Mobile Robots | **Introduction and Lecture Overview**

Autonomous Mobile Robots

https://edge.edx.org/courses/course-v1:ETH+ETHx-AMRx_Internal_FS2018+2018_T1/about

Roland Siegwart, Margarita Chli**,** Martin Rufli

Autonomous mobile robot | your teachers

- Roland Siegwart, ETH Zurich

- Margarita Chli, ETH Zurich

- Juan Nieto, ETH Zurich

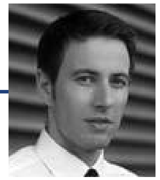
- Nick Lawrance ETH Zurich

Video segments

- Marco Hutter, ETH Zurich

- Davide Scaramuzza, Univ. of Zürich

- Paul Furgale, Apple



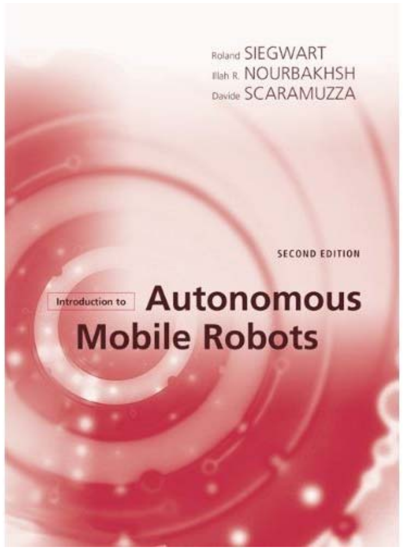
- Martin Rufli, IBM Research

Autonomous mobile robot | about the course

https://edge.edx.org/courses/course-v1:ETH+ETHx-AMRx_Internal_FS2018+2018_T1/about

- Running as an ETH-internal MOOC (Massive Open Online Course)
  - Over 30 short video lectures that we call “segments”.
  - The “segments” are complemented with:
    - short questions for each segment to verify your understanding and progress
    - various exercises (problem sets)
    - videos showing the current state-of-the-art in the field
  - Please register on edge.edx.org and sign up for the lecture AMRx of ETHx
- Textbook
  „Introduction to Autonomous Mobile Robots“
  Roland Siegwart, Illah Nourbakhsh, Davide Scaramuzza
  The MIT Press

On sale in LEE J206 for CHF 45



- Other materials
  - http://www.asl.ethz.ch/education/lectures/autonomous_mobile_robots.html

The Lecture

- We expect you to view and study the following elements beforehand:
  - **video segment**
  - **relevant AMR book chapters**
  - **problem sets and quizzes**
- Lecture on Tuesday 10:15 – 12:00 in NO C 60
  - Organized as flipped classroom – we need your active participation!!
  - Video Segments will not be repeated
  - Focus on putting the learnt content into context
    - Questions from students (in forum until Friday before the related lecture)
    - go over difficult problems
    - go a bit more in detail where needed (e.g. proofs of theorems, etc.)
- Exercises on Tuesday 14:15 – 16:00 in CAB G 11 (around every second week)
  - Special exercises only supported for ETH students

Lecture Program

ETH Master Course
Autonomous Mobile Robots - 151-0854-00L

Agenda Spring 2018

Lecture: Weekly on Tuesday 10.15 - 12.00, NO C 60

Exercises: Approximately every second week, Tuesday 14.15 - 16.00, CAB G 11

MOOC on edx: https://edge.edx.org/courses/course-v1:ETHx+AMRx_Internal_FS2018+2018_T1/about

Responsable MOOC:
T. Novkovic, M. Grinvald

Week #	Date	Topic	Lecture segment names	Lecturer	Online release date and problem set
1.	20.02.2018	Introduction and Motivation	Introduction and Lecture Overview	R. Siegwart	14.02.2018
2.	27.02.2018	Locomotion Concepts	Intorduction to Legged Robotics Basics of Rigid Body Kinematics Application of Rigid Body Kinematics (optional) *Worked Exercise 1 & 2 (optional)* Example of Wheeled, legged and Flying Robots (lecture)	R. Siegwart	21.02.2018
Ex1	27.02.2018	Introduction to V-Rep simulator		In Kyu Sa, K. Bodie	21.02.2018
3.	06.03.2018	Mobile Robots Kinematics	Introduction to Wheeled Locomotion Differential Kinematics Wheeled Kinematics *Worked Exercise*	R. Siegwart	28.02.2018
4.	13.03.2018	Perception I (to 4.3) and Perception II (to 4.4)	Sensors Camera Image Formation, Perspective Projection Introduction to Computer Vision Omnidirectional Projection, Camera Calibration, Unified Model Stereo Vision *Worked Example: Structure from Motion*	M. Chli	07.03.2018
Ex2	13.03.2018	Kinematics and Control of a differential drive vehicle		A. Vempati, H. Blum	07.03.2018
5.	20.03.2018	Perception III: Image Saliency (to 4.5)	Correlation and Convolution Edges and Points *Worked Example on Image Filtering*	M. Chli	14.03.2018
6.	27.03.2018	Perception IV: Place Recognition & Line Fitting (to 4.5)	Place Recognition The Error Propagation Law	M. Chli	21.03.2018

Exam

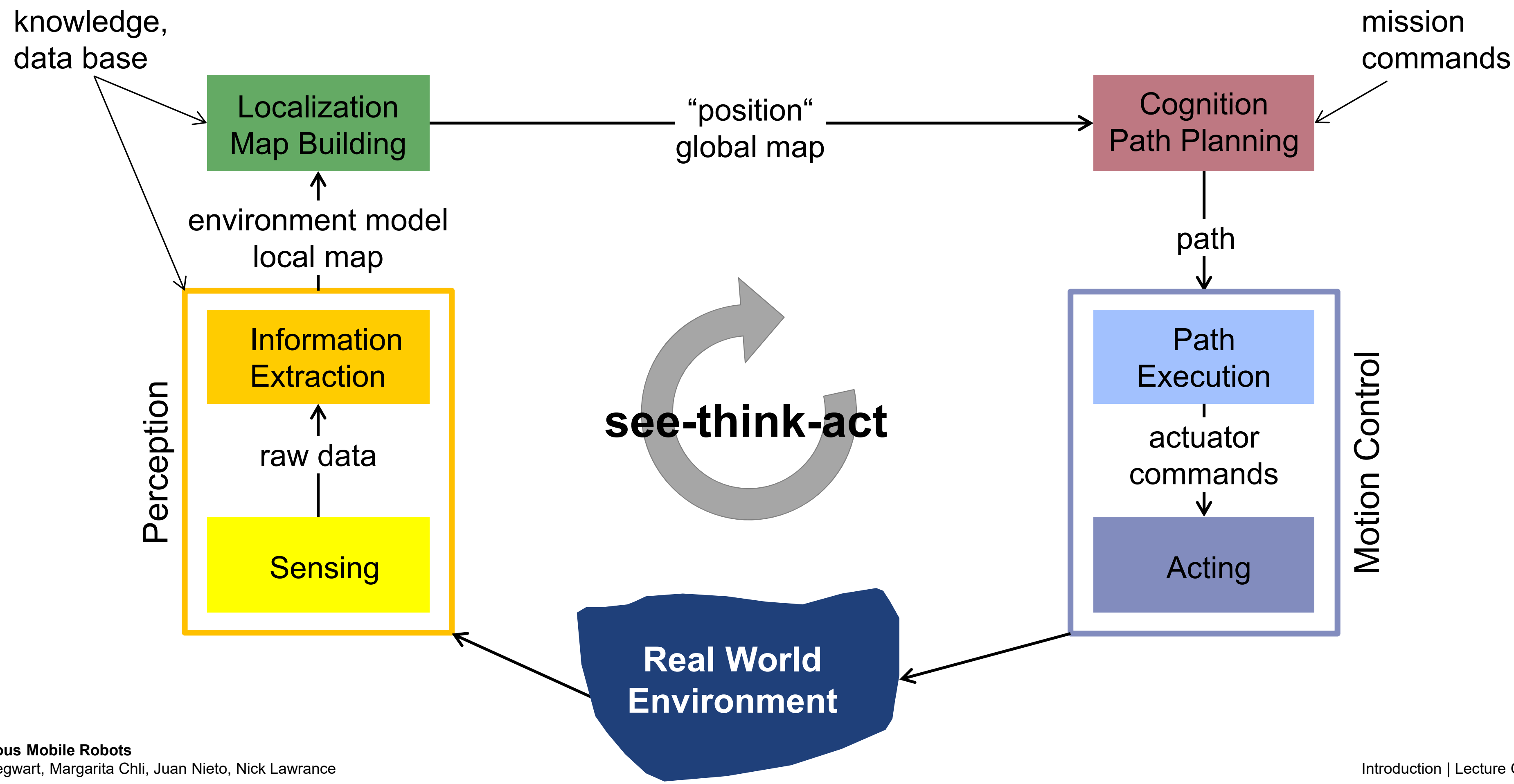
- Type
  - Written session examination
- Language of examination
  - English
- Course attendance confirmation required
  - No
- Repetition
  - The performance assessment is only offered in the session after the course unit. Repetition only possible after re-enrolling.
- Mode of examination
  - Multiple Choice and comprehension questions
  - Calculations, similar to exercises, but simpler and solvable without computer
- Written aids
  - 4 A4-pages personal summary

Autonomous mobile robot | the key questions

- The three key questions in Mobile Robotics
  - Where am I ?
  - Where am I going ?
  - How do I get there ?

