DTU

Lazaros Nalpantidis & Evangelos Boukas

Software Architectures for Autonomous Systems

Outline

- Introduction to the Course
- Introduction to Software Architectures
  - Operation Paradigms
  - Hardware Abstraction Layer & Middleware
  - Characteristics of Software Architectures
- Summary

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Overview

- 5 ECTS
- Technological Specialization course for the MSc. in Autonomous Systems
- Elective for other DTU MSc programmes

- All course lectures and activities:
  - Physical presence in rooms: B325-009, B325-017, B325-025 supported by:
    - Zoom (lectures)
    - Discord (excercices and support)
  - Mondays 13:00-17:00

Lecturers

- **Lecturers:**
  - Evangelos Boukas, Associate Professor, build. 326, room 020.

  - Lazaros Nalpantidis, Associate Professor, build. 326, room 018.

- **Teaching Assistants:**
  - Ronja Güldenring, build 326, room 030.

  - Sara López Alaguero

Learning Objectives

A student who has met the objectives of the course will be able to:

- Design components for control of autonomous systems
- Choose components in ROS
- Understand installation and configuration of ROS
- Explain differences in hard and soft real-time
- Explain the control of a robot arm using ROS
- Find errors in process communication
- Verify the timing of software for autonomous systems
- Document software for autonomous systems
- Deploy autonomously navigating robotic agents
- Re-use High-level perception systems
- Simulate autonomous robots

Course Timeline

Calendar Week		
35	30-Aug	• Introduction • Software architecture • Exercises
36	6-Sep	• Middleware for Autonomous Systems • Introduction to Robot Operation System • Exercises
37	13-Sep	• ROS Transforms (TF), Robot Visualization (RVIZ) and Simulation (Gazebo) • Exercises
38	20-Sep	• Robot Kinematics, Motion Planning and Execution • Exercises
39	27-Sep	• Mini-Project 1: Motion Planning • Exercises
40	4-Oct	• Mini-Project 1: Day 2 • Exercises
41	11-Oct	• Autonomous Guided Vehicles • Exercises
42	18-Oct	Autumn Holiday
43	25-Oct	• Guest Lecture - UAV intro • Final Project description • Optional Hands-on Session
44	1-Nov	• Guest Lecture • Optional Hands-on Session • Final Project
45	8-Nov	• Guest Lecture • Optional Hands-on Session • Final Project
46	15-Nov	• Optional Hands-on Session • Final Project
47	22-Nov	• Final Project
48	29-Nov	• Final Project

Course Format (1/3)

- **Lectures:**
  - All course lectures will be physical in room B325-009, supported by **Zoom** for rooms B325-017, B325-025. Students can pose questions or use the chat to communicate with the lecturer. All lectures will be broadcasted through the same link.

Course Format (2/3)

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- **Exercises:**
  - Students will work on all course exercises as groups. Our 3 rooms are available for this purpose.
  - The course TAs will be available for questions on **Discord** during the class hours; reach them by writing to the "# general" channel.

Course Format (3/3)

- **Lectures:**
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- **Exercises:**
  - – Students will work on all course exercises as groups. Our 3 rooms are available for this purpose.
  - – The course TAs will be available for questions on **Discord** during the class hours; reach them by writing to the "# general" channel.
- **Group Formation:**
  - – students need to form groups of 4 people.
  - – The formed groups will work together on all exercises and projects during the course.
  - – Group formation starts from the start of the course and needs to be finalized by 5. Sept. Students form groups by themselves and register them in the online excel file: https://dtudk-my.sharepoint.com/:x:/r/personal/evanb_dtu_dk/_layouts/15/guestaccess.aspx?e=fDcGL2&share=EdGwUQRExrpNjWURMj-Y_UQB7otrCZHqT8fjLoepO-PRVA

Important Dates

5. September 2021	Deadline for formation of student groups. Students form groups of 4 people to work together on the exercises and on the course projects. Students register their groups in: [Group Formation link] .
25. October 2021	Announcement from the teachers of the Final Project description.
30. November 2021	Hand-in of group report of Final Project.
3. December 2021	Information about non-qualification for participating in the exam by email to the members of groups with inadequate reports.
8. December 2021	1 hour online Exam with multiple choice questions!

Exams / Evaluation

- In order to successfully complete the course, you need to:
  - Submit a group report about your final Project.
    - Final Project:
      - students are expected to work in their groups of 4 people
      - to solve a bigger assignment that will be given to them.
      - the outcome of the Final Project is a report of 10±2 pages that includes a link to a video demonstrating the group's main achievements.
      - A positive evaluation (pass/fail) of the report is mandatory for the group members to participate in the final exam.
  - Participate in an individual multiple choice exam
    - You get a Pass or Fail result.

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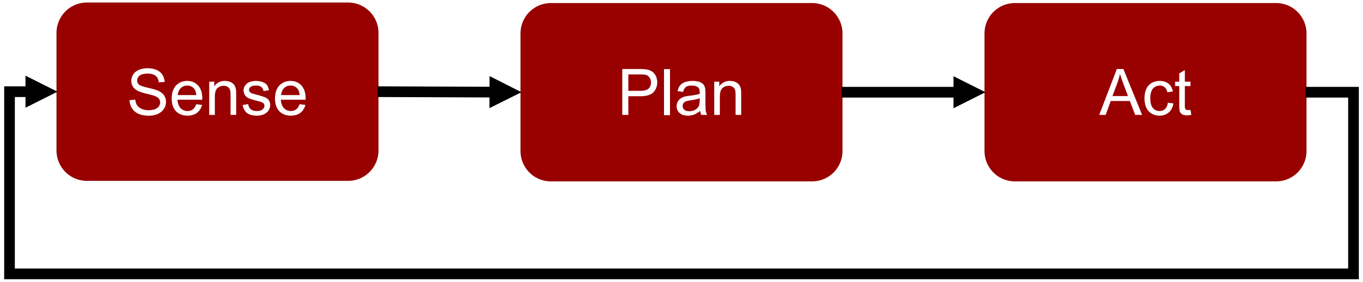
Operation Paradigms / Software Architectures

