Spring 2016

Mobile Robots | **Introduction and Lecture Overview**

Autonomous Mobile Robots

https://edge.edx.org/courses/course-v1:ETHx+AMRx_Internal_FS2016+2016_Spring/

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

Autonomous mobile robot | your teachers

Roland Siegwart, ETH Zurich

Margarita Chli, ETH Zurich

Martin Rufli, IBM Research

Video segments

Marco Hutter, ETH Zurich

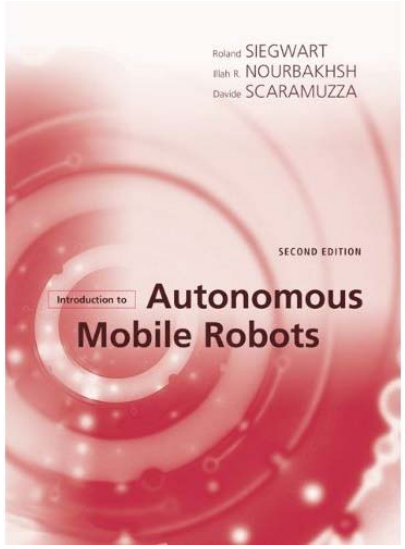
Davide Scaramuzza, Univ. of Zürich

Paul Furgale, Apple

Autonomous mobile robot | about the course

https://edge.edx.org/courses/course-v1:ETHx+AMRx_Internal_FS2016+2016_Spring/

- 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 40**
- 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 CAB G 11
  - 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

Week #	Date	Topic	Lecturer
1.	23.02.2016	Intro and Review	R. Siegwart
2.	01.03.2016	Locomotion Concepts	R. Siegwart
Ex1	01.03.2016	Introduction to V-Rep simulator	
3.	08.03.2016	Mobile Robots Kinematics	R. Siegwart
4.	15.03.2016	Perception I (to 4.3)	R. Siegwart
Ex2	15.03.2016	Kinematics and Control of a differential drive vehicle	
5.	22.03.2016	Perception II (to 4.4)	M. Chli
	29.03.2016	Week off - Easter Holiday	
6.	05.04.2016	Perception III: Image Saliency (to 4.5)	M. Chli
7.	12.04.2016	Perception IV: Place Recognition & Line Fitting (to 4.5)	M. Chli
Ex3	12.04.2016	Line extraction	
Quiz 1	12.04.2016	Quiz 1	T. Novkovic, A. Millane, T. Schneider
8.	19.04.2016	Localization I (to 5.2)	R. Siegwart
9.	26.05.2104	Localization II	R. Siegwart
Ex4	26.04.2016	Line-based Extended Kalman Filter	
10.	03.05.2016	SLAM I	M. Chli
11.	10.05.2016	SLAM II	M. Chli
Ex5	10.05.2016	EKF SLAM	
12.	17.05.2016	Planning I (to 6.2)	M. Rufli
13.	24.05.2016	Planning II (to 6.3)	M. Rufli
Ex6	24.05.2016	Dijkstra's algorithm and the dynamic window	
Quiz 2	24.05.2016	Quiz 2	T. Novkovic, A. Millane, T. Schneider
14.	31.05.2016	Summary	R. Siegwart

Exam

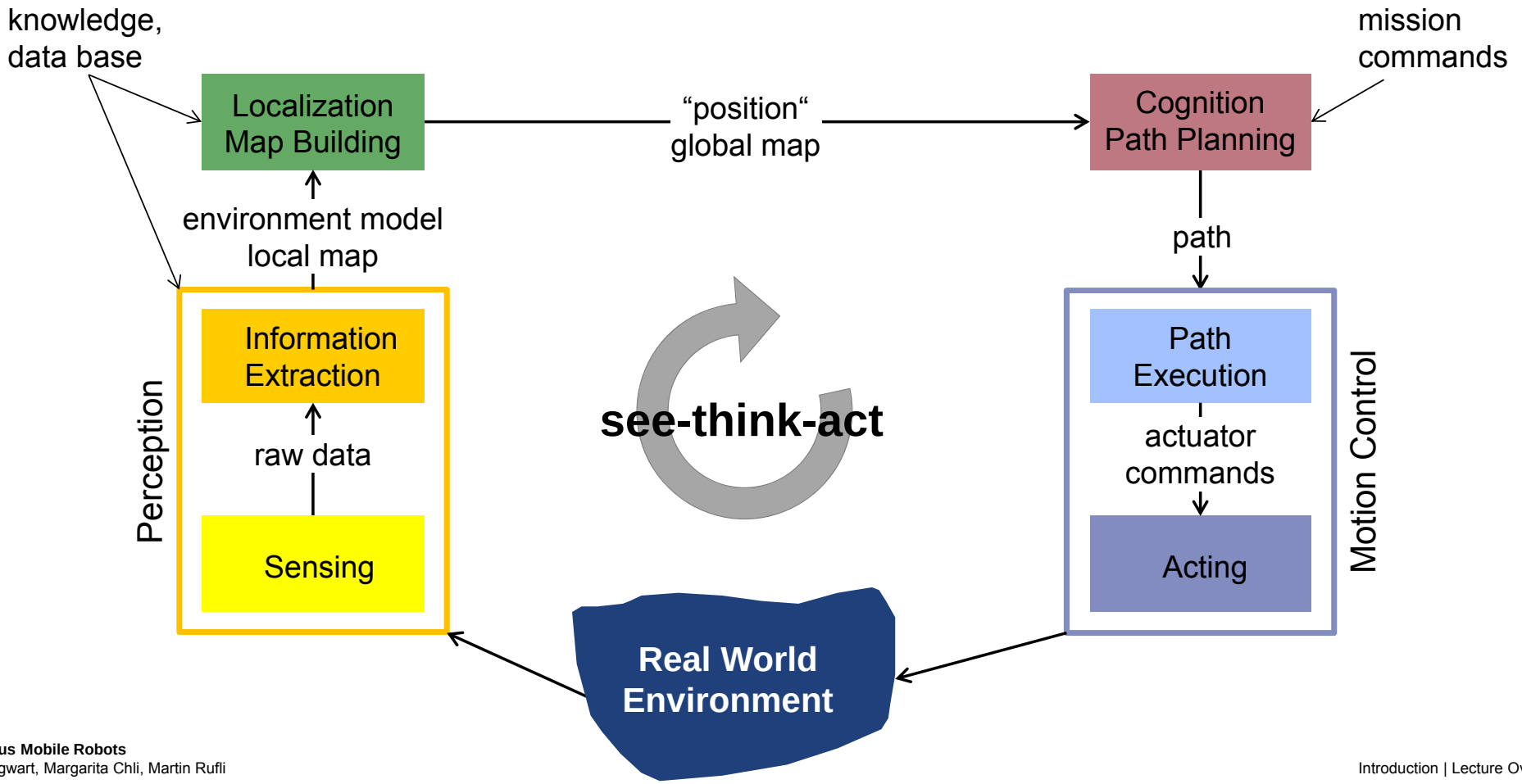
- Type
  - Written session examination
- Language of examination
  - English
- Course attendance confirmation required
  - No
- Repetition
  - The performance assessment is only offered in the session after the course unit. Repetition only possible after re-enrolling.
- Mode of examination
  - written 120 minutes
- 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 ?

