TAMPERE UNIVERSITY OF TECHNOLOGY

Advanced Robotics Introduction

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IHA-4506 Advanced Robotics

Course setup

- Elective course in 'Factory Automation and Robotics' and 'Robotics and AI' major
- 5 ECTS
- Intensive course, advanced topics
- Lectures, hands-on programming and algorithm development
- No exam
- Lecture room TB220 and K2341D
- Experiments in Robolab (Konetalo lobby)

Course setup

- Students will learn advanced topics in Robotics. We will introduce number of topics in series of lectures every second week. Students are given assignments on each topic. Assignments: algorithm development, programming, experimenting on a real robot. We will use ROS and Franka_ROS for the robotics software environment, Python or C++ for programming and the Franka Panda and MIR robots for experiments. Experience with ROS is highly recommended!
- Covered topics are
  - Robot control and control architectures
  - Visual control and obstacle avoidance
  - Force and compliance control
  - Learning from demonstration

Pre-requisites

- Knowledge on ROS, Python, C++, basics in robotics
- Not used: Matlab or other high-level programming (e.g. Robostudio)

- ASE-1130 Automaati / ASE-1258 Introduction to control
- ASE-9407 Robot Manipulators: Modeling, Control and Programming
- IHA-4206 Mechatronics and Robot Programming
- (IHA-4306 Fundamentals of Mobile Robots)

Lectures

Complementary knowledge

- Resolved rate control and inverse dynamic control
- state estimation, kinematics
- feedback control
- dynamic systems, optimization

Core content

- Robot motion control
- Visual feedback and obstacle avoidance
- Force feedback and compliance control
- Robot control architectures
- Learning from demonstration

Specialized knowledge

- Stability, state feedback, Lyapunov based control design
- vector fields

Industrial Robots

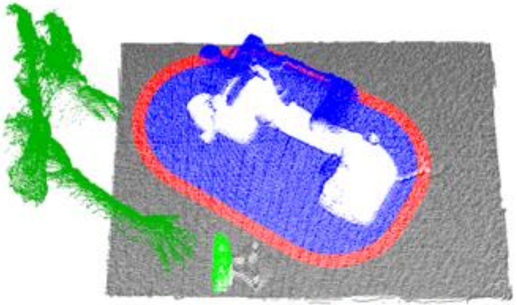
Franka Panda

Structured environment,
no human presence

Trend: Flexible manufacturing, low volume, using Intuitive interfaces, trainable system, compliant robots
- Big data, IoT, I4, web-based services,…

Pre-programmed, deterministic, mass production

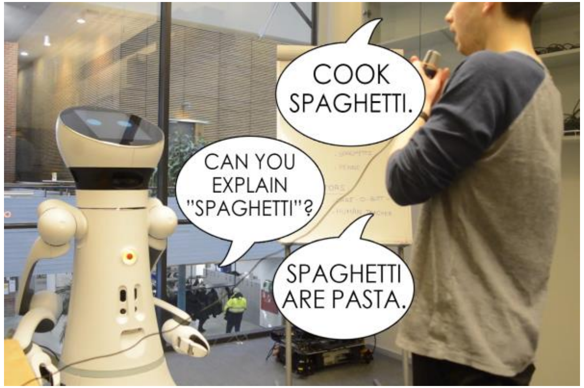
KUKA FlexFellow



Depth-based safety model

Service robots

- Gummi Arm
- Care-O-Bot
- Human-robot interaction
- Domestic environment
- Human-centred design
- Cognitive modelling (attention, behavior, etc)
- Reasoning over knowledge
- Safety



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Field robotics

Robots that work out of factories in all types of environments (land, water, air) and weather

Tele-operation ← → Autonomous

Characteristics:

- Mobile, large operation space - energy autonomy
- Challenging environment - locomotion and communication
- Unstructured, unknown, dynamic environment – localization and mapping
- Human presence - safety, interaction
- Unforeseen events – efficient HMI, AI
- Big robots – logistic and safety
- Lots of SW & HW development

Fields of Field robotics

- Mining robots
- Agriculture robots
- Intelligent vehicles
- Construction robots
- Marine robots
- Aerial robots
- Space robots

What is common

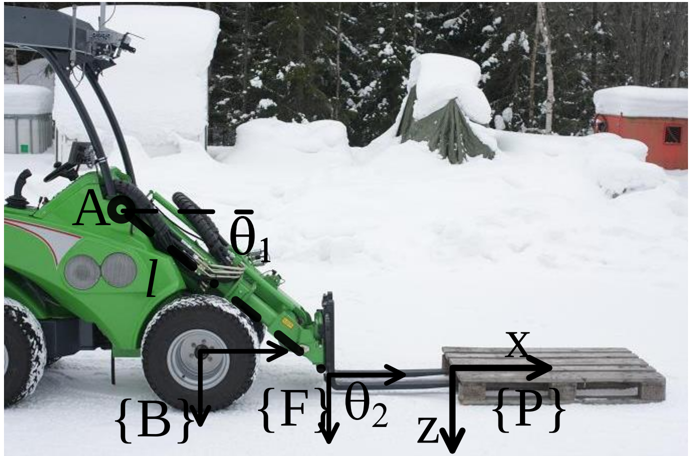
- Robots working alongside human in
  - Industry
  - Home
  - Field

share similar challenges: Need to make decision based on complex sensory input, in dynamic and uncertain environment, hard to program tasks

What problems you need to solve to address this challenge?

