Humanoid Robots Lab

BA-INF 051 Projektgruppe
MA-INF 4213 Seminar
MA-INF 4214 Lab

Prof. Dr. Maren Bennewitz

Supervisors:
Dr. Marcell Missura, Arindam Roychoudhury, Nils Dengler, Jorge de Heuvel, Tobias Zaenker
# Courses

<table>
<thead>
<tr>
<th></th>
<th>Bachelor PG</th>
<th>Master</th>
<th>Master</th>
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<tbody>
<tr>
<td></td>
<td>Lab + Seminar</td>
<td>Lab</td>
<td>Seminar</td>
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<tr>
<td>ECTS points</td>
<td>6 + 3</td>
<td>9</td>
<td>4</td>
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<tr>
<td>Workload</td>
<td>180 h + 90 h</td>
<td>270 h</td>
<td>120 h</td>
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- **Seminar**: Presentation and discussion of relevant scientific work
- **Lab**: Programming project on robot simulation software and on physical robots
- **Project Group**: Lab (2/3) + Seminar (1/3)
MA-INF 4213 Seminar
Seminar Overview

- **Presentation and discussion** of relevant scientific work (conference/journal papers)
- What is the new contribution of the work? How does the technique work? What are the strengths and the weaknesses of the approach?
- MSc students: **Summary and discussion** of the work (7 pages not counting figures, LaTeX template provided on web page)
Seminar Overview

- **Prepare** during the semester (at home)
  - Understand the paper
  - Write summary (MSc)
  - Prepare your presentation

- **Seminar Day** at the end of the semester
  - Everybody has to present
  - Everybody has to be present
  - It’s a full day event! (depending on the number of participants)
  - Presentations in a video conference (As of now; liable to change)
Seminar Grade

BSc Students:
- Presentation: 100%

MSc Students:
- Presentation: 70%
- Summary and discussion: 30%
Seminar Papers
Predicting Pushing Action Effects on Spatial Object Relation
Paus, Huang, and Asfour,
IEEE Int. Conf. on Robotics and Automation (ICRA), 2020,
Supervisor: Maren Bennewitz

- Goal: Generation of pushing actions to achieve desired state
- Representation as object-centric graph
- Learn internal model to predict object pose changes due to pushing actions
- For a given scene and goal state, generate possible pushing actions by sampling the parameter space
- Evaluate candidates by internal simulation
2. Real-time Optimal Navigation Planning Using Learned Motion Costs

IEEE Int. Conf. on Robotics and Automation (ICRA), 2021, Supervisor: Maren Bennewitz

- Goal real-time autonomous navigation in complex terrain based on elevation maps
- Combination of global path planning with optimization, aware of the robot’s locomotion capabilities
- Neural network-based locomotion cost predictor trained in simulation
- Evaluation on the ANYmal C quadrupedal
Can I lift it? Humanoid robot reasoning about the feasibility of lifting a heavy box with unknown physical properties
Yuanfeng Han, Ruixin Li, and Gregory S. Chirikjian
IROS 2020, Supervisor: Marcell Missura

- Robot reasoning whether it can lift a box
- Weight and joint torque considerations
- Finds a good grip during interaction with the box
PolySLAM: A 2D Polygon-based SLAM Algorithm
Johann Dichtl, Xuan Sang Le, Guillaume Lozenguez, Luc Fabrese, Noury Bouraqadi
ICARSC 2019, Supervisor: Marcell Missura

- Building of a polygonal map and localization within
- Polygons are computed from laser data
Push-Net: Deep Planar Pushing for Objects with Unknown Physical Properties
Jue Kun Li et al.
Robotics, Science and Systems. 2018,
Supervisor: Nils Dengler

- Enable a robot to push objects of unknown physical properties
- Re-orientation and re-positioning, using only visual camera images as input
COCOI: Contact-aware Online Context Inference for Generalizable Non-planar Pushing
Zhuo Xu et al.
IROS 2021, Supervisor: Nils Dengler

- Non planar 3D object pushing
- Consideration of physical properties such as center of mass and pushing force
Learning Human-Aware Robot Navigation from Physical Interaction via Inverse Reinforcement Learning
Kollmitz et al. 2020
IROS 2020, Supervisor: Jorge de Heuvel