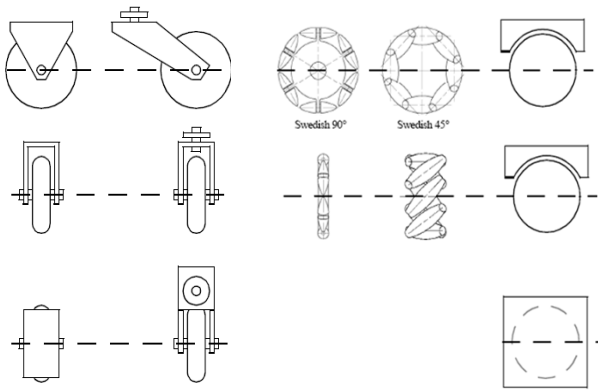
- To answer these questions the robot has to
  - have a model of the environment (given or autonomously built)
  - perceive and analyze the environment
  - find its position/situation within the environment
  - plan and execute the movement

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)

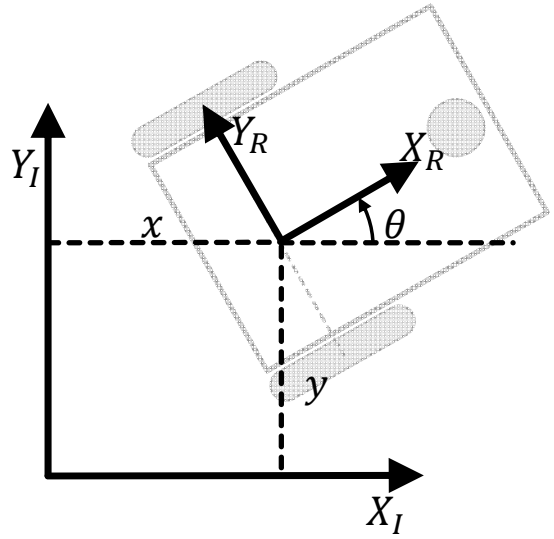


- Motion control

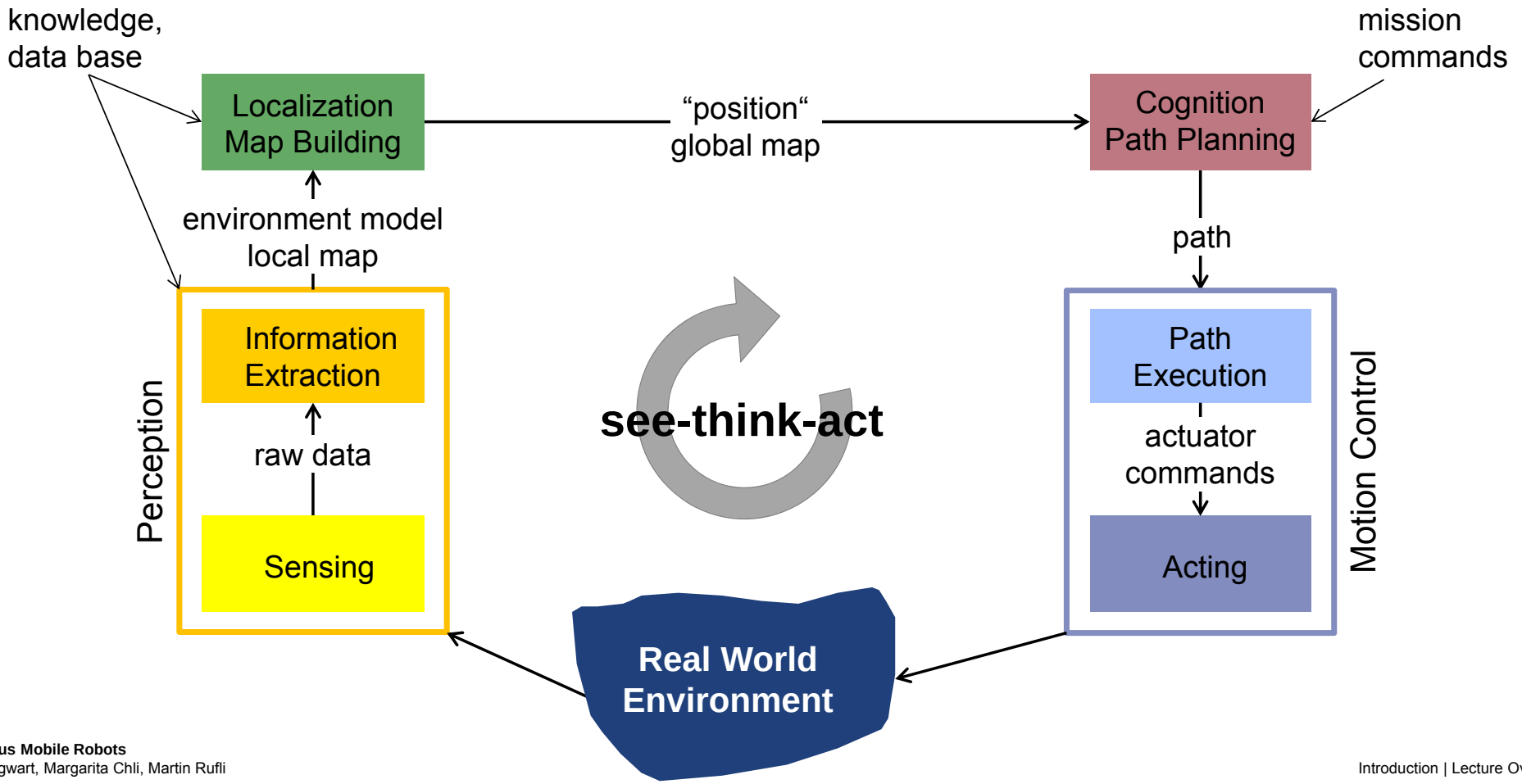
$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = f(\dot{\varphi}_1 \cdots \dot{\varphi}_n, \theta, geometry)$$

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

?

