlo, Dick Hähnel, Pieter Abbeel and many others.

## **Probabilistic Robotics**

Probabilistic robotics is a subfield of robotics concerned with the **algorithms** to couple the **perception** and **control** part. It relies on **statistical techniques** for representing information and making decisions. By doing so, it accommodates the uncertainty that arises in most contemporary robotics applications.

## **Physical situated agent**



An **agent** is anything that can be viewed as **perceiving** its environment through sensors and acting upon that environment through **actuators**<sup>†</sup>

<sup>†</sup> Russell & Norvig, 'Artificial Intelligence – A modern approach', Prentice Hall, 2003

#### Structure of the course

 Lectures at Mondays and Wednesdays
 Practical Sessions at Tuesdays and Thursdays

### **Goals for the Course**

Insight in the mathematical foundation of the techniques and algorithms applied in the field

- Experience with the derivation of models from clear problem descriptions
- Practical experience with applying the techniques to datasets & "real robots"

#### **Reason with uncertainty**



#### **Probabilistic reasoning**



Combine preliminary information and models with observations

#### **Prediction-Correction Cycly**



#### **Prediction-Correction Cycle**

![](_page_8_Figure_1.jpeg)

## **Localization and Mapping**

![](_page_9_Figure_1.jpeg)

#### Literature

Sebastian Thrun, Wolfram Burgard and Dieter Fox, Probabilistic Robotics, The MIT Press, 2005.

http://www.probabilistic-robotics.org

![](_page_10_Picture_3.jpeg)

#### Literature

#### □ Raja Chatila, LAAS-CNRS, France:

"A robot is an uncertainty machine: its perception and decisionmaking capabilities must embed at their core the processes dealing with uncertainty. The book is an essential reference for the student, the teacher, and the researcher to understand the basics and the advanced methods of estimation theory, and the probabilistic models and processes underlying robot localization, SLAM, and decision making. A 'must have' textbook!"

# Grading

- □ 1/2 exam grades, 1/2 assignments grade
- Exam grade: final exam
- Exams will be "open-book"

## Some practical issues

- Try to keep up with reading the chapters
- Ask questions whenever something in the lecture or the book is not clear to you
- □ Slides will become available online
- Links to recordings from Prof. Burgard lectures are available on Canvas

#### Assignments

Exercises from the book
Experiments based on datasets
Experiments based on real robots

![](_page_14_Picture_2.jpeg)

![](_page_14_Picture_3.jpeg)

#### **Topics covered in the course**

- **D** Robot Motion and Perception
- □ Localization
- **D** Mapping
- **Exploration**

## Mapping & Exploration @ RoboCup

![](_page_16_Picture_1.jpeg)

## The Book

- □ Part I: The Basics
  - Introduction
  - State Estimation & Recursive Filters
  - Robot Motion
  - Robot Perception
- □ Part II: Localization
  - Markov and Gaussian
  - Grid And Monte Carlo
- □ Part III: Mapping
  - Occupancy Grid Mapping
  - Simultaneous Localization and Mapping
  - Advanced SLAM algorithms
- Part IV: Planning and Control
  - Approximate POMDP Techniques
  - Exploration

#### **Sebastian Thrun**

#### □ Former Director of the Stanford AI Lab

![](_page_18_Picture_2.jpeg)

 Winner of the DARPA Grand Challenge 2005
 Founder of the Google X lab
 Builder of the interactive museum tour-guide robot Rhino-Minerva

#### Currently

![](_page_19_Figure_1.jpeg)

#### Currently

![](_page_20_Picture_1.jpeg)

#### Kitty Hawk's Flyer

## **Wolfram Burgard**

Head of the research lab for Autonomous Intelligent Systems at the Universität Freiburg

![](_page_21_Picture_2.jpeg)

Supervisor of Sebastian Thrun

Initiator of the interactive museum tour-guide robot Rhino/ Minerva

Advisor in the NurseBot project

## Currently

□ *President* of the IEEE Robotics and Automation Society

![](_page_22_Picture_2.jpeg)

#### □ Supporter of an European Center of AI

## **Dieter Fox**

#### Director of the Robotics and State Estimation Lab at the University of Washington

![](_page_23_Picture_2.jpeg)

□ Student of Sebastian Thrun

Programmer of the interactive museum tour-guide robot Rhino / Minerva

RoboCup Aibo League veteran

#### Currently

![](_page_24_Picture_1.jpeg)

#### Impact

![](_page_25_Picture_1.jpeg)

#### Sebastian Thrun

Stanford Verified email at stanford.edu Cited by \$1800 Artificial Intelligence Robotics

![](_page_25_Picture_4.jpeg)

Wolfram Burgard

Professor of Computer Science, University of Freiburg Verified email at Informatik.uni-freiburg.de Cited by 55861 Artificial Intelligence Robotics

![](_page_25_Picture_7.jpeg)

Dieter Fox Professor of Computer Science and Engineering, University of Washington Verified email at cs.washington.edu Cited by 49935 Robotics Artificial Intelligence Computer Vision

#### **Common background: Museum Tour-guides**

![](_page_26_Picture_1.jpeg)

#### Rhino, Bonn, 1997

![](_page_26_Picture_3.jpeg)

#### Minerva, Washington, 1998

Probabilistic Robotics Course at the Universiteit van Amsterdam

#### **Tour-guide Minerva**

![](_page_27_Picture_1.jpeg)

## Conclusion

Essential for everybody involved in robotics scientific research.

■ Valuable experience for everybody dealing with real-world sensor-data.