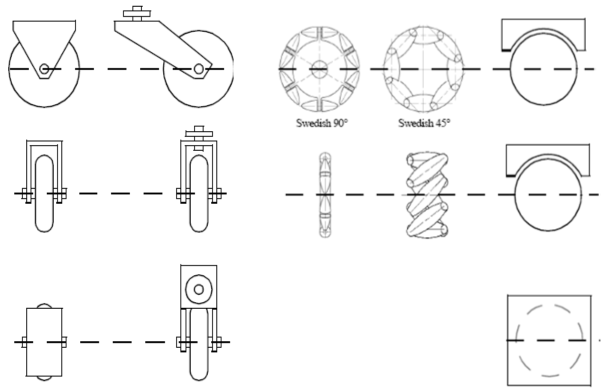
- To answer these questions the robot has to
  - have a model of the environment (given or autonomously built)
  - perceive and analyze the environment
  - find its position/situation within the environment
  - plan and execute the movement

Autonomous mobile robot | the see-think-act cycle



Motion Control | kinematics and motion control

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

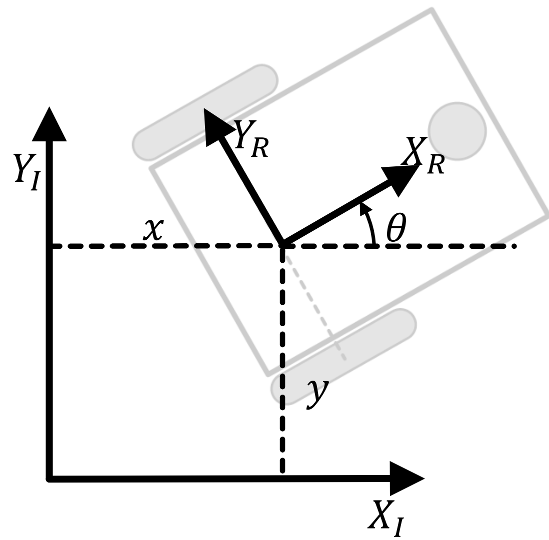


- Motion control

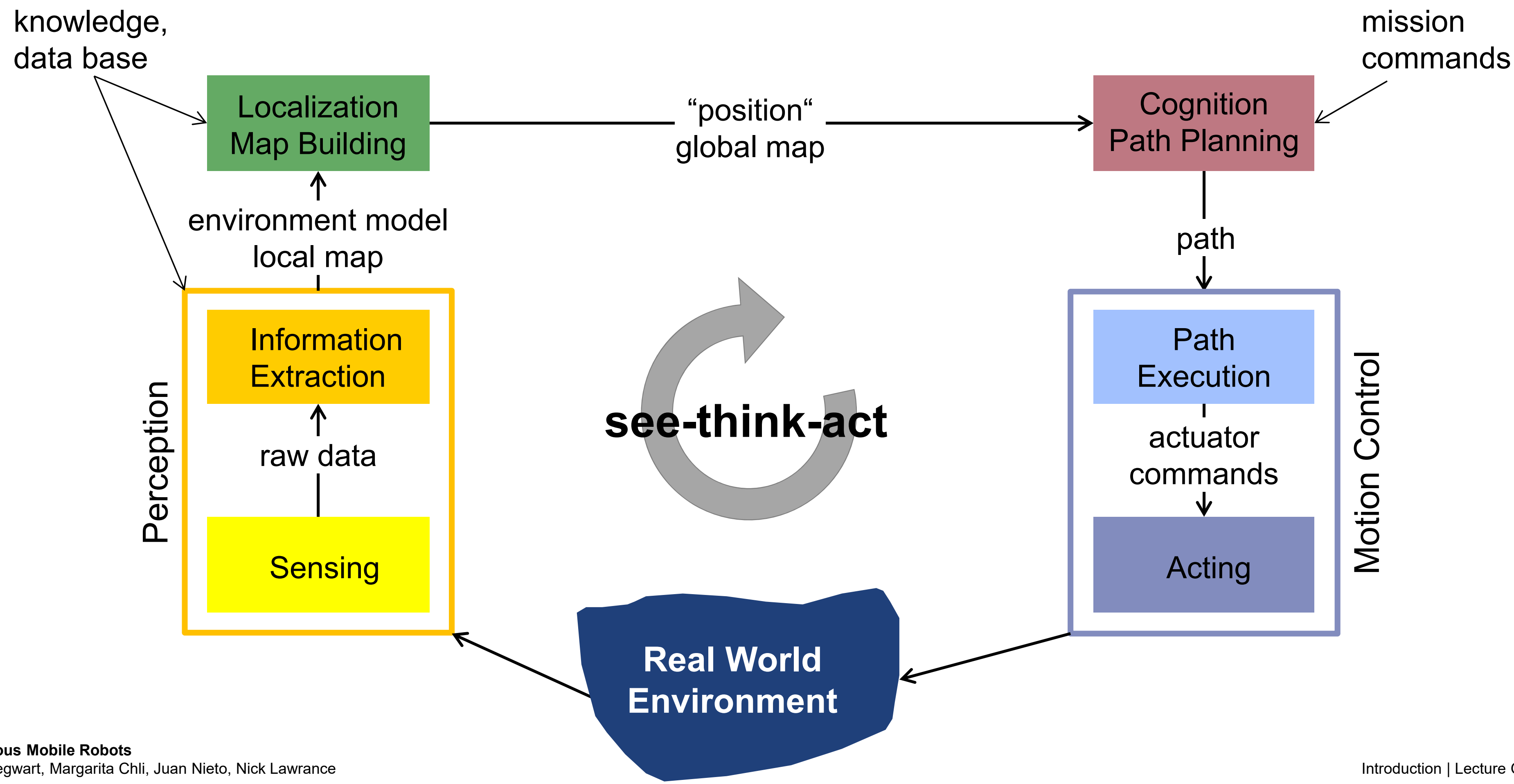
$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = f(\dot{\varphi}_1 \cdots \dot{\varphi}_n, \theta, geometry)$$

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

?

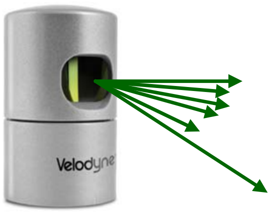


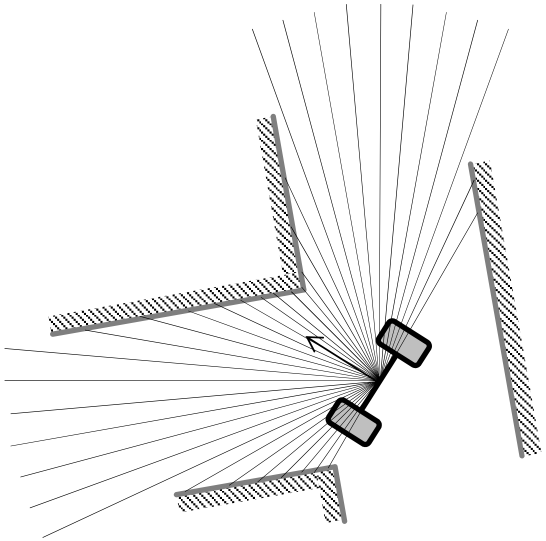
Autonomous mobile robot | the see-think-act cycle