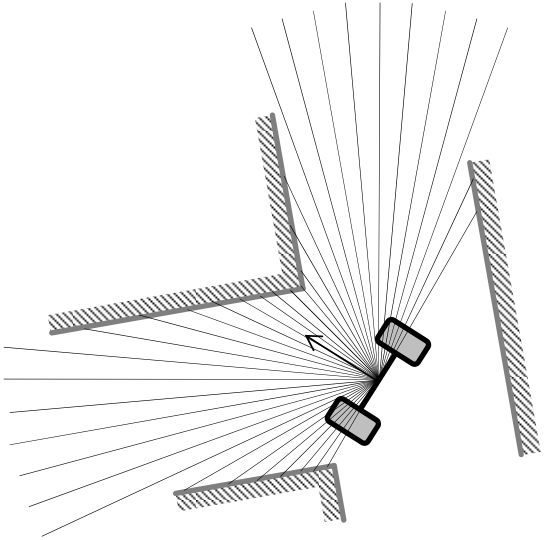


Autonomous mobile robot | the see-think-act cycle

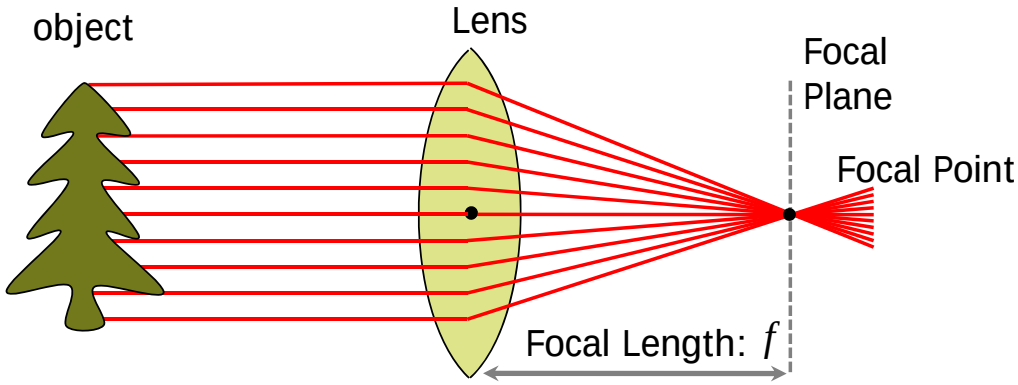


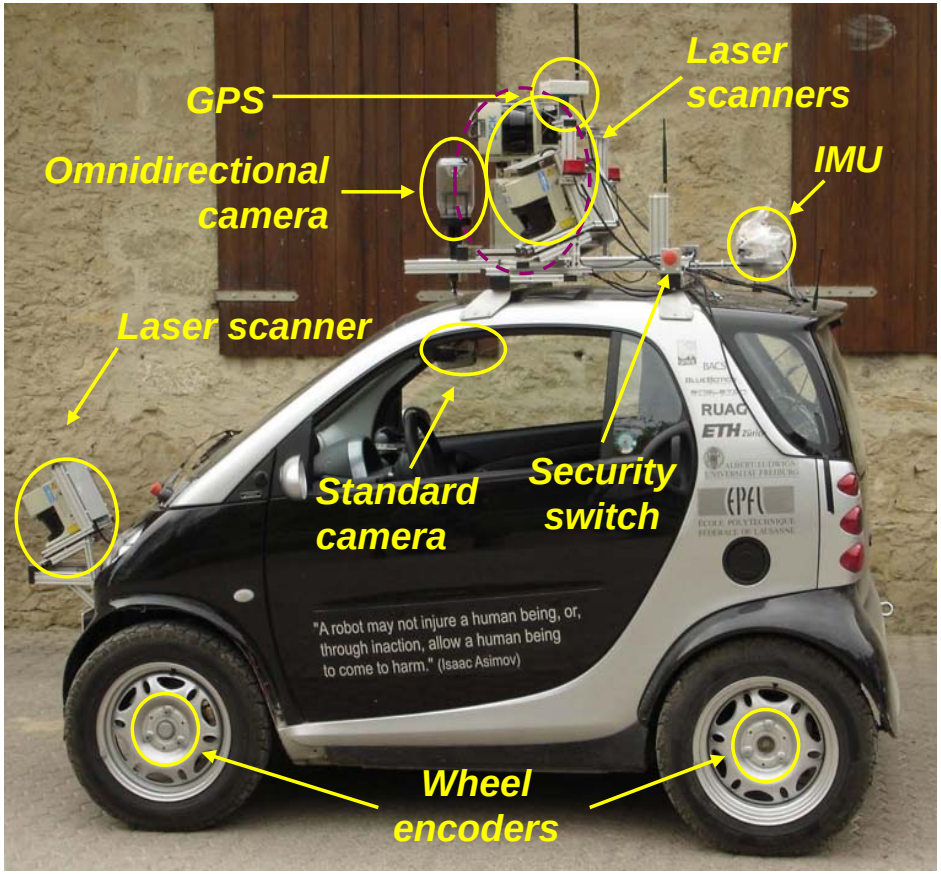
Perception | sensing

- Laser scanner
  - time of flight



- Camers





Perception | information extraction

- Filtering / Edge Detection

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

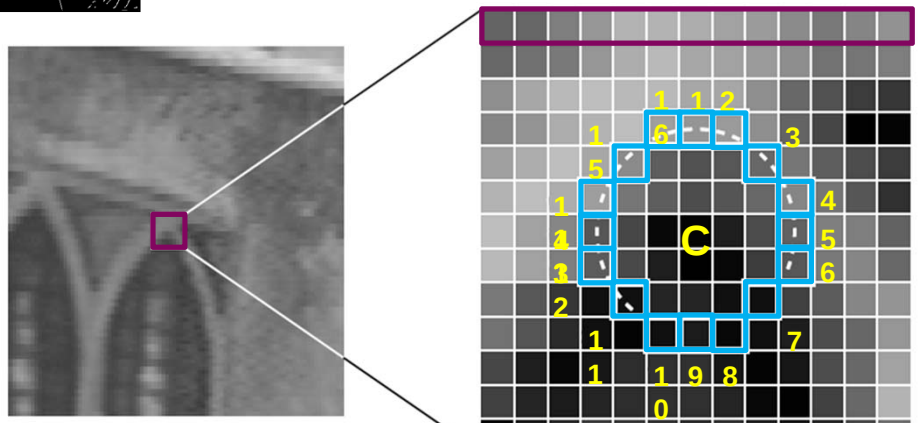
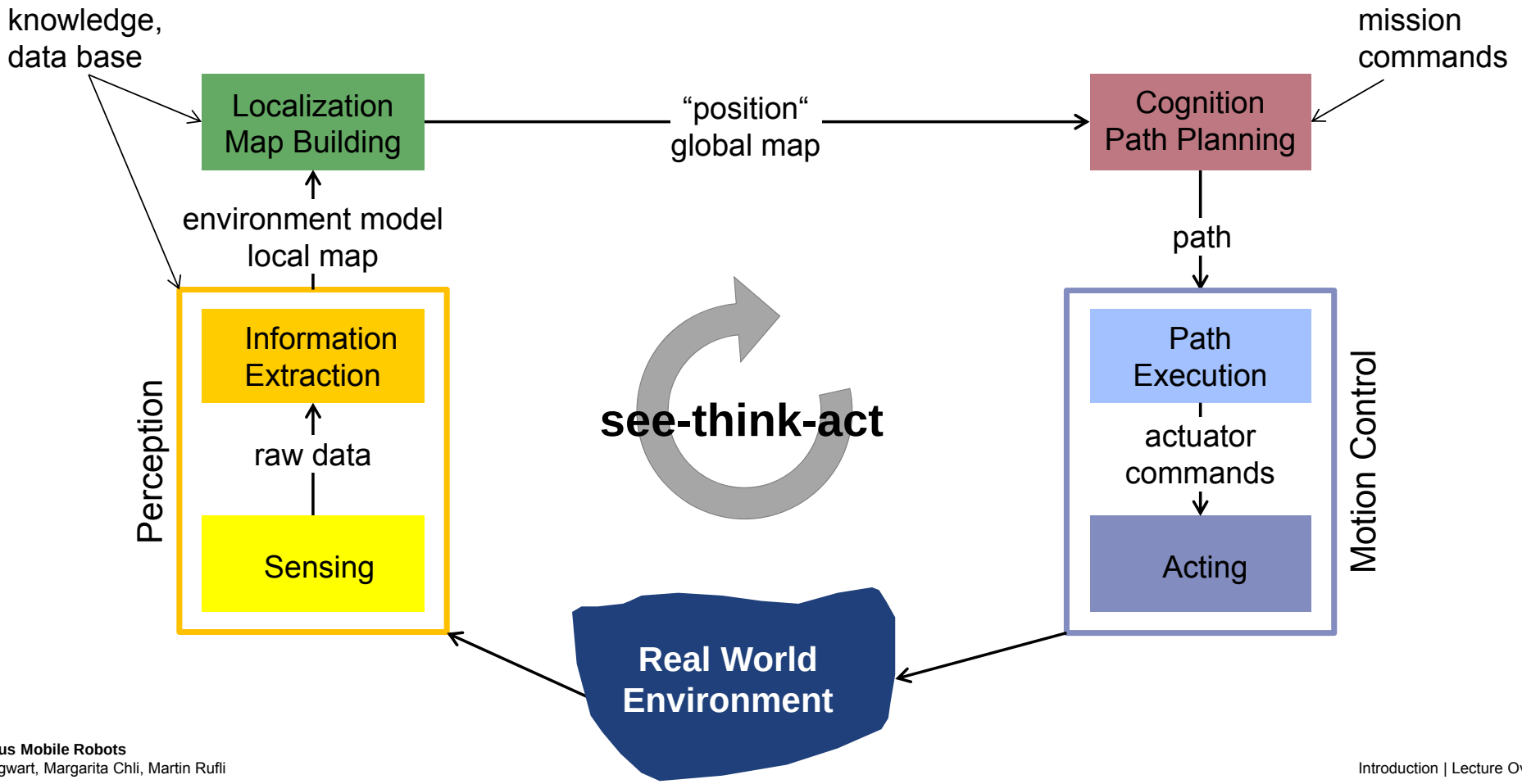