- A high-level model of how an Autonomous System operates

- Example from Robotics: **Robotic Paradigm**
  - Robot software architectures can be built by combining 3 primitive operations:
    - Sense
    - Plan
    - Act

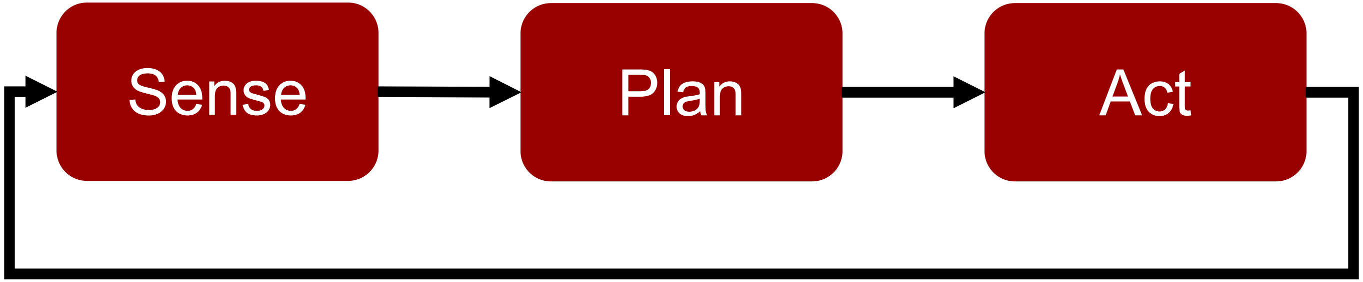
Operation Paradigms / Software Architectures

- Hierarchical (deliberative) paradigm



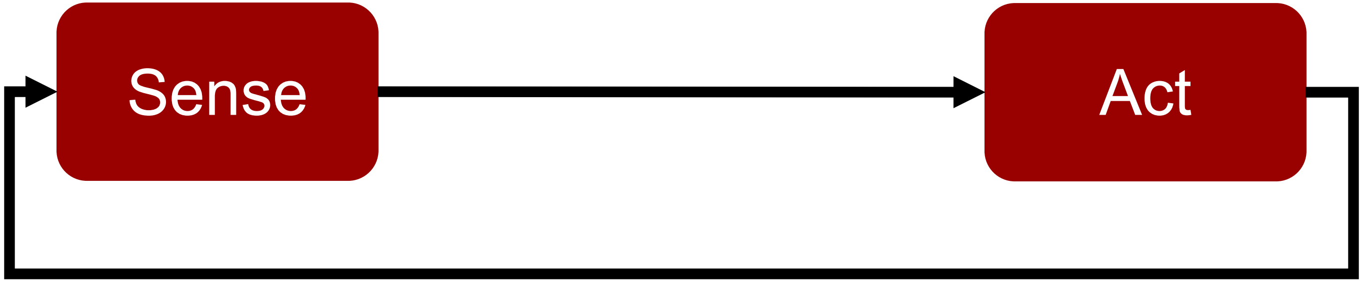
Operation Paradigms / Software Architectures

- Hierarchical (deliberative) paradigm
  - First introduced with the Shakey Robot in 1966-1972.
  - A “world model” is needed that fully describes the operation environment.
  - Planners can be formalized and used to provide next actions.



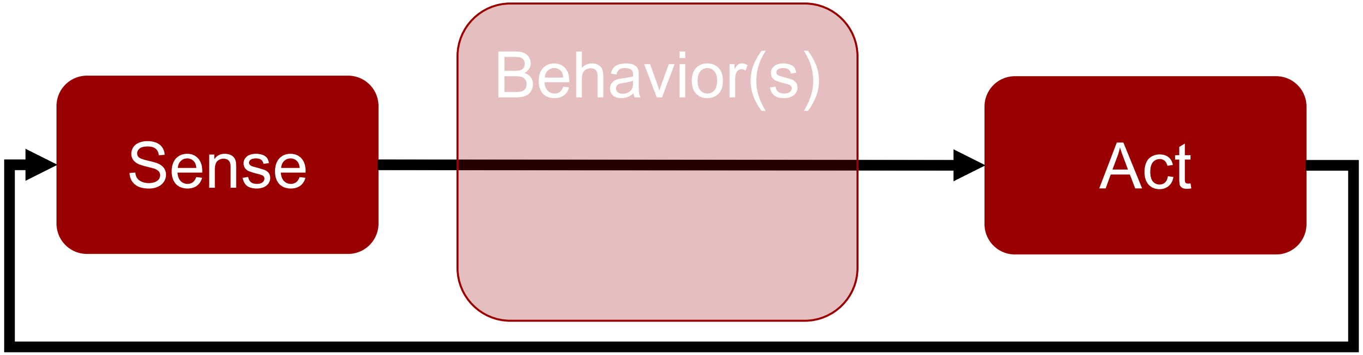
Operation Paradigms / Software Architectures