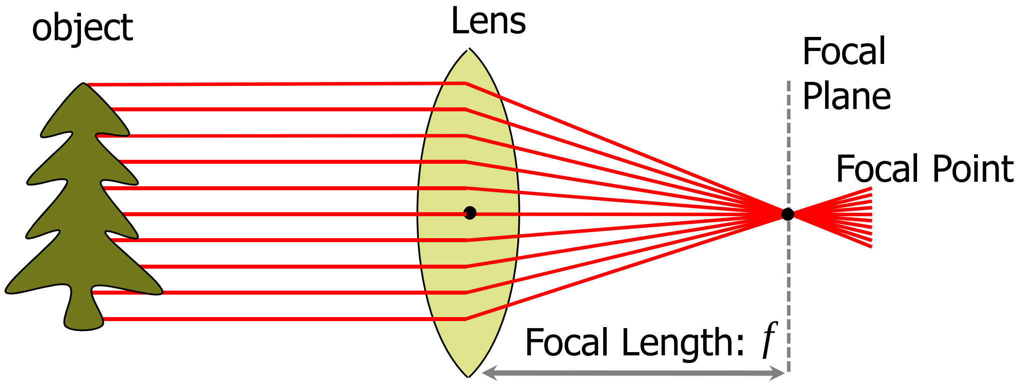
Perception | sensing

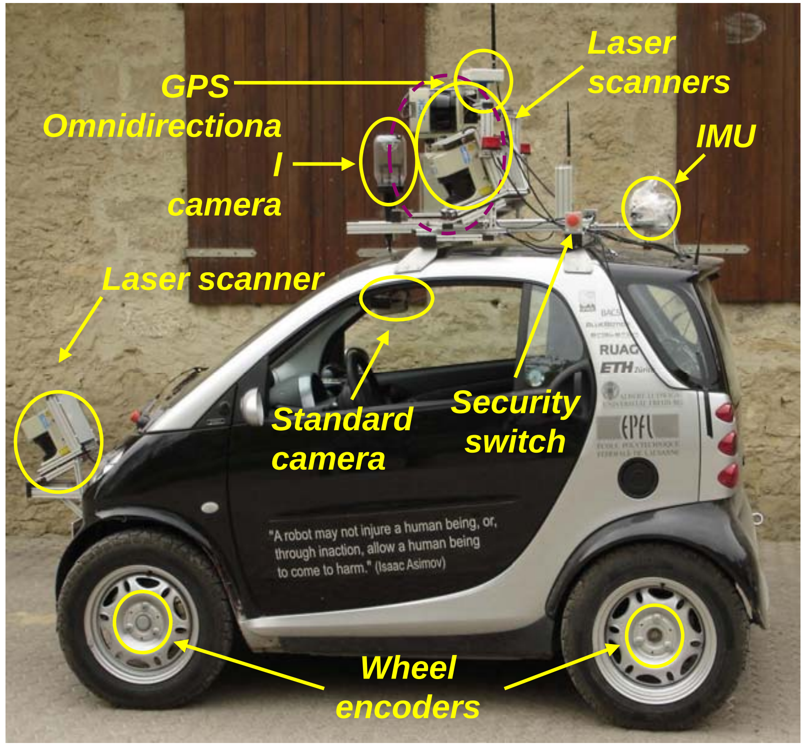
- Laser scanner
  - time of flight

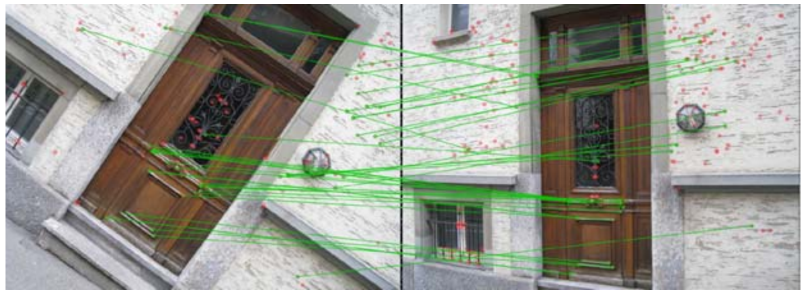




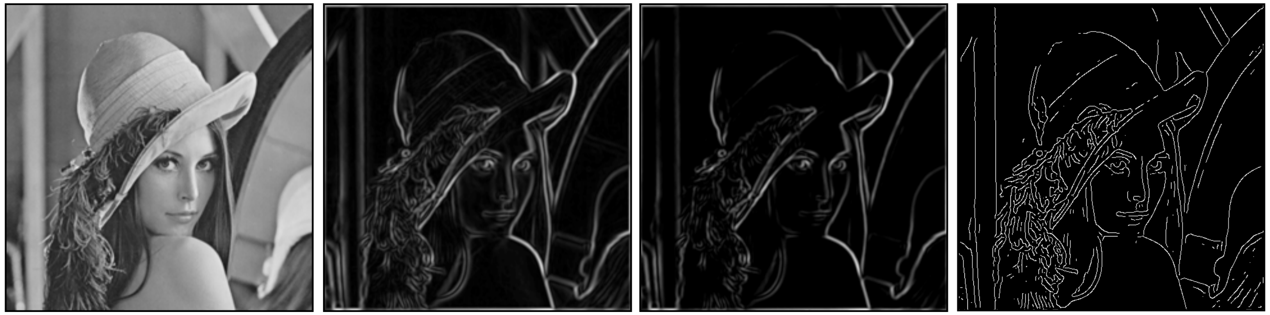
- Camera





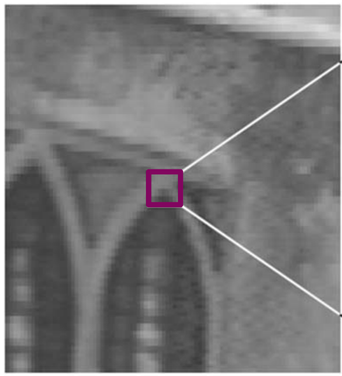


Perception | information extraction



- Filtering / Edge Detection

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



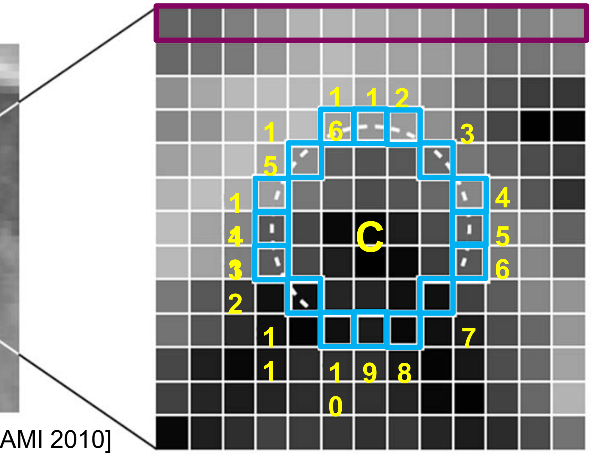
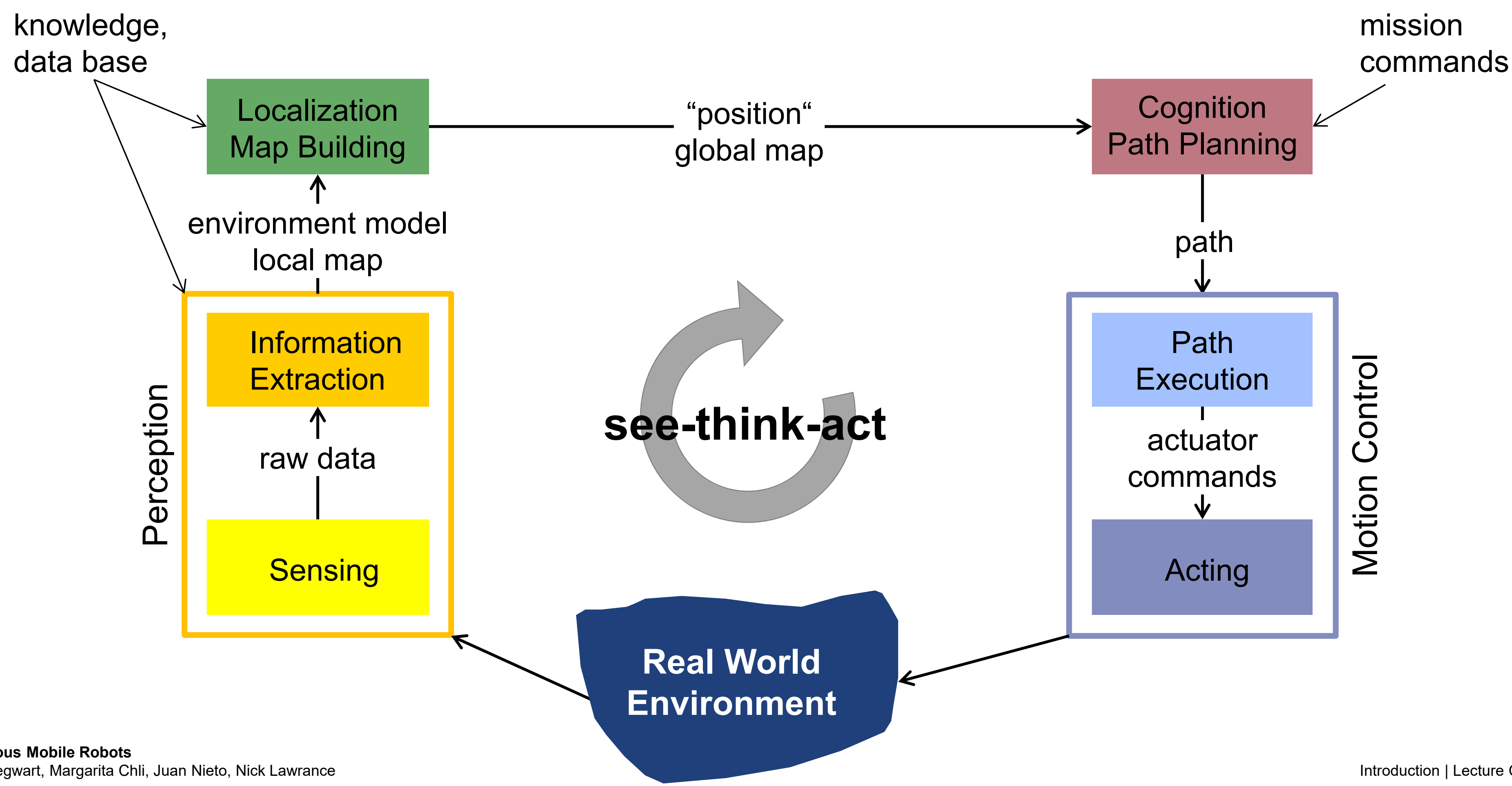


Image from [Rosten et al., PAMI 2010]