Image from [Rosten et al., PAMI 2010]

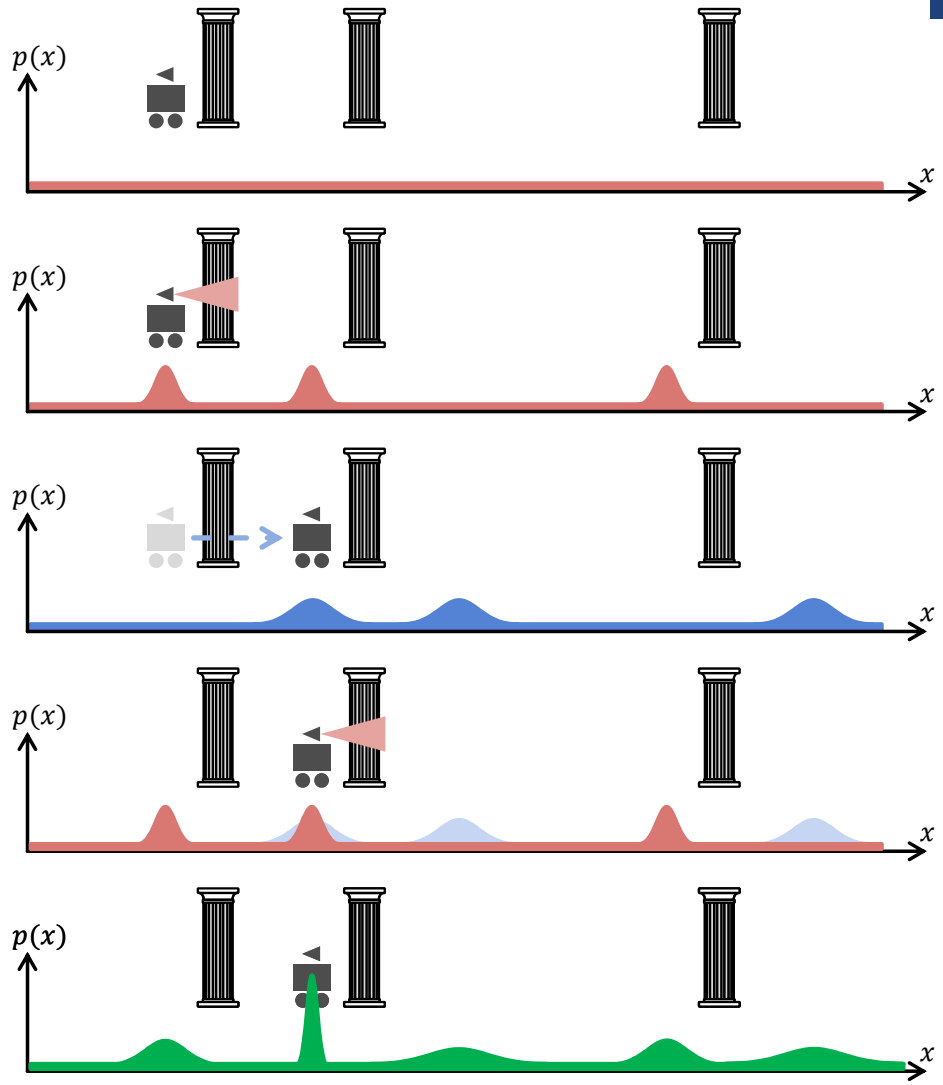
- Keypoint matching
  - BRISK example

Autonomous mobile robot | the see-think-act cycle

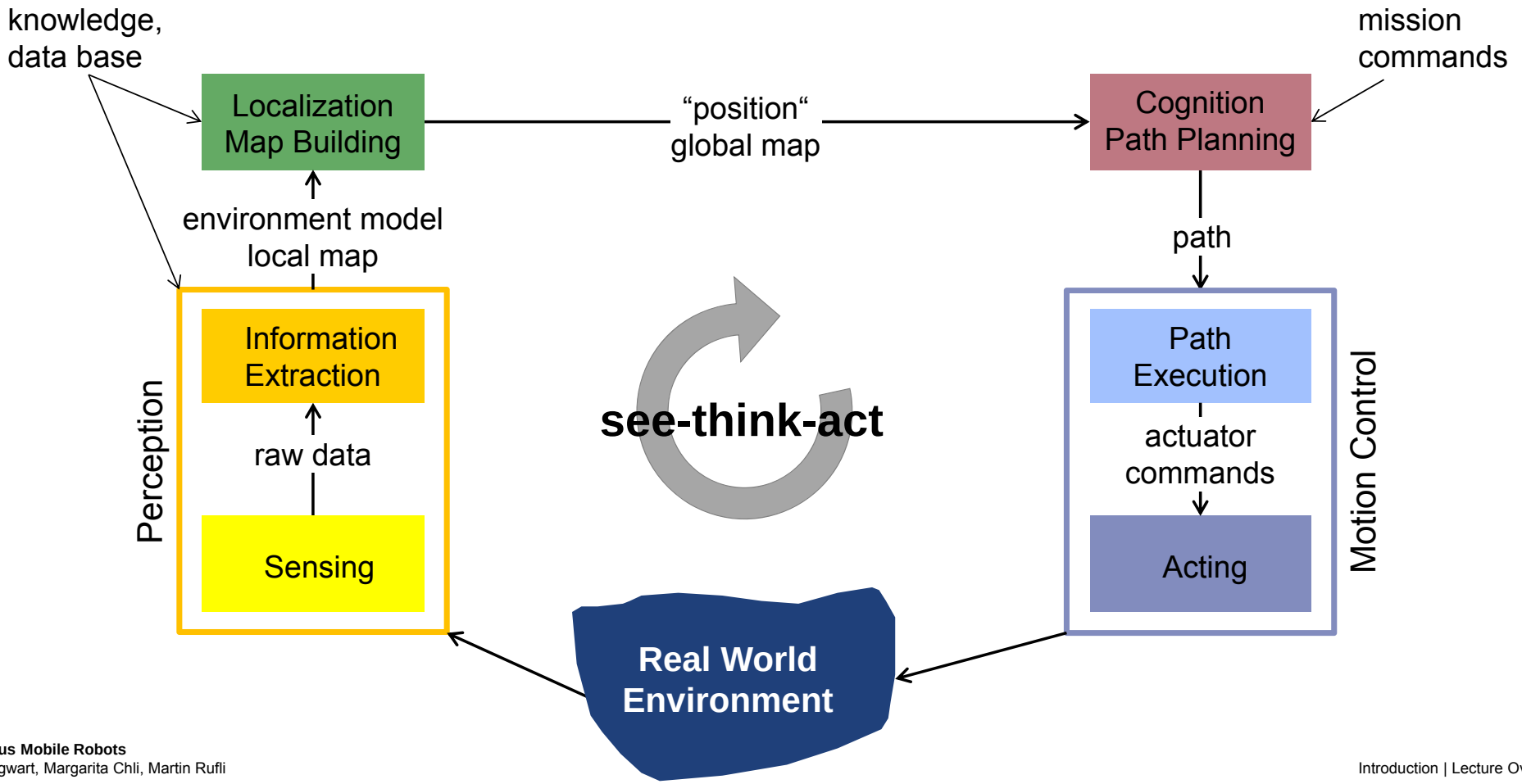


Localization | where am I?