- Reactive paradigm



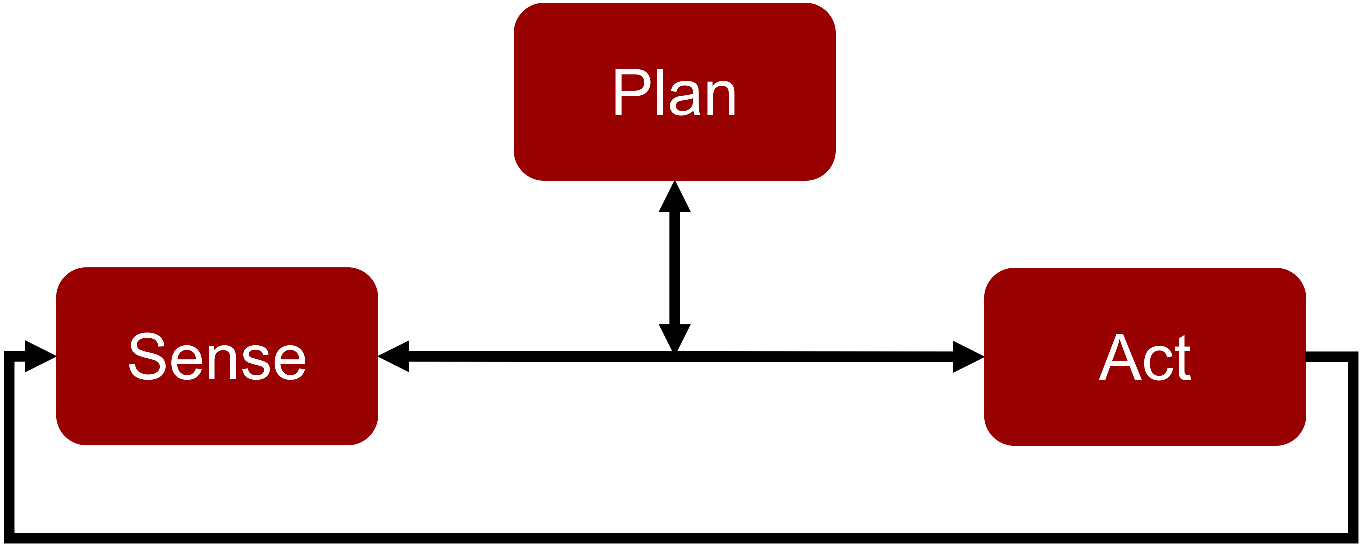
Operation Paradigms / Software Architectures

- Reactive paradigm
  - Biologically inspired like instincts/reflexes
  - No need for world models and model updates
  - Behavior-based robotics (there can be multiple behaviors)



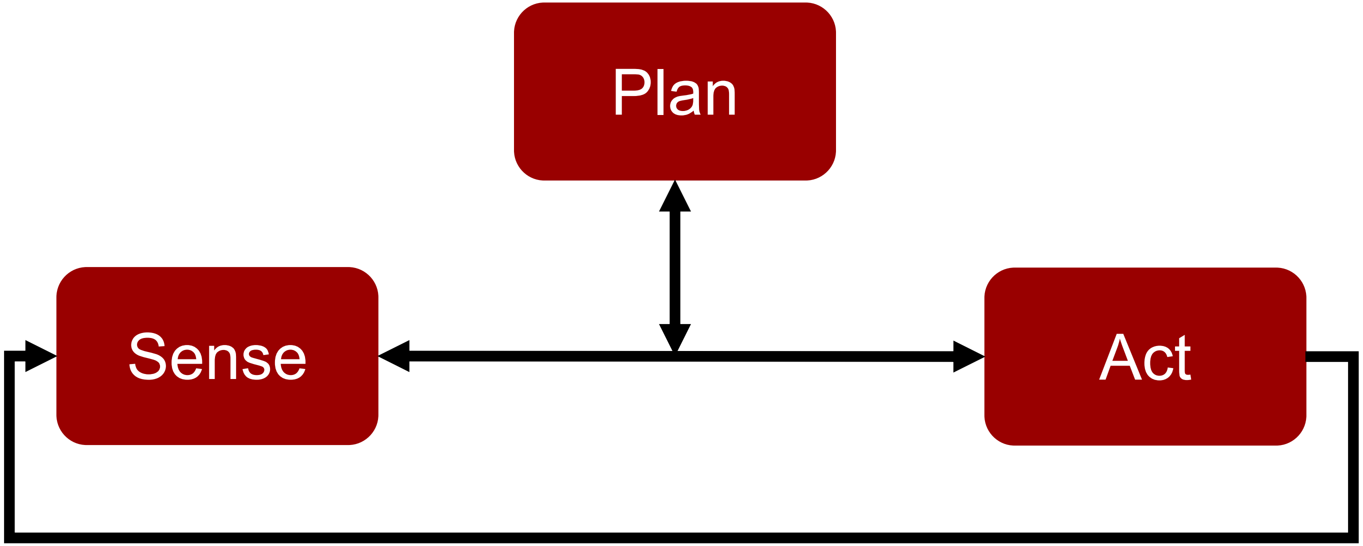
Operation Paradigms / Software Architectures

- Hybrid paradigm / Three Layer Architecture



Operation Paradigms / Software Architectures

- Hybrid paradigm / Three Layer Architecture
  - Best of the 2 first paradigms
    - Planning operates on a long horizon
    - Reactive behaviors act on the short horizon