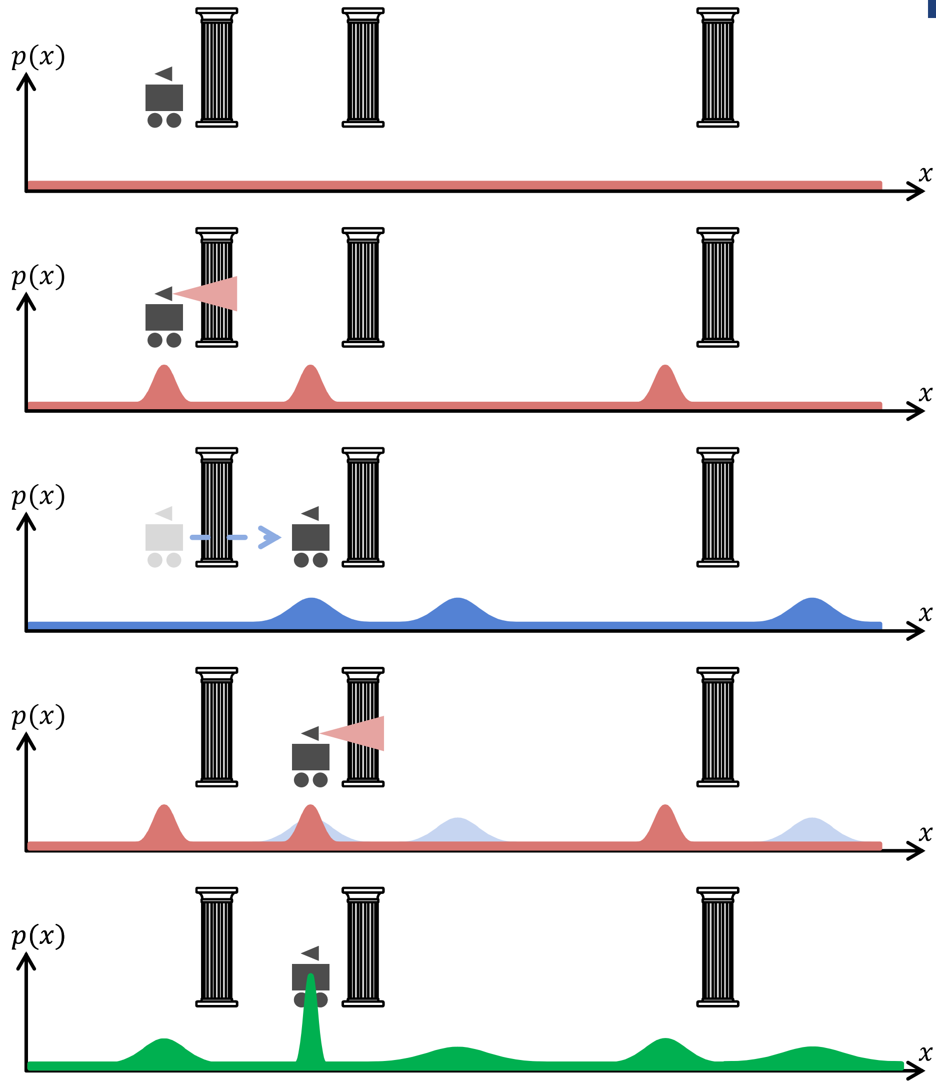
- Keypoint matching
  - BRISK example

Autonomous mobile robot | the see-think-act cycle

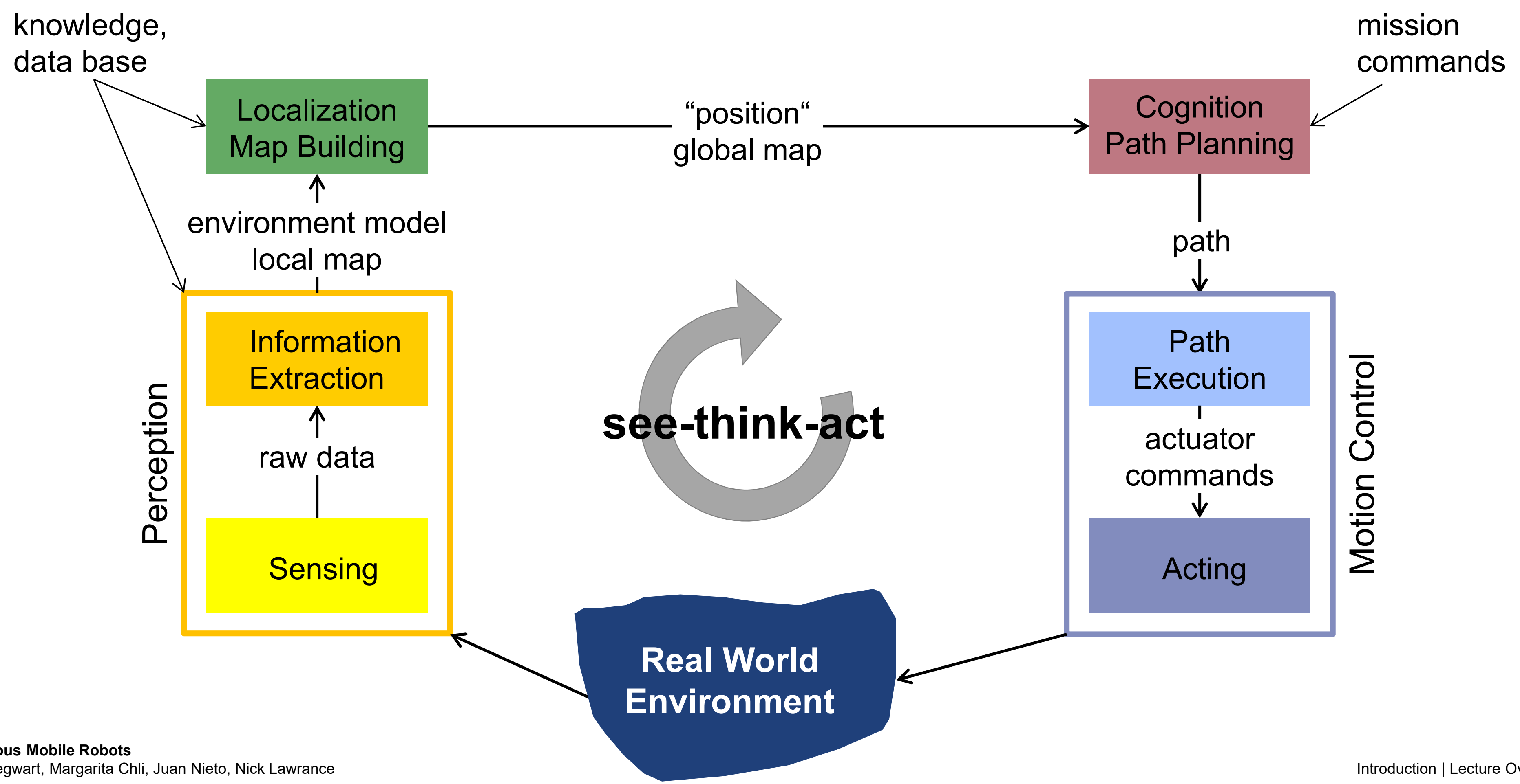


Localization | where am I?

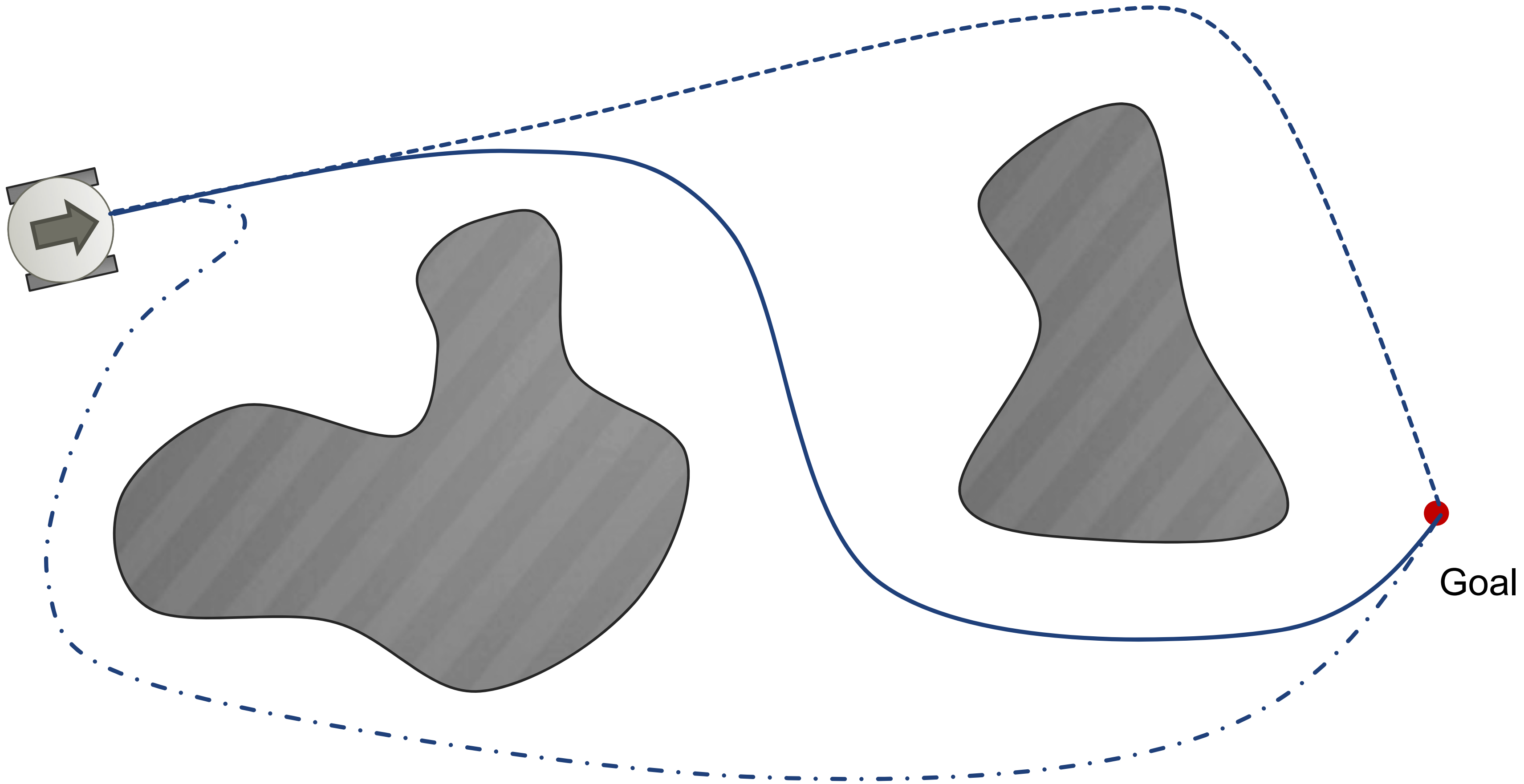
- SEE: The robot queries its sensors → finds itself next to a pillar
- ACT: Robot moves one meter forward
  - motion estimated by wheel encoders
  - accumulation of uncertainty
- SEE: The robot queries its sensors again → finds itself next to a pillar
- Belief update (information fusion)