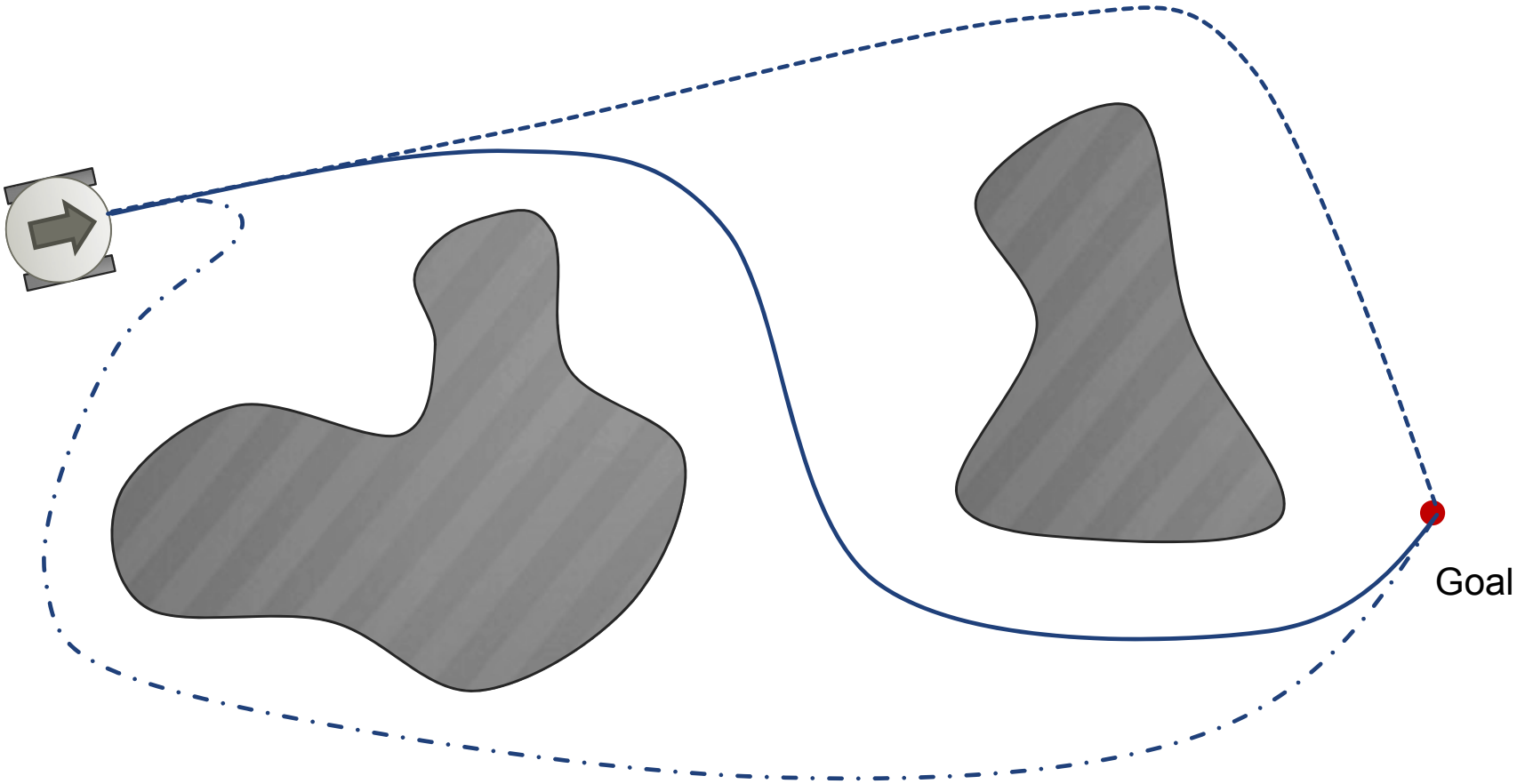
- SEE: The robot queries its sensors → finds itself next to a pillar
- ACT: Robot moves one meter forward
  - motion estimated by wheel encoders
  - accumulation of uncertainty
- SEE: The robot queries its sensors again → finds itself next to a pillar
- Belief update (information fusion)



Autonomous mobile robot | the see-think-act cycle

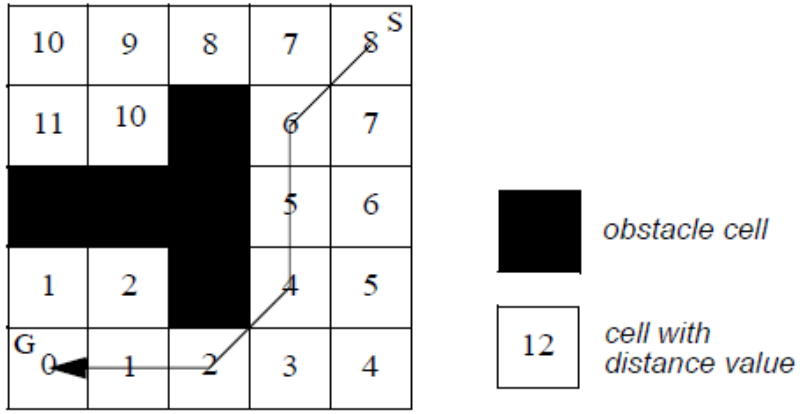


Cognition | Where am I going ? How do I get there ?

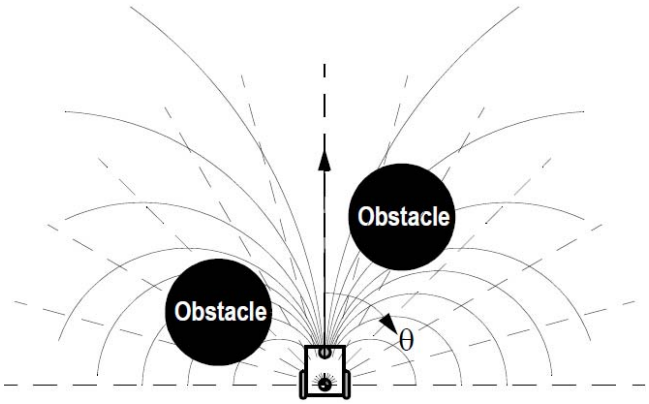


Cognition | Where am I going ? How do I get there ?