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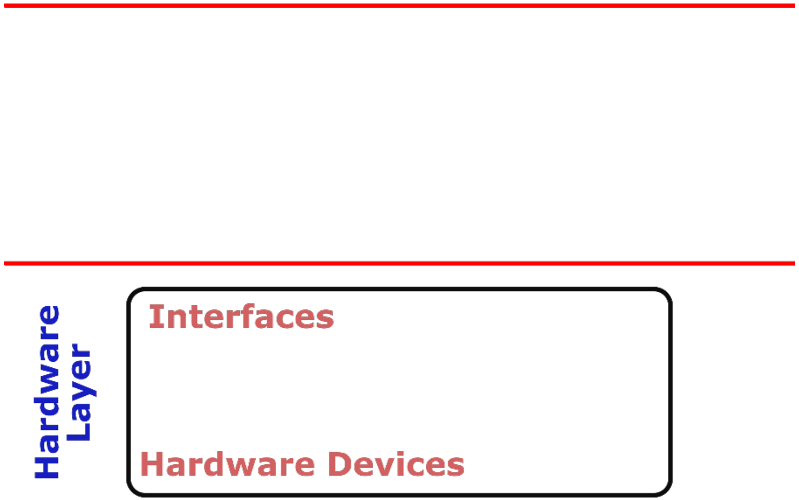
Hardware Abstraction Layer & Middleware