Autonomous mobile robot | the see-think-act cycle

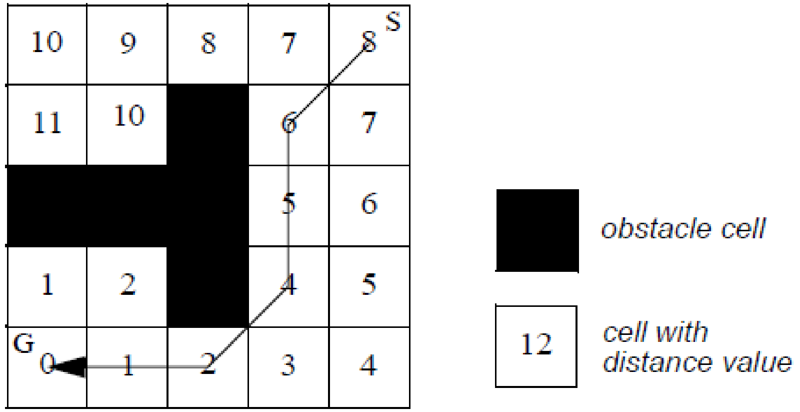


Cognition | Where am I going ? How do I get there ?

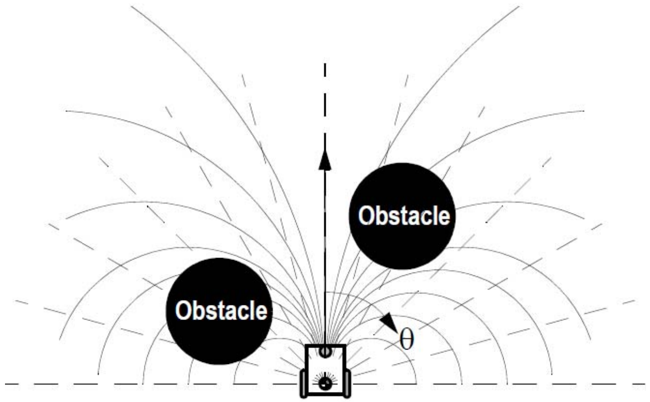


Cognition | Where am I going ? How do I get there ?

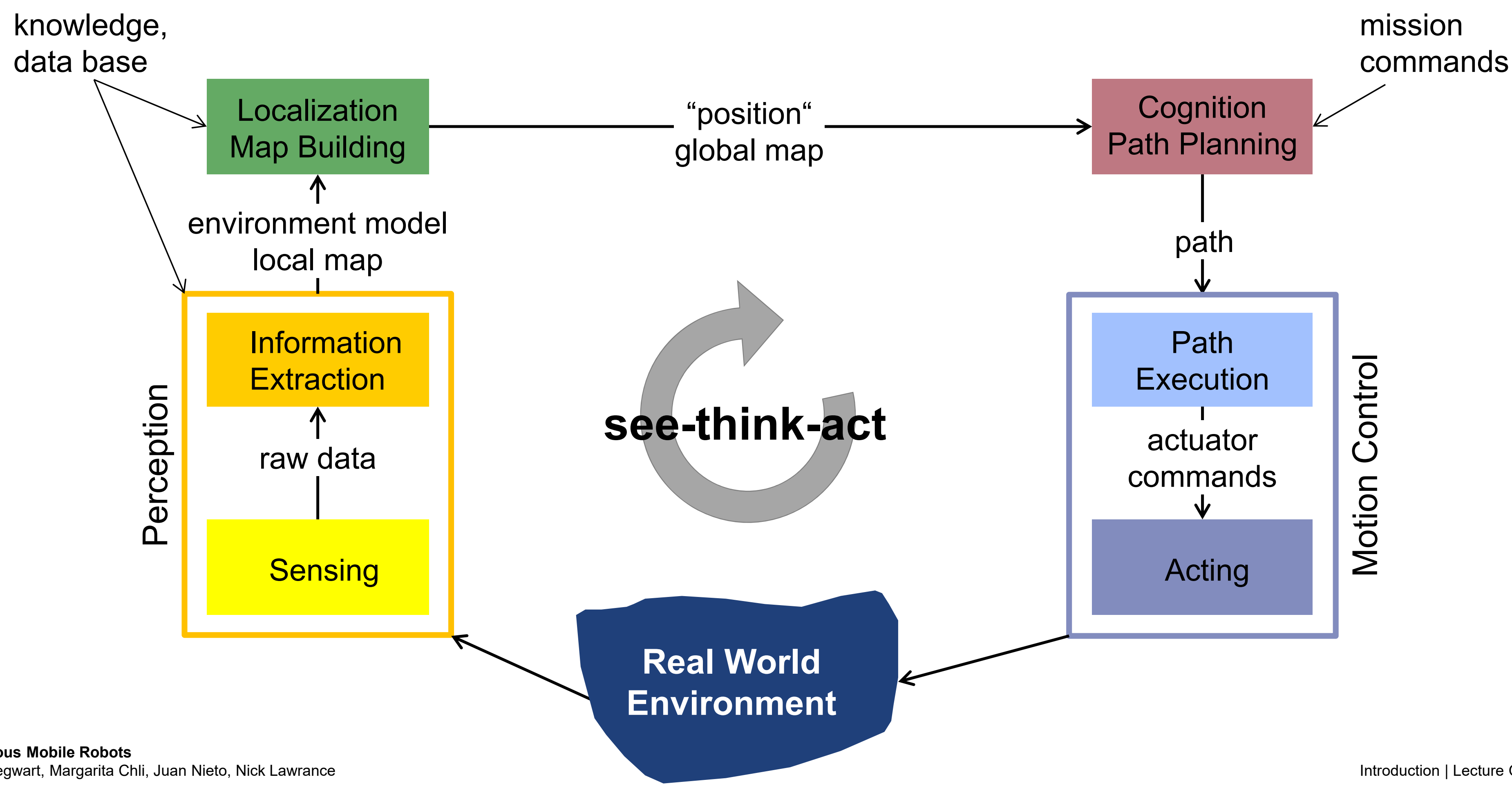
- Global path planning
  - Graph search



- Local path planning
  - Local collision avoidance



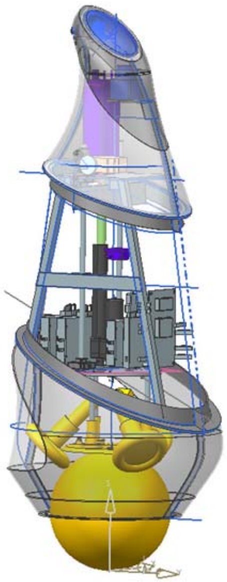
Autonomous mobile robot | the see-think-act cycle

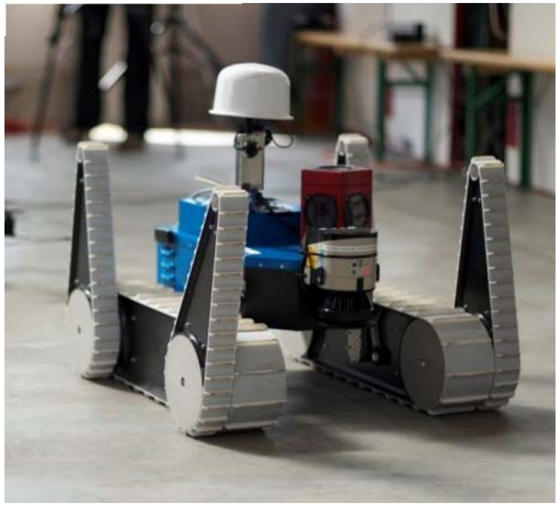


Autonomous mobile robot | we invite you to join the course

Autonomous Mobile Robots | Some recent examples

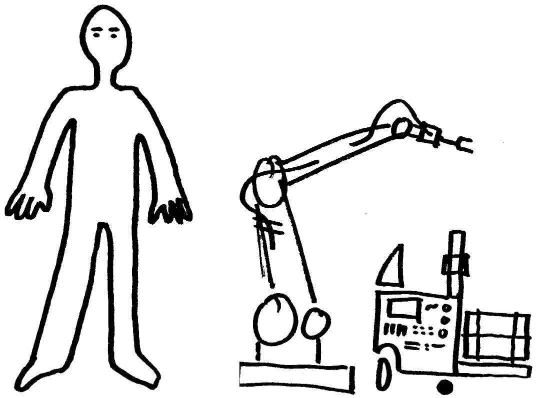
Examples – not part of MOOC Video Segment



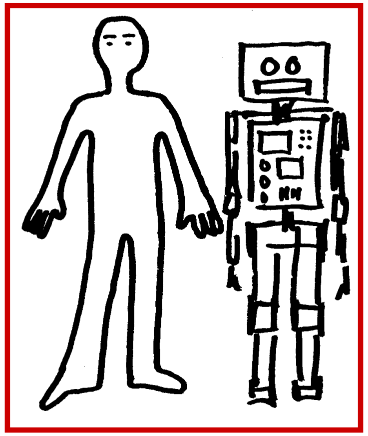


Next generation of Robots

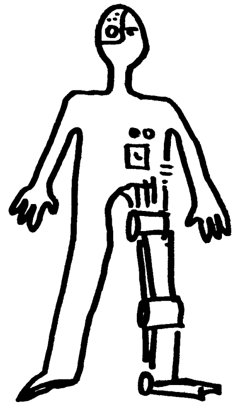
| mobile, smart, connected, adaptive and closer to humans