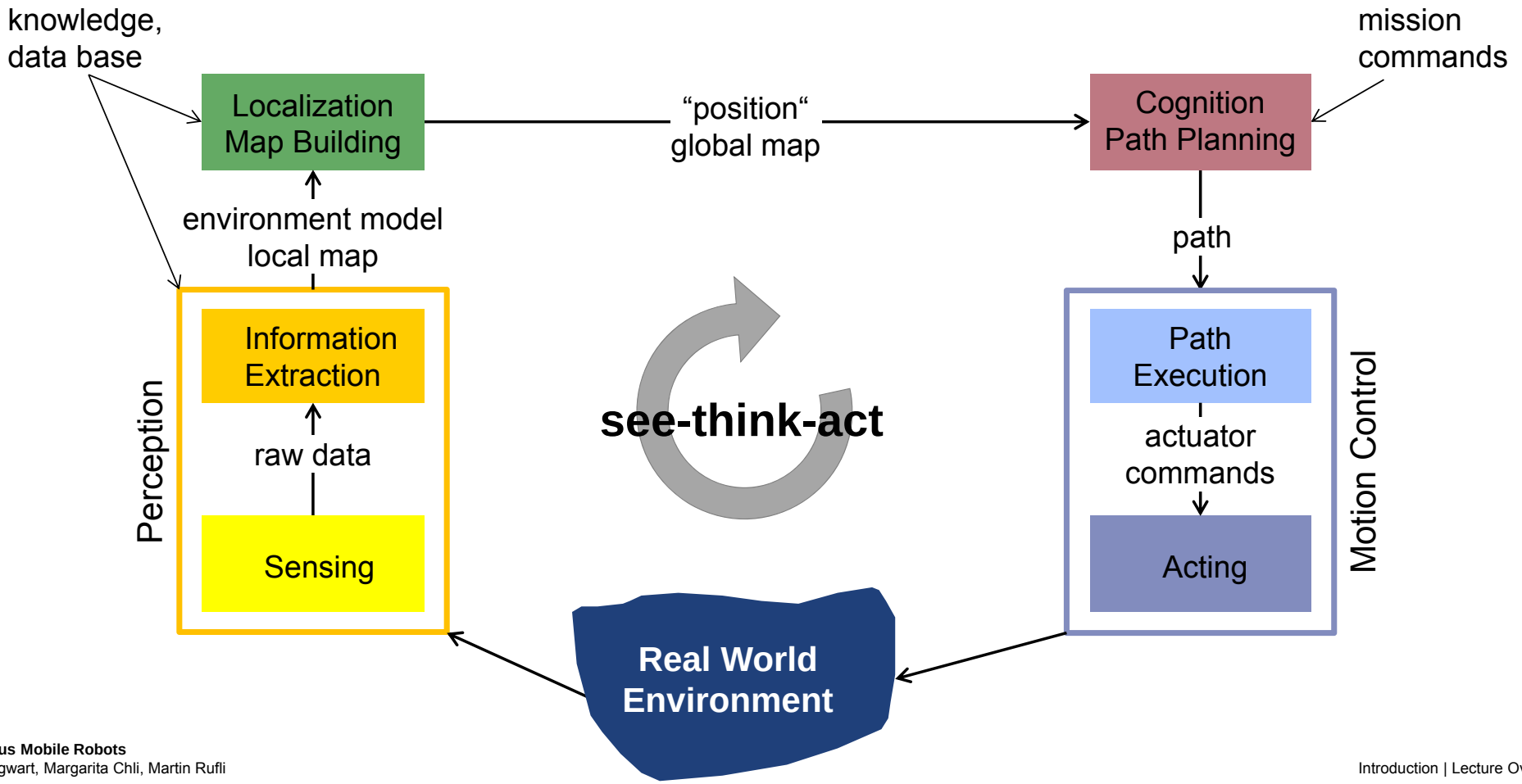
- Global path planning
  - Graph search



- Local path planning
  - Local collision avoidance



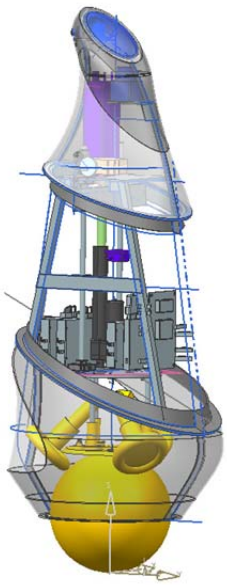
Autonomous mobile robot | the see-think-act cycle

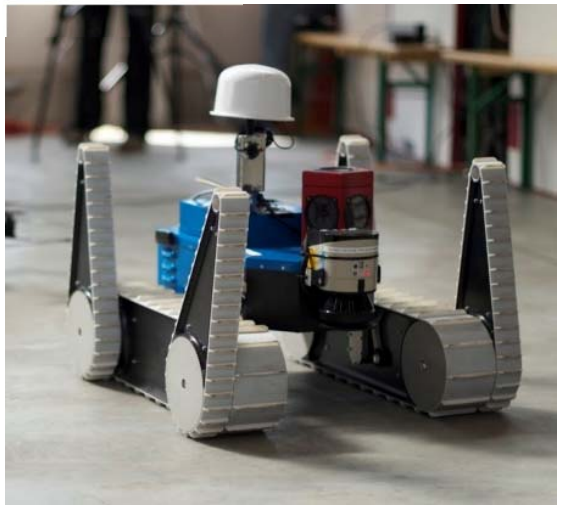


Autonomous mobile robot | we invite you to join the course

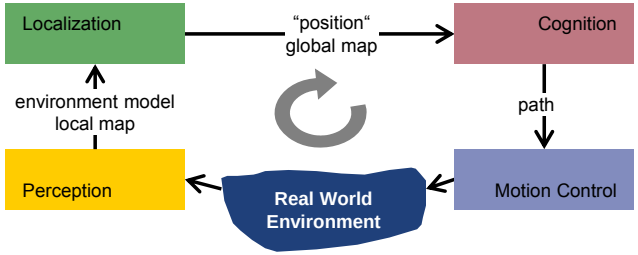
Autonomous Mobile Robots | Some recent examples

Examples – not part of MOOC Video Segment





From Perception to Understanding



Fusing & Compressing Information

Places / Situations
A specific room, a meeting situation, …

Servicing / Reasoning

- Functional / Contextual Relationships of Objects
  - imposed
  - learned
  - spatial / temporal/semantic

Objects
Doors, Humans, Coke bottle, car , …

Interaction

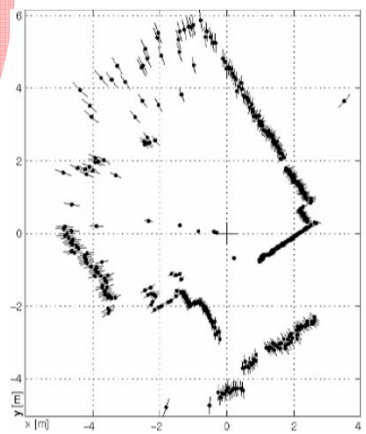
- Models / Semantics
  - imposed
  - learned

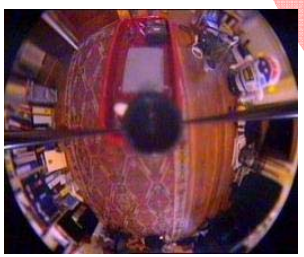
Features
Lines, Contours, Colors, Phonemes, …