Hardware Abstraction Layers #1

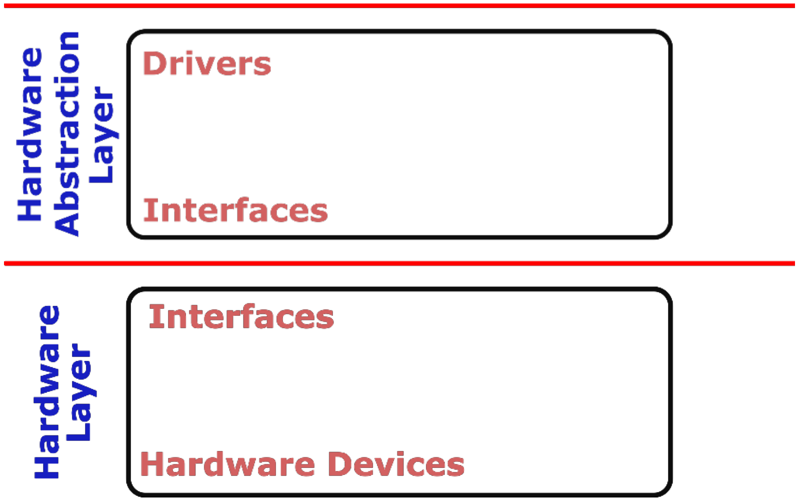


Hardware Layer

Interfaces

Hardware Devices

Hardware Abstraction Layers #1



Hardware Abstraction Layer

Drivers

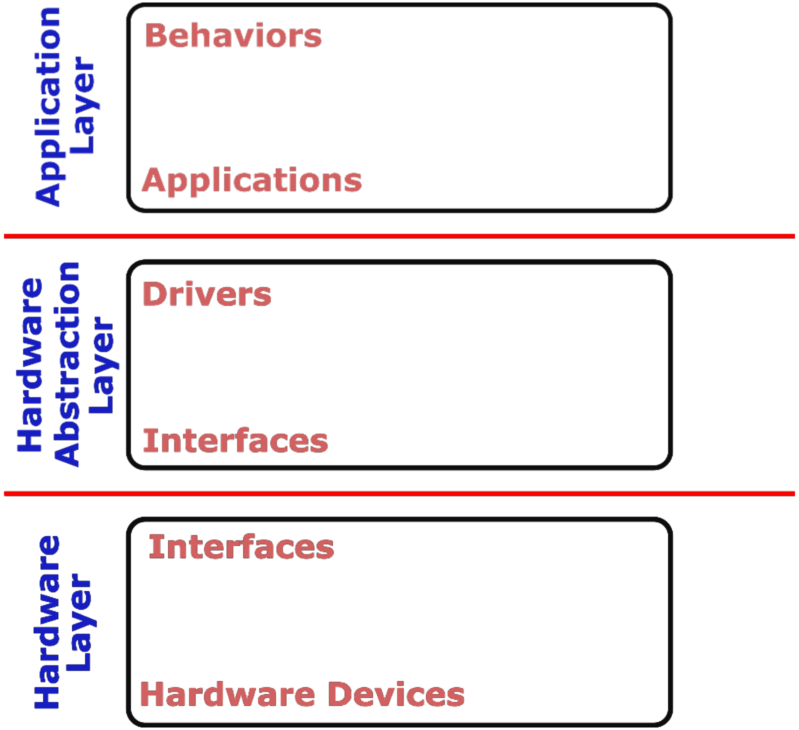
Interfaces

Hardware Layer

Interfaces

Hardware Devices

Hardware Abstraction Layers #1



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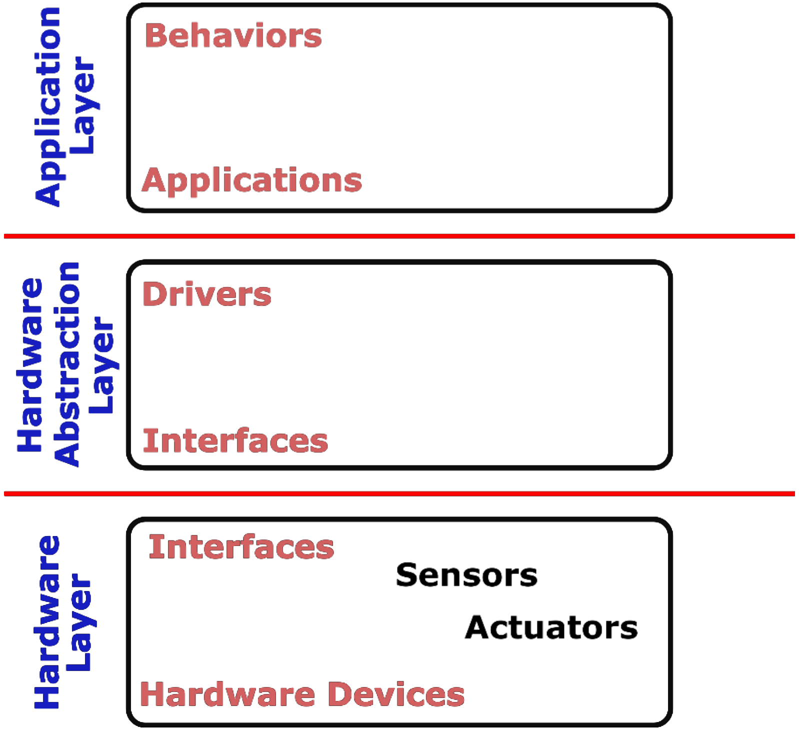

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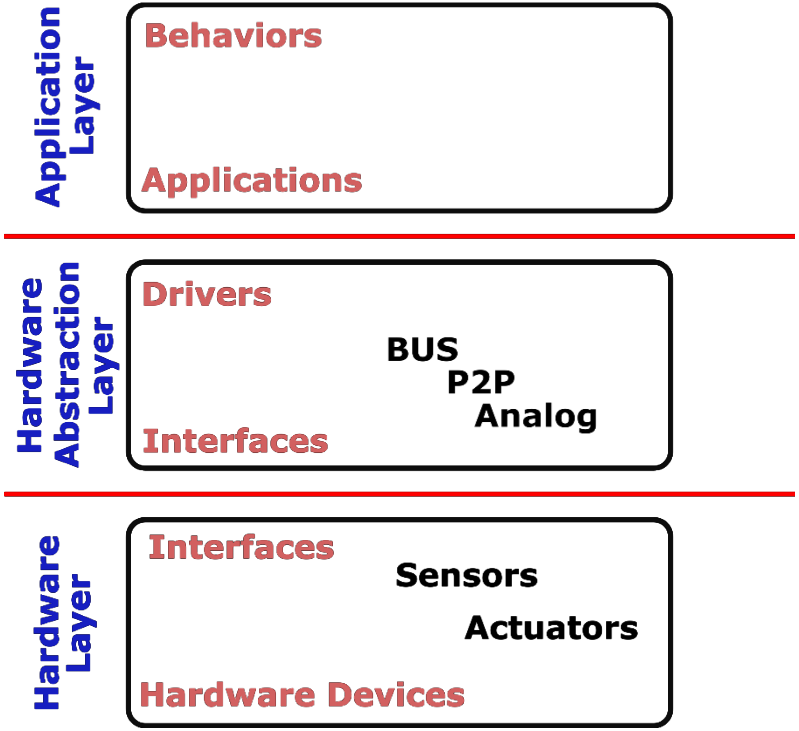