- Teach human preferences to the robot
- Learn parameters of navigation cost function through human-robot interaction
- Intuitive feedback mechanism by pushing robot to trajectory
Reinforced Imitation: Sample Efficient Deep Reinforcement Learning for Mapless Navigation by Leveraging Prior Demonstrations
Pfeiffer et al. 2018
IEEE Robotics and Automation Letters Vol. 3, No.4, 2018
Supervisor: Jorge de Heuvel

- LIDAR-based navigation
- Combination of deep reinforcement and imitation learning
- End-to-end architecture (sensor in --> steering out)
Jayaraman and Grauman: Learning to Look Around
Supervisor: Tobias Zaenker

- Given views observed so far: Learn where to look next to obtain most information
- RL agent predicts viewgrid, selects action
- Reward based on predicted viewgrid
Sukkar et al.: Multi-Robot Region-of-Interest Reconstruction
Supervisor: Tobias Zaenker

- Goal: Reconstruct regions of interest (ROIs) in a science with multiple robotic arms
- Viewpoints are evaluated based on multiple criteria, including visibility of ROIs
- Decentralized Monte Carlo tree search used to coordinate actions
Autonomous Indoor Exploration via Polygon Map Construction and Graph-based SLAM Using Directional Endpoint Features

Gao et al.
IEEE Transactions on Automation Science and Engineering, 2018
Supervisor: Arindam Roychoudhury

- 2D laser based autonomous exploration approach for mobile robots
- Graph-based SLAM using directional endpoint features
- Novel polygon map for navigation
- Autonomous exploration through information gain calculation and collision detection
Autonomous vehicle self-localization based on abstract map and multichannel LiDAR in urban area
Javanmardi et al.
Int. Assoc. of Traffic and Safety Sciences, 2019
Supervisor: Arindam Roychoudhury

• Combination of multiple mapping modes:
  • Multilayer 2D vector map.
  • Probabilistic planar surface map.
• Lidar based localization using NDT (Normal Distribution Transforms).
MA-INF 4214 Lab
(also for BA-INF 051 Projektgruppe)
Programming Projects

- Small groups of 2-3 people
- A selection of projects involving perception and action generation for different robots
- Demonstration and written documentation at the end of the semester
- First, work with robot simulation software at home
- Move on to real robots in our lab (covid restrictions apply)
Rules

- **3G**
- **Only one group at a time in the lab (up to 3 people)**
- **Time slots in the lab can be reserved in advance on a time sheet in sciebo (link will be provided)**
- **Sufficient performance in simulation is required to move on to real hardware**

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<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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<tbody>
<tr>
<td>Date</td>
<td>Timeslot</td>
<td>Lab Downstairs</td>
<td>Lab Upstairs</td>
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<tr>
<td>Tuesday, 12. October, 2021</td>
<td>10:00-12:00</td>
<td>Goalie Destroyers</td>
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<td>12:00-14:00</td>
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<td>Kick Machine</td>
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<td>14:00-16:00</td>
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<td>Ballgun</td>
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<td>16:00-18:00</td>
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<td>Wednesday, 13. October, 2021</td>
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<td>16:00-18:00</td>
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Lab Grade

- Individual grade for each group member
- Depends on participation during the semester and the performance of the system in the final demonstration
- Lab documentation is a precondition!
Lab Projects
Soccer

- Score a penalty kick
- Detect goal and ball, walk up to the ball, and kick the ball into the goal
- Defend with the goalie
Turtlebot

- Program a mobile robot to avoid obstacles and to find an object in a labyrinth
Robot Arm

- Program a robot arm to sort objects into a cup
Registration
Next Steps

- Two separate registrations are necessary!

1. Registration on our web site (first-come-first-serve!) until Sunday, 24.10.

2. Topic and group assignment (Hungarian algorithm): Monday 25.10 (notification via e-mail).

3. Registration in BASIS until Sunday, 31.10.
Registration

In order to take part in this course you have to complete two separate registrations:

1. Complete the registration form including the selection of topics at the link below until Friday, October 28 at noon:

   Registration form

2. Register for the exam in BASIS until Monday, October 31.

Only students who completed both registrations will be allowed to take part.