Navigation

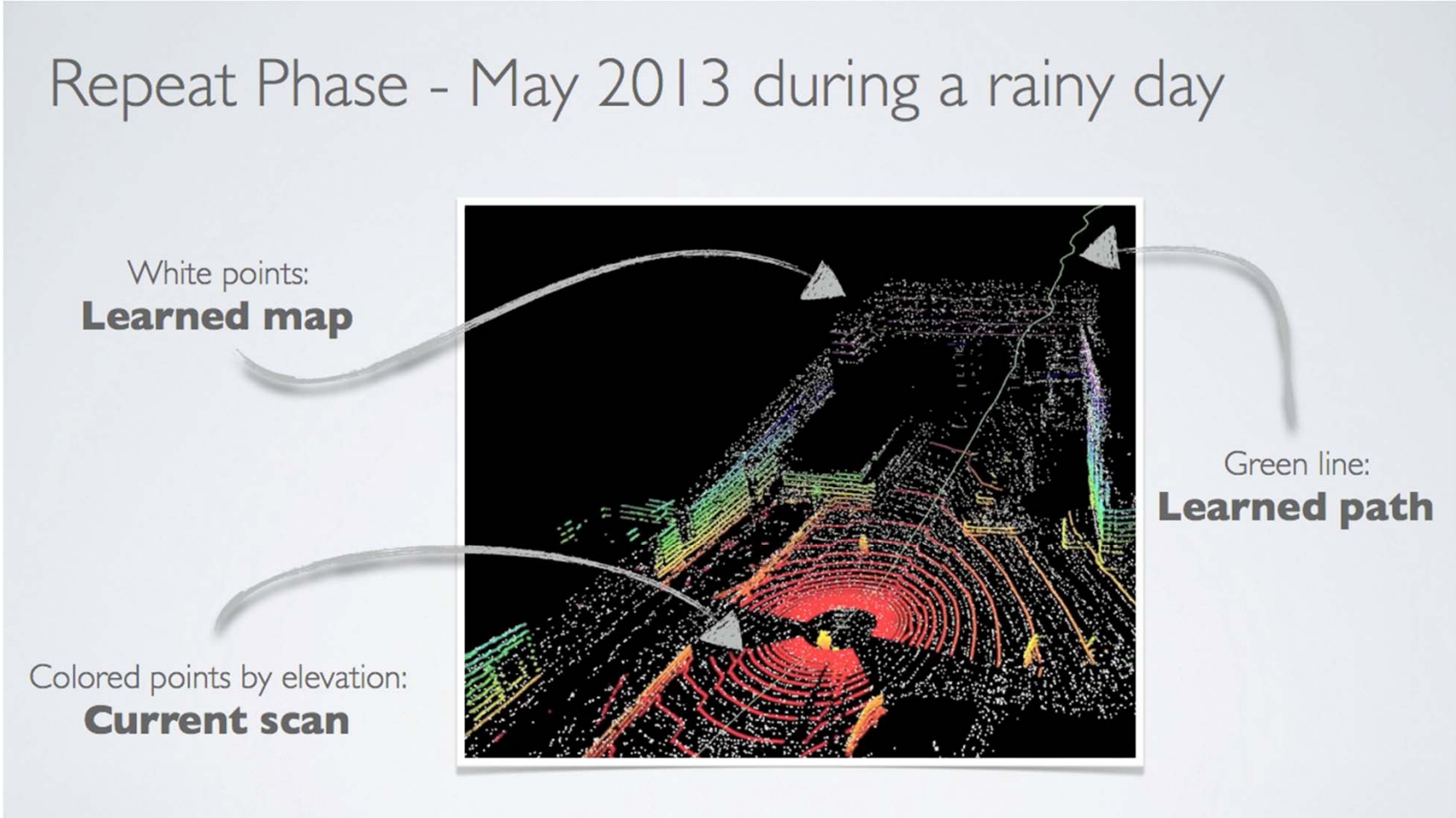
- Models
  - imposed
  - learned

Raw Data
Vision, Laser, Sound, Smell, …

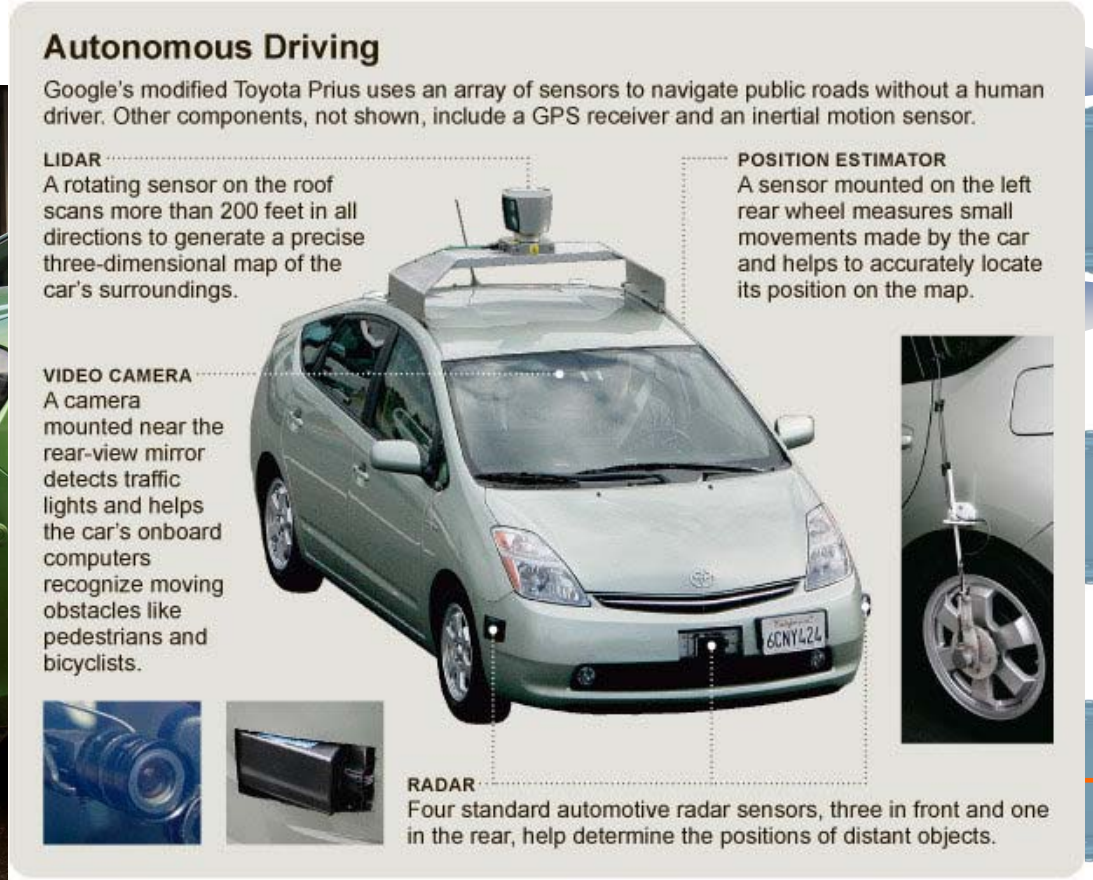


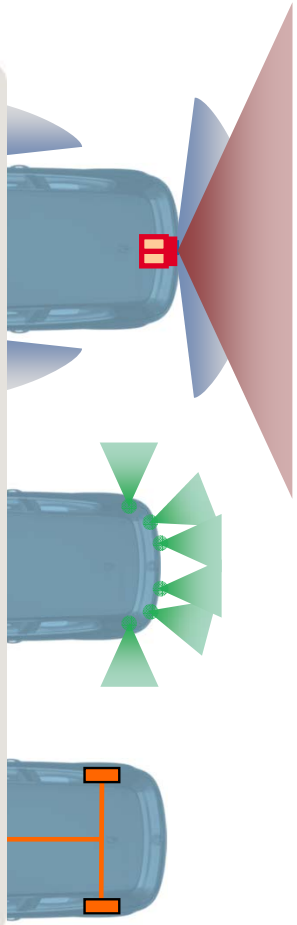


Laser-based outdoor navigation



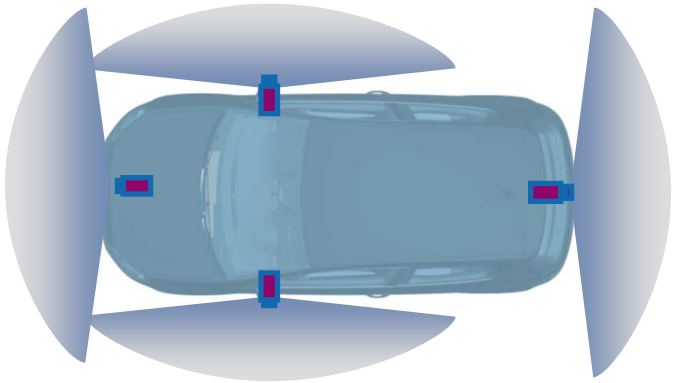
V-Charge | Automonous driving using close-to-market sensors