Application Layer

Behaviors

Applications

Hardware Abstraction Layer

Drivers

BUS

P2P

Analog

Interfaces

Hardware Layer

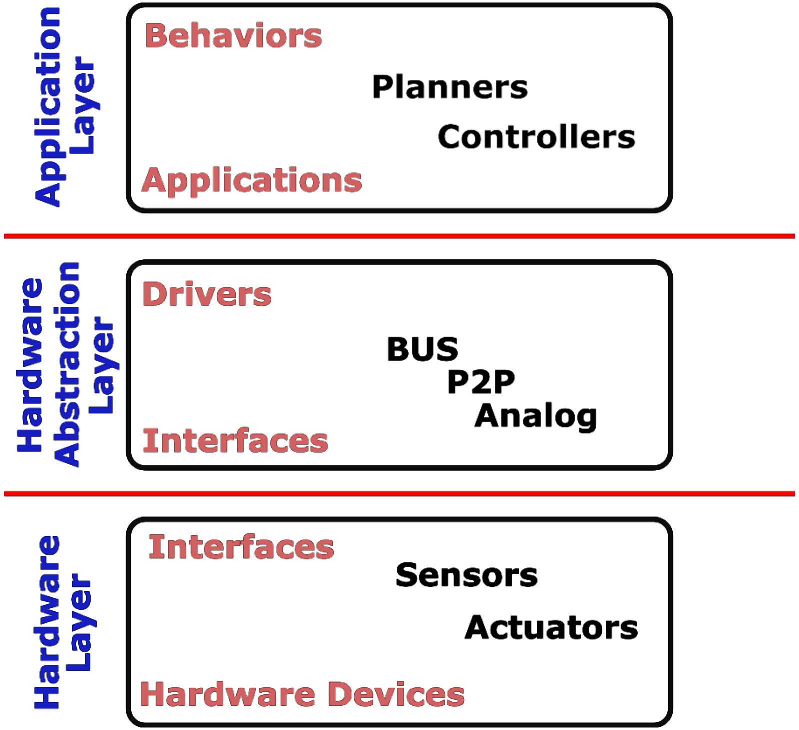
Interfaces

Sensors

Actuators

Hardware Devices

Hardware Abstraction Layers #1



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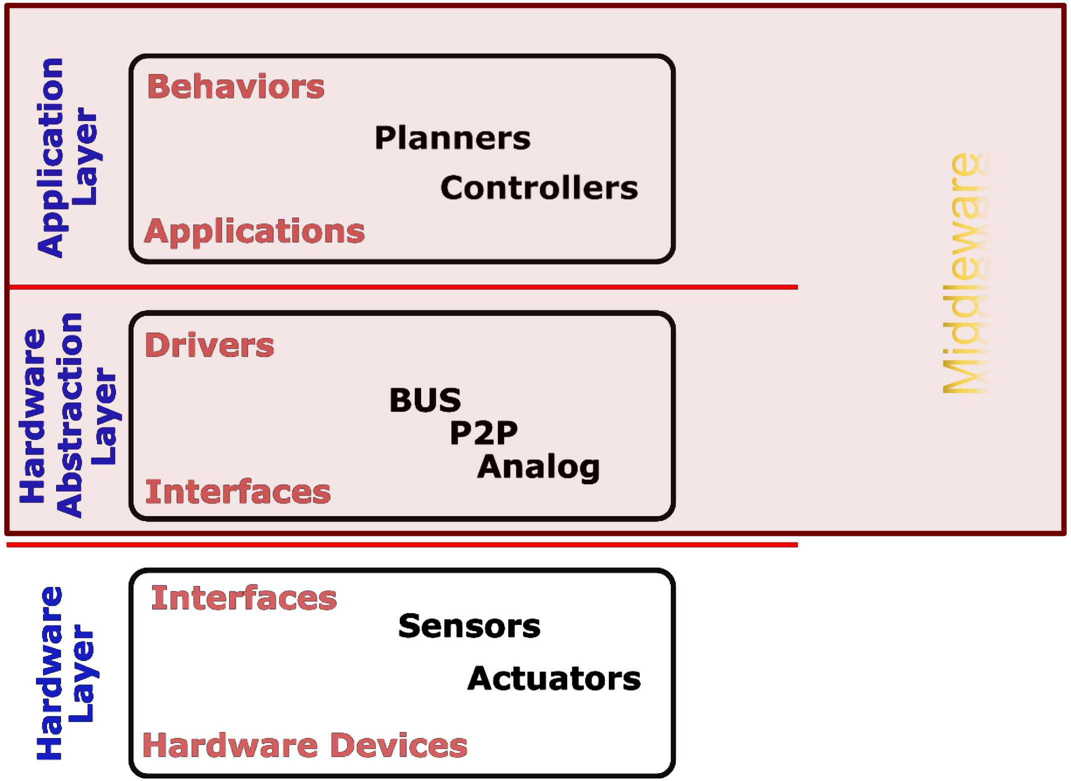

Hardware Abstraction Layers #2

- Let’s add a little detail..

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Hardware

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Hardware
Sensors
Actuators

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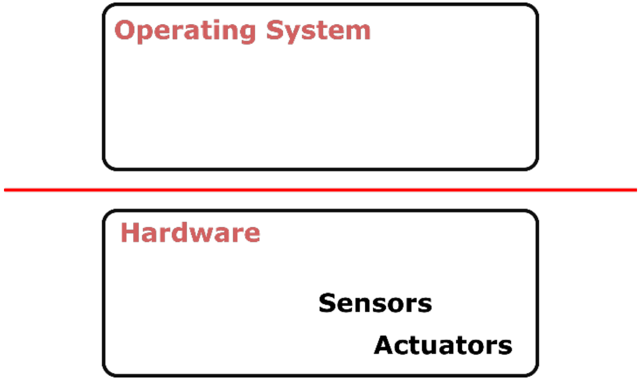

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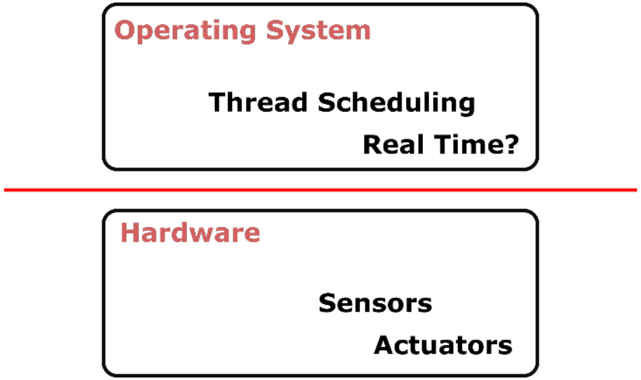

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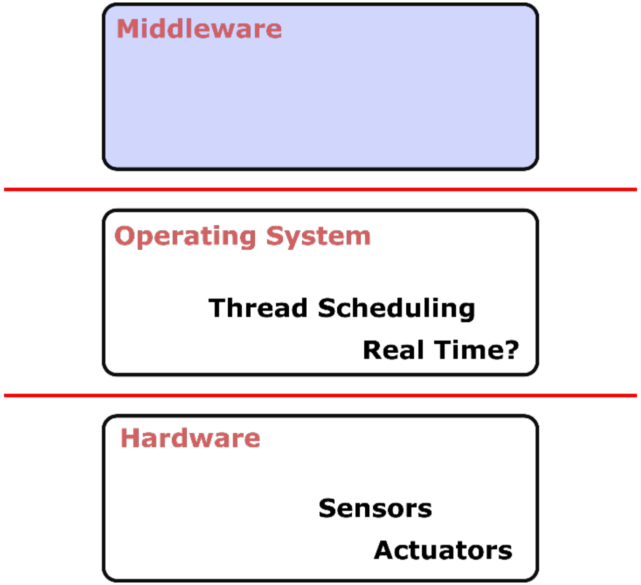