<u>Sensing</u>: Position & orientation of fork-frame in pallet frame

<u>Task</u>: given in work space
<u>Work space</u>: pallet-frame



<u>Inverse kinematics</u>:
work space → joint space

<u>Control</u> of each joint (actuator)

Lecture schedule (tentative)

- Mondays (17/9, 1/10, 22/10, 5/11, 19/11, 26/11, 3/12) in TB220
- Wednesdays (5/9, 12/9, 19/9, 26/9, 3/10, 10/10, 24/10, 31/10, 7/11, 14/11, 27/11) in K2341D
- And in Robolab (Konetalo 1st floor)

Lectures: K2341D	Date: Wednesday	Time
Lecture 1: Introduction + exercise 1 explanation (Reza + Roel)	5.9.2018	14:00-16:00
Lecture 2: Exercise 1 questions/evaluation (Roel)	12.9.2018	"
Lecture 3: Robot Control Architectures (Roel) + exercise 2	19.9.2018	"
Lecture 4: Background: Math, PD control, Lyapunov stability, trajectories (Reza)	26.9.2018	"
Lecture 5: Kinematic control + obstacle avoidance (Reza) + exercise 2	3.10.2018	"
Lecture 6: Visual servoing (Roel) + exercise 3	10.10.2018	"
Lecture 7: Force and compliance control (Reza) + exercise 4	24.10.2018	"
Lecture 8: Learning from demonstration (Reza) + exercise 5	31.10.2018	"

Lecture schedule (tentative)

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- And in Robolab (Konetalo 1st floor)

Session: TB220 and Robolab	Date: Monday	Time
Exercise 1 evaluation	17.9.2018	14:00-16:00
Exercise 2 evaluation: Reactive control	1.10.2018	"
Exercise 2 evaluation: Obstacle avoidance	22.10.2018	"
Exercise 3 evaluation: Visual servoing	5.11.2018	"
Exercise 4 evaluation: Force and compliance control	19.11.2018	"
Exercise 5 evaluation: Learning from demonstration	26.11.2018	"
End demo: all exercises combined	3.12.2018	"

Background material

- We’ll present relevant reading material in the lecture slides
- Some advanced robotics books:
  - Robotics: Modelling, Planning and Control, Siciliano
  - Robotics, Vision and Control, Corke
  - Planning Algorithms, LaValle

Practical

Franka Panda

- Group work: 4 people per group max! Make your own group!
- Franka Panda and MIR in Robolab
- Reserve via Outlook (4 hrs per group per day, 10h per week): 'Robolab Franka Panda'
- In Robolab: 1 PC with installed software for Franka Panda
- PC room (TBD)
- Own PC with Ubuntu 16.04 and ROS kinetic is highly recommended!
- Slack: tut-robotics (you'll get an invitation by e-mail)
- Gitlab as software repository: https://gitlab.tut.fi/AUT/Advanced_Robotics

Robolab

- Rules of conduct and safety lecture for Robolab
- Access control: 24/7
- Do not work **alone** outside normal workhours!
- Introduction to Panda will be given at your 1st lab booking: inform us!
- Assistants:
  - Pallab Ganguly (pallab.ganguly@student.tut.fi, Panda)
  - Alex Angleraud (alexandre.angleraud@tut.fi, Panda)
  - Damoon Mohamadi (damoon.mohamadi@student.tut.fi, MIR)
  - Amir Mehmat Sefat (amir.mehmansefat@student.tut.fi, MIR)
  - Andrei Ahonen (andrei.ahonen@tut.fi, Panda + LfD)

Grade (pass min 50%)

- Activity in the class (prof. assessment) 10%
- Activity in reading groups and implementation (peer assessment) 20%
- Demo and Questions (whole class vote/assessment) 60%
- Final open day demo (prof assessment) 10%
- No exam!

Big project

- All exercises combined form the end project that mimics a real application

Project 1: Tree grappling

- Panda + gripper
- Motion planning
- Sensing of 'logs'
- Optimal gripping
- Sequence planning

Project 2: Assembly by demonstration

- Panda + gripper
- Hand-guide motion for assembly
- Plan sequence
- Sense assembly state

Project 3: Mobile manipulation

- Panda + MIR (separately)
- MIR motion + Panda motion
- Fetch object across the room: Panda places object on MIR

Project 4: Force control

- Panda
- Open door or valve
- Write #TUTRobLab on the whiteboard

Questions?

Initial exercise

Franka Panda

- ROS, Robot manipulator motion control
- *Simulation* of Panda with MoveIt!
- ROS node: Joint point-to-point motion
- ROS node: Cartesian point-to-point motion
- ROS node: Obstacle avoidance motion
- Both in Rviz and with Python/C++ node

- See exercise document (will be send via e-mail)
- Questions session: 12.9.2018 @ 2PM in K2341D
- Evaluation: 17.9.2018 @ 2PM in TB220