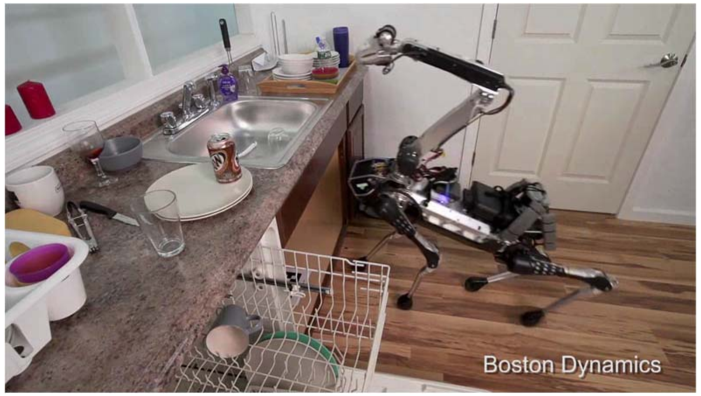
Industrial Robots



Service Robots



Cyborgs



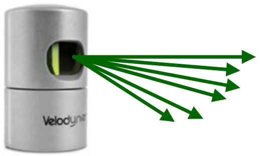
Robotics | challenges and technology drivers

- The challenges
  - ***Seeing***, ***feeling*** and ***understanding*** the world
  - Dealing with ***uncertain*** and ***partially available*** information
  - ***Act*** appropriately onto the environment

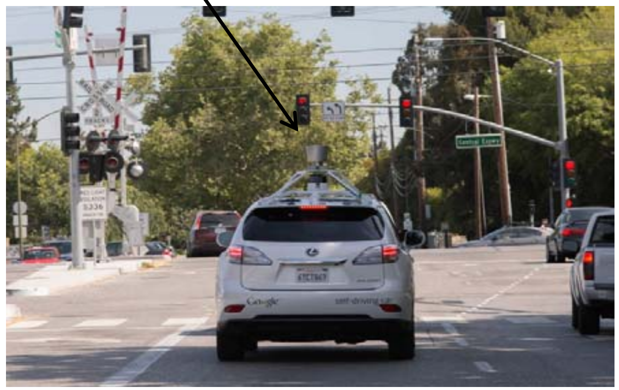
Willow Garage

- Technology drivers
  | *technology evolutions enable robotics revolutions*
  - Laser time-of-flight sensors
  - Cameras and IMUs combined with required calculation power
  - Torque controlled motors, “soft” actuation
  - New materials

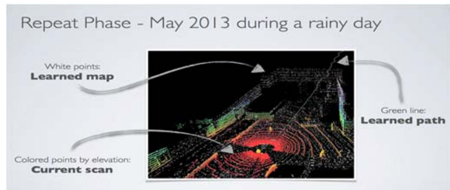
Today | 3D laser sensors



Expensive, complex and cumbersome

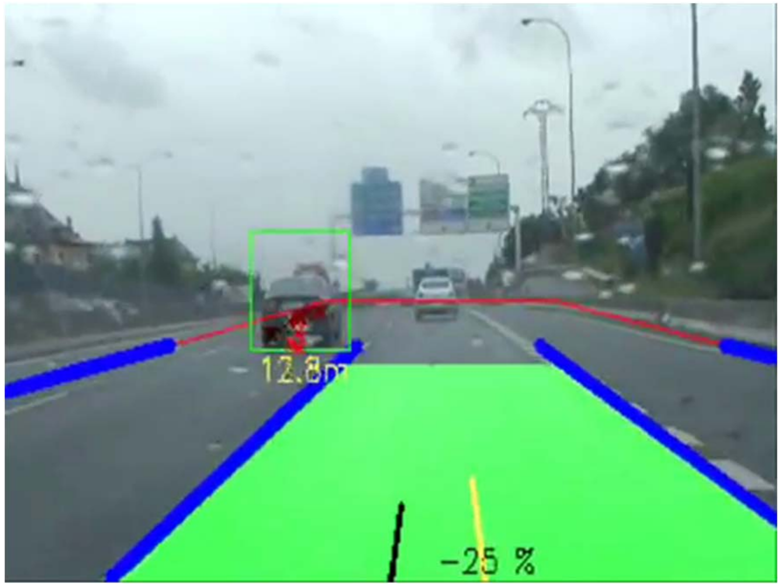


- Google Self-Driving Car Project (status summer 2015)
  - > 20 vehicles in use
  - > 2,7 mio km, 1.5 mio km in autonomous mode
  - > 11 accidents
    - No people insured
    - Non of them caused by car control algorithm



https://www.youtube.com/watch?v=eJCR2TaeSFc

Today | cameras (lane tracking, …)



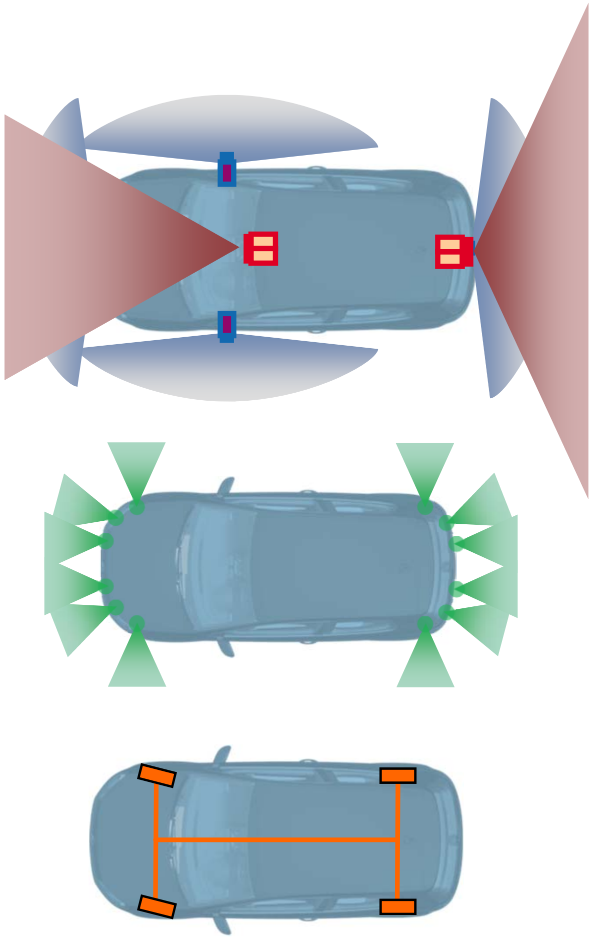
https://www.youtube.com/watch?v=JmxDIuCIIcg

https://www.youtube.com/watch?v=aGW4nRzx8Iw

MOBILEYE

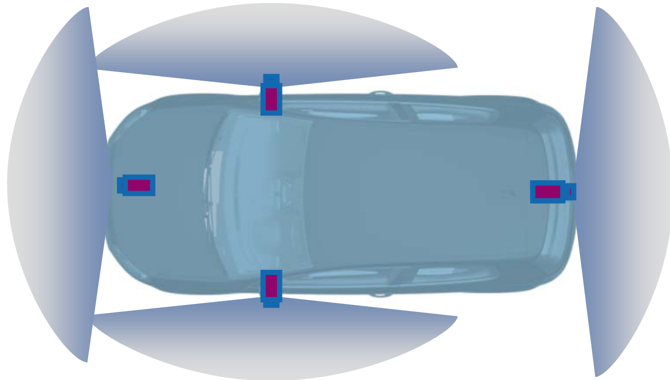
- Detection and tracking of
  - Lanes
  - Street signs
  - Other cars
  - …

V-Charge | Automonous driving using close-to-market sensors



ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich · University of Oxford · Technische Universität Braunschweig · VOLKSWAGEN AKTIENGESELLSCHAFT · Università degli Studi di Parma · BOSCH