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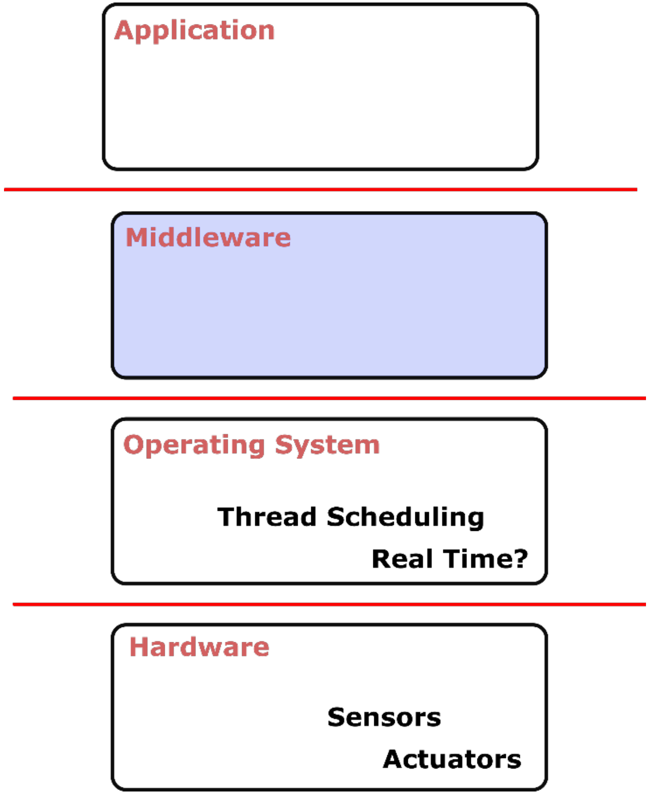

Application

Middleware

Operating System

Thread Scheduling

Real Time?

Hardware

Sensors

Actuators

Hardware Abstraction Layers #2

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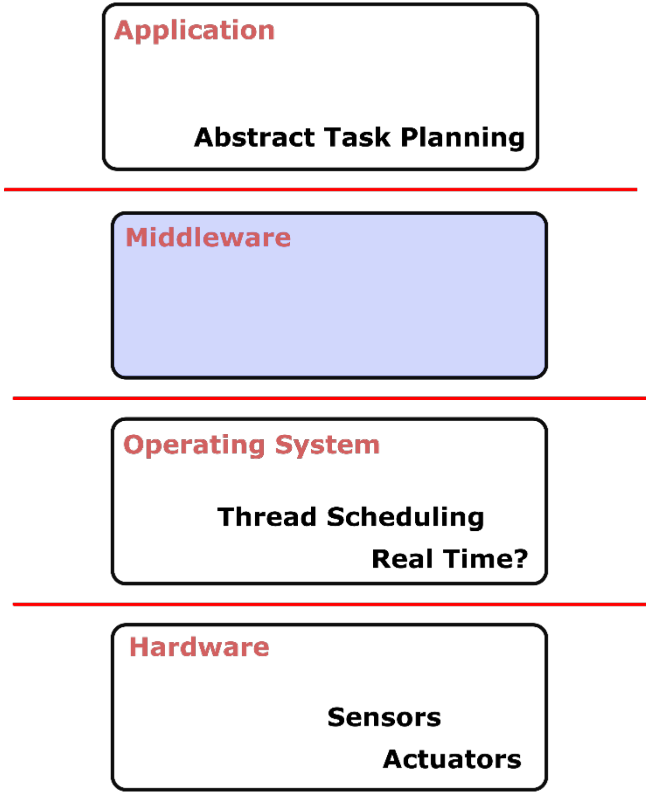

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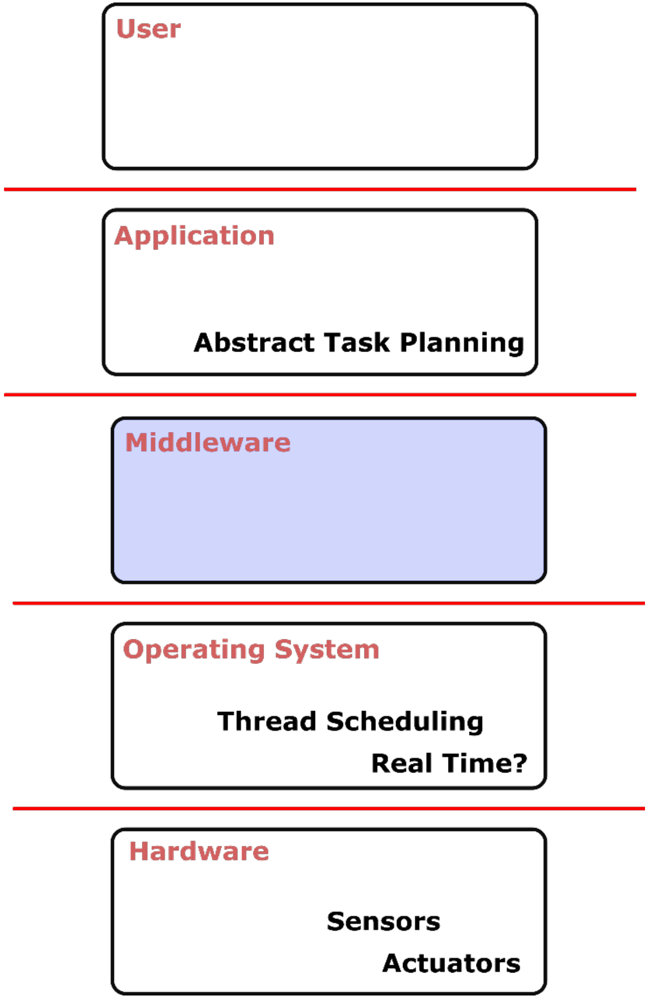