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**

V-Charge | the ultimate vision

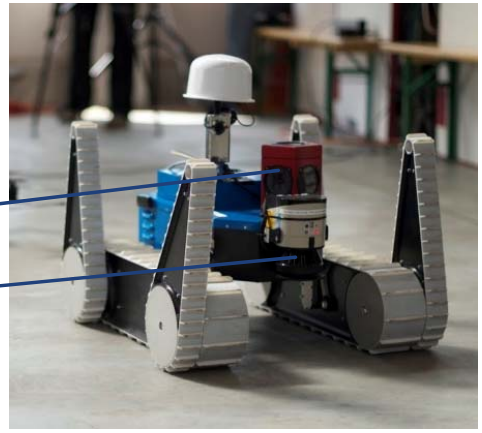
- Mixed-traffic scenarios

NIFTi – Urban Search and Rescuing

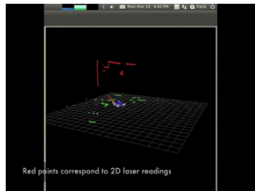
www.nifti.eu/

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



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



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

UAV | collision avoidance and path planning

- Real time 3D mapping (on-board)
- optimal path planning considering localization uncertainties

Solar powered fixed wing airplanes: Long duration / continuous flights

senseSoar

Atlantik Solar

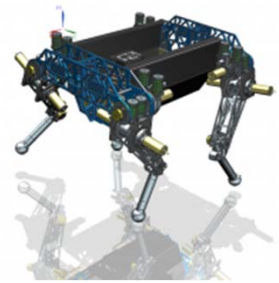
senseSoar

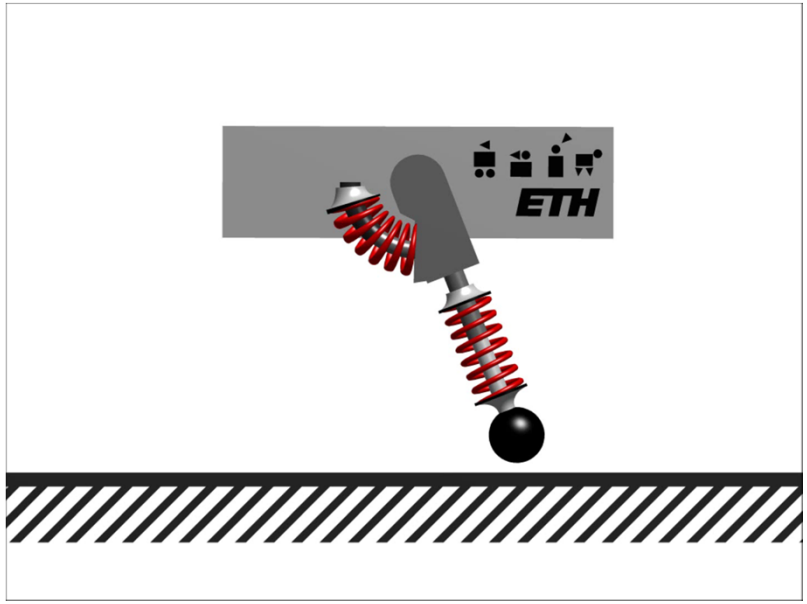
- Wingspan: 3 m
- Wing area: 0.725 m2
- Peak Solar power 140 W
- Power Consumption 50 W
- Masses:
  - Overall: 3.72 kg
  - Batteries: 1.89 kg
- Nominal Speed 10 m/s
- Sensors
  - Air speed
  - IMU, GPS
  - Camera and **IR camera**

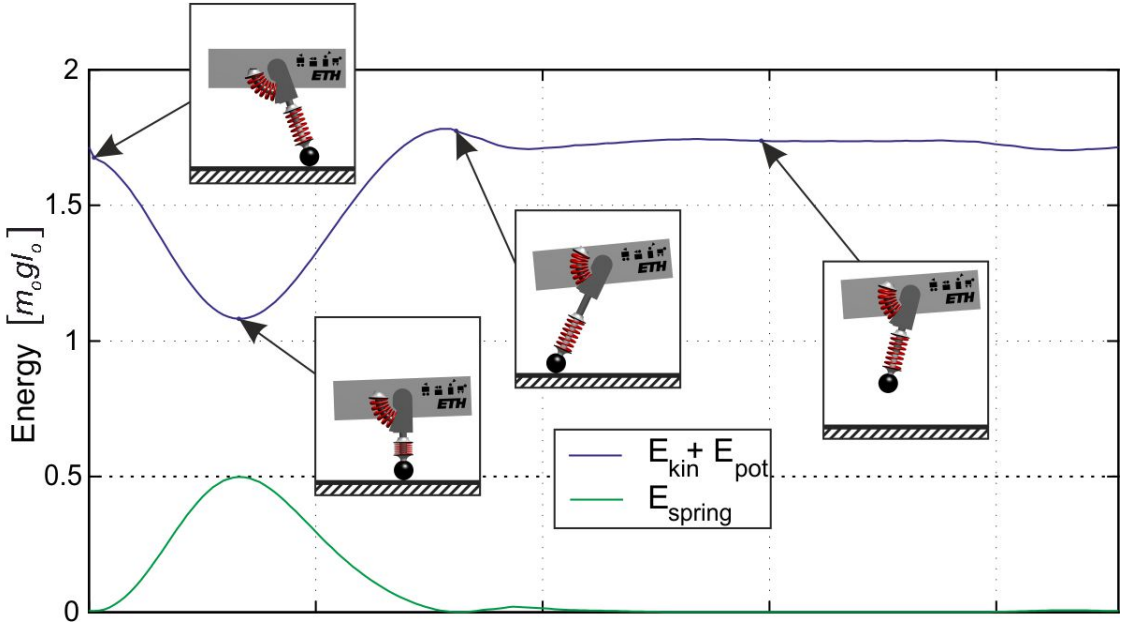
Efficient Walking and Running |
what nature evolved (Extreme Jumpy Dog)

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

Efficient Walking and Running | serial elastic actuation

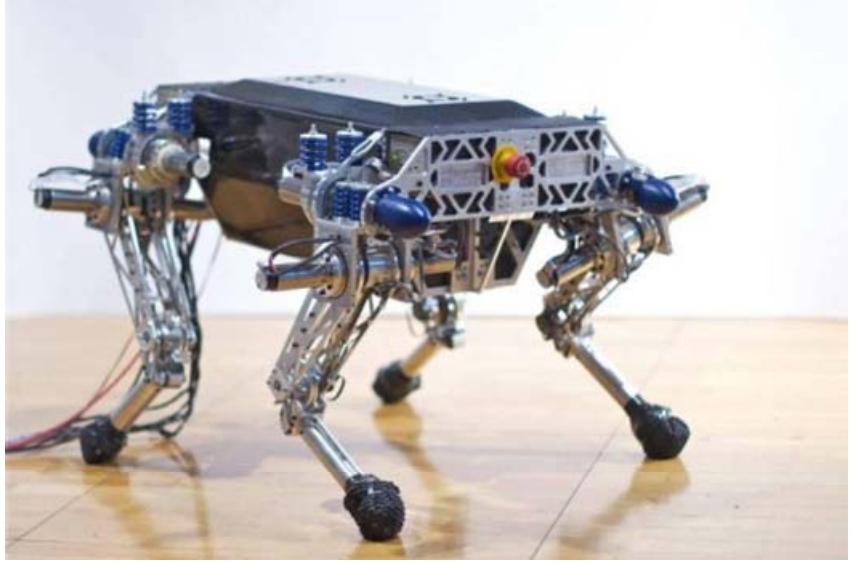






StarlETH | agile, efficiency and robust

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



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