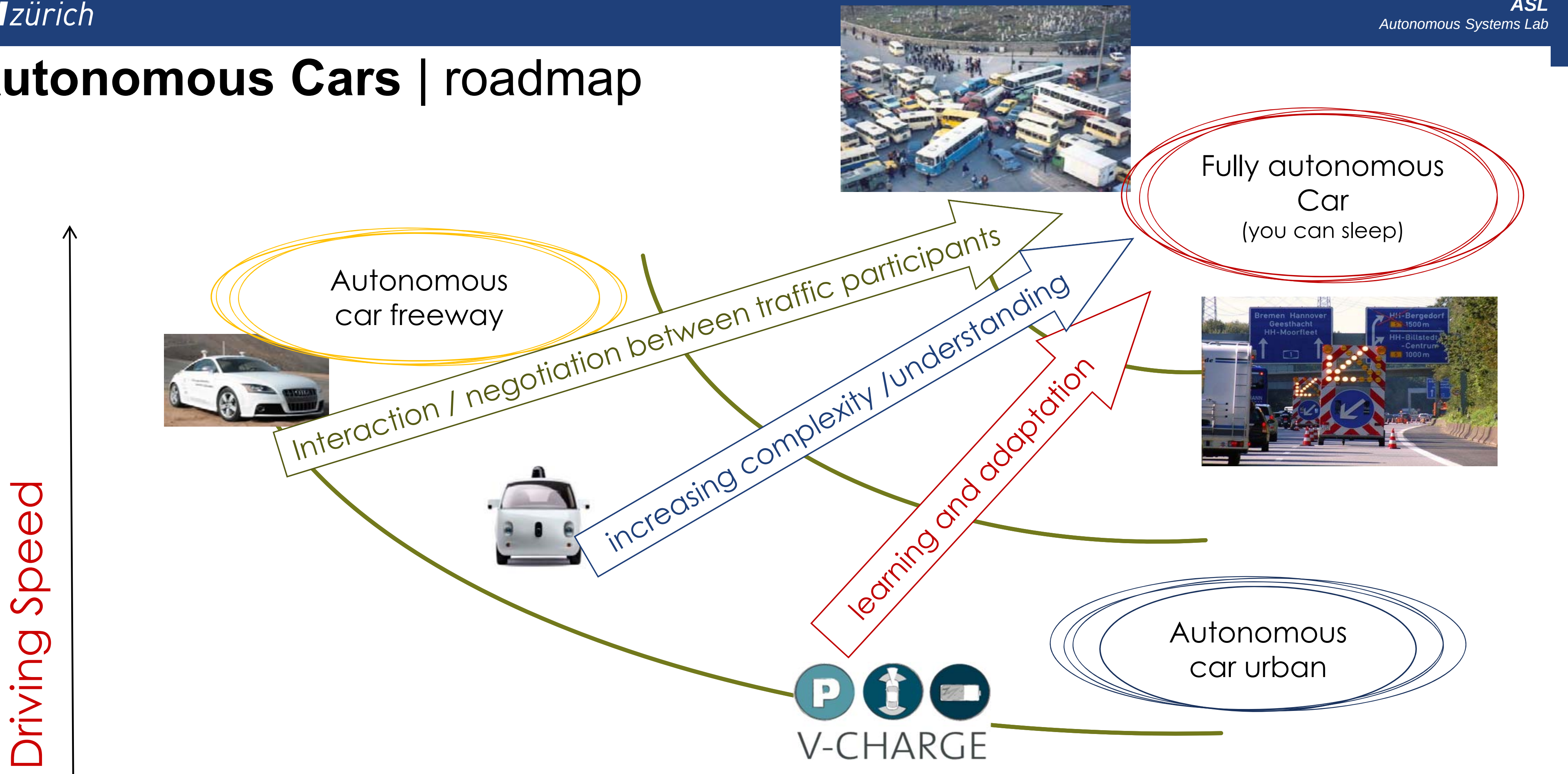
V-Charge | Autonomous driving using close-to-market sensors



Typical Situation

V-Charge Review 2 | **Driving Demo**

Autonomous Cars | roadmap



Complexity of Environment → Perception and Interaction

V-Charge | the ultimate vision

- Mixed-traffic scenarios

NIFTi – Urban Search and Rescuing

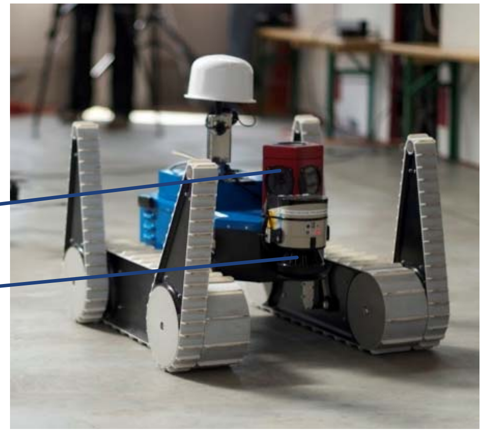
www.nifti.eu/

Natural Human-Robot Cooperation in Dynamic Environments

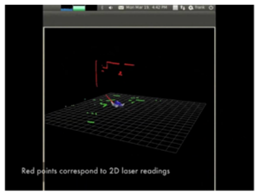
- Project goals
  - Robotic help for Urban Search and Rescue
  - UGV and UAV combined for scene exploration
  - Yearly evaluation of system by firemen

Omnicam

Rotating Laser



- Environment modeling
  - Online 3D mapping from laser sensor
  - Based on enhanced ICP released open-source
  - Topological segmentation for human-robot interaction



Service Robots – flying robots for challenging tasks

wingtra – developed by students

| the VTOL UAV

https://www.youtube.com/watch?v=QADvPDWtgFU

AtlantikSolar

| 81 hours non-stop in summer 2015

| 5.64 m, 6.2 kg

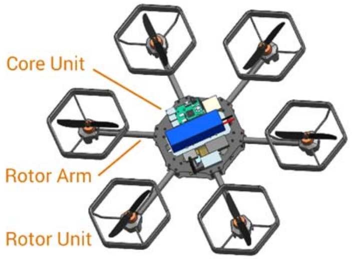
https://www.youtube.com/watch?v=8m4_NpTQn0E

https://www.youtube.com/watch?v=wyS6W1t_ryQ

Voliro – developed by students

| the omni-directional multi-copter

https://www.youtube.com/watch?v=9FJn_t-YCwM

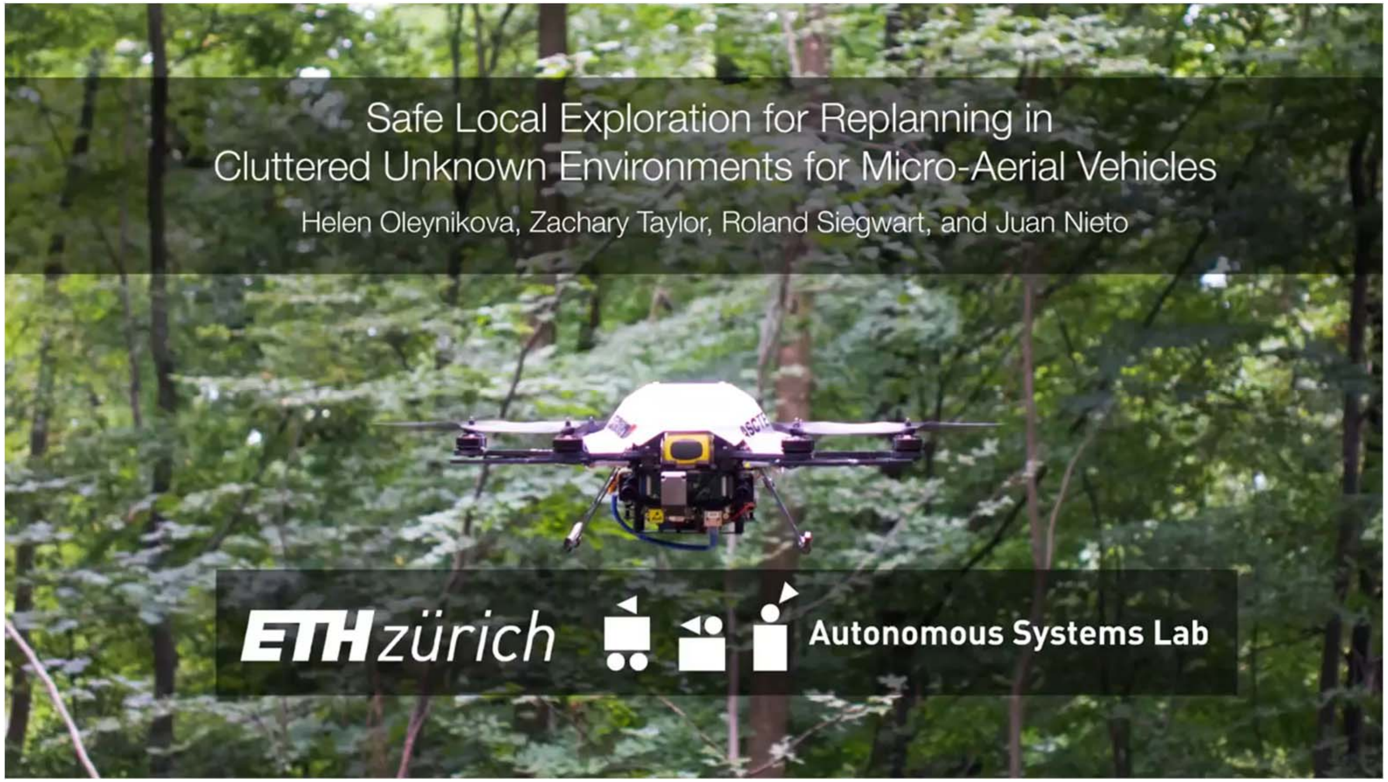


Vision only UAV navigation

www.sfly.ethz.ch/

- Swarm of small helicopters
  - Vision only navigation (one camera, GPS denied)
  - Fully autonomous with on-board computing
  - Feature based visual SLAM

Navigation & Planning in Cluttered Environments

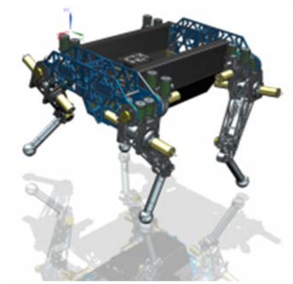


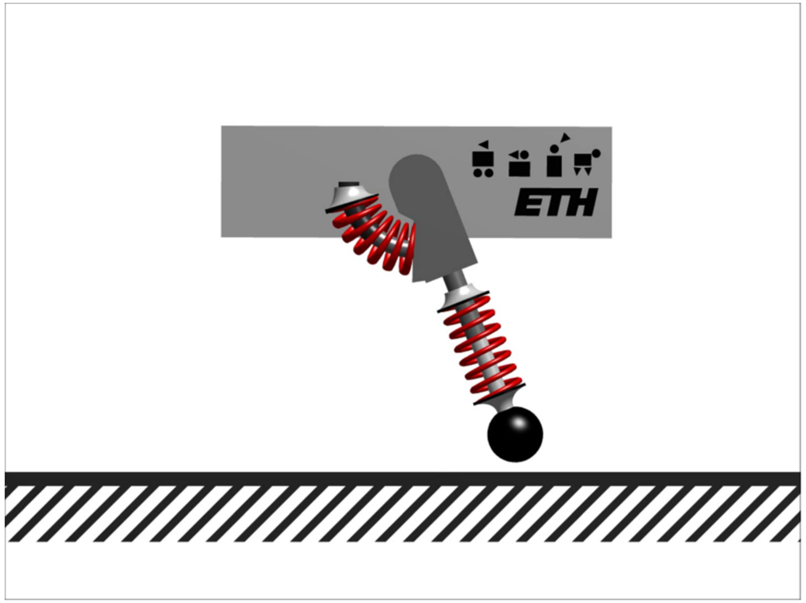
https://www.youtube.com/watch?v=rAJwD2kr7c0