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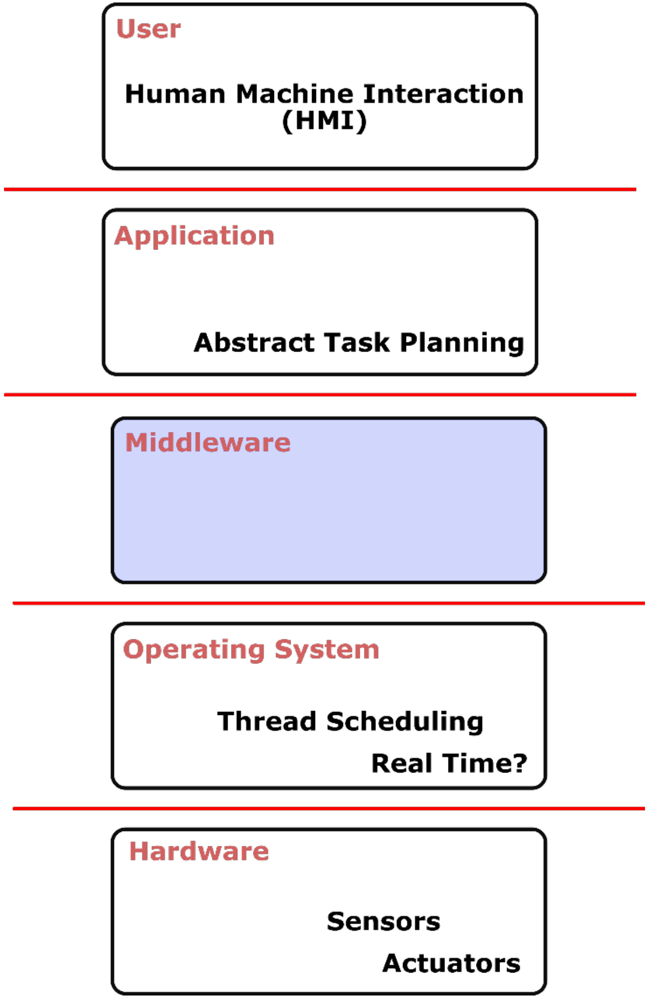


User

Human Machine Interaction (HMI)

Application

Abstract Task Planning

Middleware

Operating System

Thread Scheduling

Real Time?

Hardware

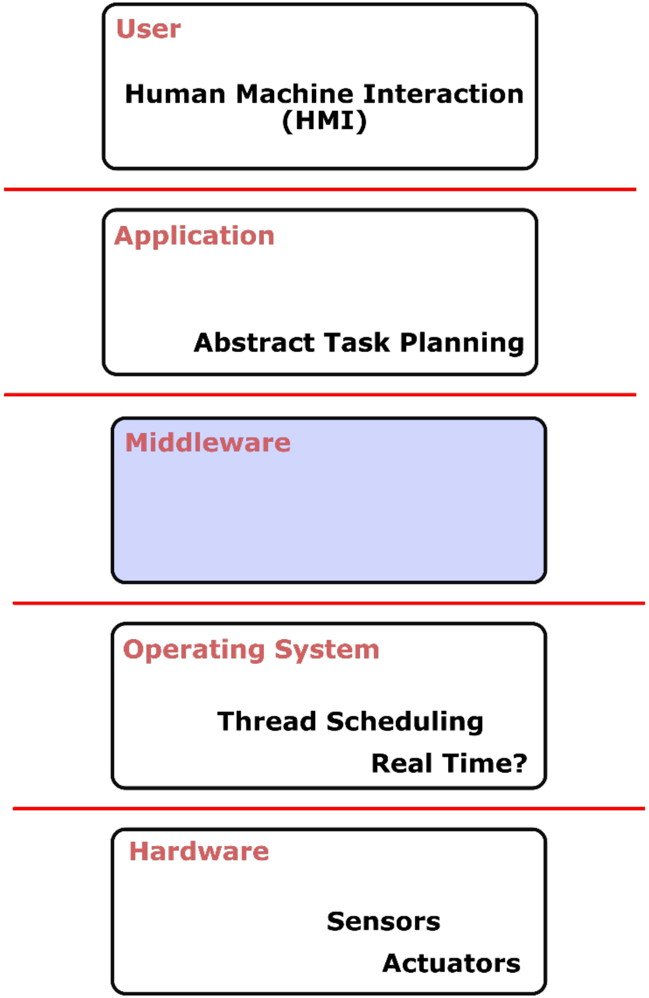
Sensors

Actuators

Hardware Abstraction Layers #2

- Let’s add a little detail..

- A class of technologies in order to handle the complexity of distributed systems



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Towards Software Architecture

- What characteristics should Software for Autonomous Systems have?

Towards Software Architecture

Must have characteristics:

- Support for multiple components
- Communication between components
- Easy way to write own components
- Possibility to replace individual components
- Easy to extend
- Means for data logging and debugging
- Support for decentralized components

Towards Software Architecture

Nice to have characteristics:

- Robustness
- Hardware abstractions
- Open access (ideal case: open source)
- Hardware/OS independent
- Means for time stamping
- Means for visualization
- …

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Introduction to the Course

- – Get your groups done by next week!

Introduction to Software Architectures

- **– Operation Paradigms**
  - – Hierarchical / Reactive / Three Layer Architecture
- **– Hardware Abstraction Layer & Middleware**
  - – ROS lives here!!
- **– Characteristics of Software Architectures / Frameworks**
  - – Make our life easier and simpler

Lazaros Nalpantidis & Evangelos Boukas

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