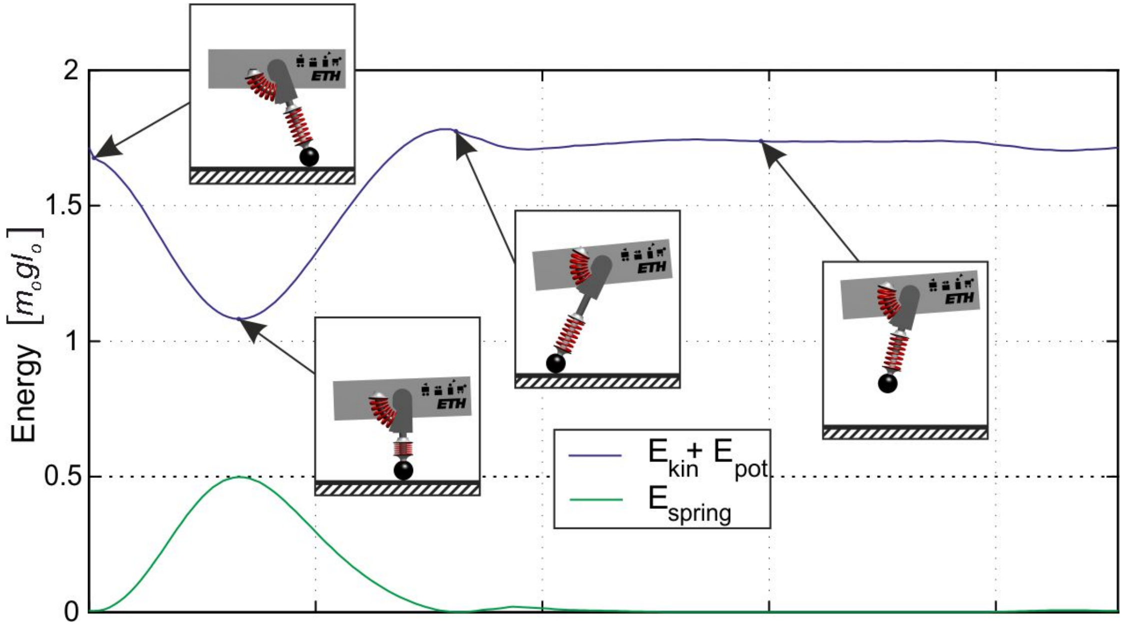
Efficient Walking and Running |
what nature evolved (Extreme Jumpy Dog)

- http://www.youtube.com/watch?v=Jql6TSyudFE

Efficient Walking and Running | serial elastic actuation

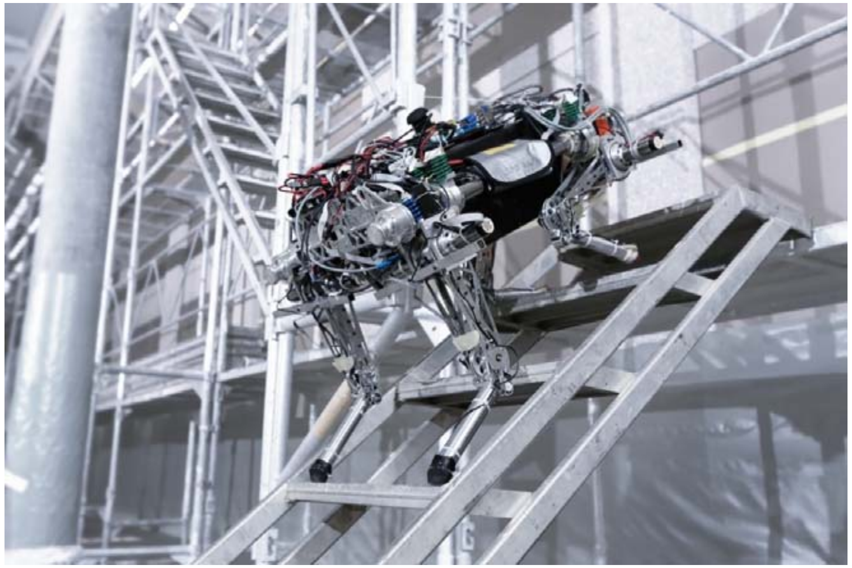


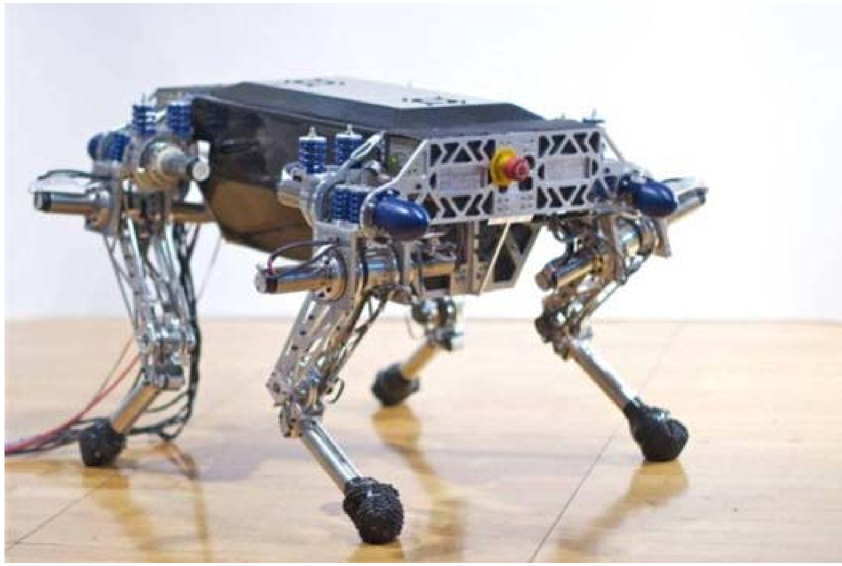




StarlETH | agile, efficiency and robust

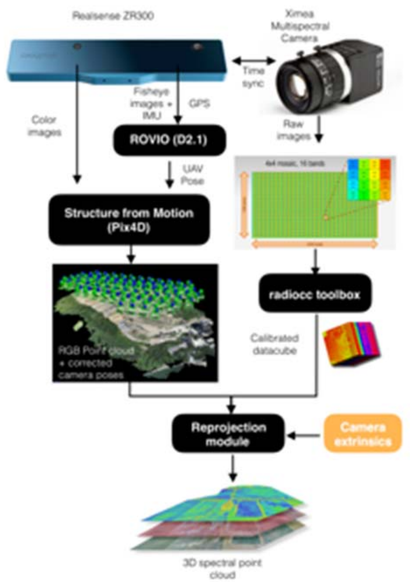
- precise torque control during stance
- fast task space position control during swing
- virtual model controller for ground contact
- autonomous gait discovery by stochastic optimization

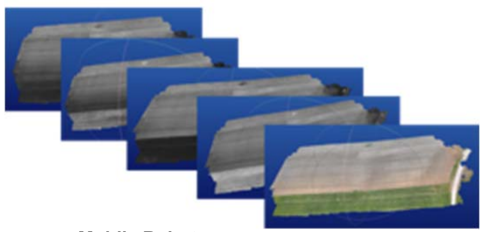




Flourish – Aerial Data Collection and Analysis, and Automated Ground Intervention for Precision Farming

Spatio-Temporal Spectral Environment Modeling

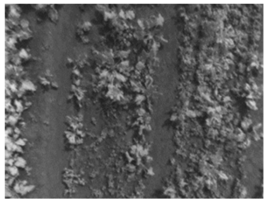


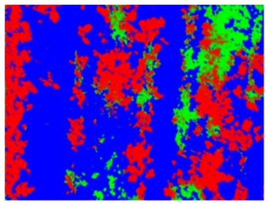


https://youtu.be/5f1EtfW76Qc

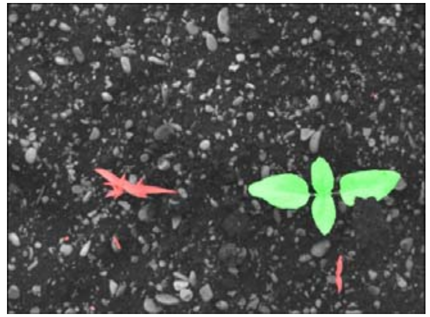
Autonomous UAV landing

UAV onboard weed detection





Weed classification on UGV (Sunflower ~95% acc.)



Automated spraying and stamping

Collaborative Visual-Inertial Navigation

in collaboration with

RSL Robotic Systems Lab
Prof. Marco Hutter

https://www.youtube.com/watch?v=9PprNdlKRaw

Humanoid Robot: ASIMO

- Honda's ASIMO - Advanced Step in Innovative MObility
- Designed to help people in their everyday lives
- One of the most advanced humanoid robots
  - Compact, lightweight
  - Sophisticated walk technology
  - Human-friendly design

Video: Honda 2012

Beyond Mobility | PR2 robot from Willow Garage

Fold towels

Courtesy of Willow Garage

Clean-up