Topics:

- **Soccer:**
  We place a ball in front of a goal. The robot has to detect the goal and the ball with its camera, walk to the ball, and kick it into the goal.
  Focus: image analysis, computer vision, motion planning, navigation

- **Roll the Dice:**
  Implement a dice game that the Nao robot can play against a human, for example “21” (blackjack with dice), “Snakes and Ladders”, “Mensch ärgere dich nicht”, or a similar game. The robot has to roll a large foam dice, read the points on the die, and play the game according to the rules, and interact with the human opponent.
  Focus: image analysis and computer vision, navigation, human-robot interaction

- **Autonomous Life:**
  Implement a comprehensive state machine to simulate autonomous behavior. The Nao robot will respond to different sensory inputs (touch, vision, sound) and interact with a human in a natural and random way. You will implement multiple control loops to allow the robot to navigate autonomously.
  Focus: image analysis, computer vision, motion planning, navigation, human-robot interaction
Registration for Humanoid Robots Lab Course

Questions marked with (*) are mandatory.

Name (*)

E-Mail address (*)

Study program (*)
- M.Sc. Computer Science (Bonn)
- M.Sc. Media Informatics (Aachen)
- Other: (please specify)

Experience (*)
Please tell us whether you are already experienced with the following technologies. Note that these technologies are not requirements for taking the course. Your answers will only be used to prepare the course materials.

<table>
<thead>
<tr>
<th>Technology</th>
<th>No experience</th>
<th>Basic knowledge</th>
<th>Advanced knowledge</th>
<th>Expert</th>
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<tbody>
<tr>
<td>Linux</td>
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<td>C++</td>
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<td>Python</td>
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<td>ROS (Robot Operating System)</td>
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<td>Nao framework (Choregraphe, NaoQi)</td>
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<td>Computer vision (e.g., OpenCV)</td>
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Topics

Please choose four topics and rank them from 1 = highest priority to 4 = lowest priority.

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<thead>
<tr>
<th>#</th>
<th>Topic</th>
<th>Priority (1-4)</th>
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<tbody>
<tr>
<td>1</td>
<td>Generating Legible Motion</td>
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<tr>
<td>2</td>
<td>Considering Avoidance and Consistency in Motion Planning for Human-Robot Manipulation in a Shared Workspace</td>
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<td>3</td>
<td>Omnidirectional Bipedal Walking with Direct Fused Angle Feedback Mechanisms</td>
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<td>4</td>
<td>Trajectory Free Linear Model Predictive Control for Stable Walking in the Presence of Strong Perturbations</td>
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<td>5</td>
<td>Bipedal Walking Control Based on Capture Point Dynamics</td>
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<td>6</td>
<td>Robust Physics-Based Locomotion Using Low-Dimensional Planning</td>
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<td>7</td>
<td>Optimizing Energy Consumption and Preventing Slips at the Footstep Planning Level</td>
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<td>8</td>
<td>Cooperative SLAM-Based Object Transportation by Two Humanoid Robots in a Cluttered Environment</td>
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Apply for Exam in BASIS

Apply for Exams

Please choose the exam from the structure given below. Click on the identifiers.

*Master of Science Computer Science 2007*

- **2000 Konto: Algorithmics**
- **3000 Konto: Graphics, Vision and Audio**
- **4000 Konto: Information and Communication Management**
  - **612103101 Modul MA MA-INF 3101 High Performance Networking**
    - **Prüfung Modul 3101**
      - Date: 08.02.2010, Examiner: Martini, Peter, Date: 01, Room: , Start: [Prüfung anmelden](#)
  - **612103102 Modul MA MA-INF 3102 Information Systems Engineering**
  - **612103201 Modul MA MA-INF 3201 Network Security**
  - **612103202 Modul MA MA-INF 3201 Mobile Communication**
  - **612103203 Modul MA MA-INF 3203 Intelligent Information Systems**
  - **612103204 Modul MA MA-INF 3204 Distributed and Mobile Information System**
## Schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>BSc Project Group</th>
<th>MSc Lab Course</th>
<th>MSc Seminar</th>
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<tbody>
<tr>
<td>Sun Oct 24</td>
<td>Registration deadline and topic assignment</td>
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<tr>
<td>Sun Oct 31</td>
<td>BASIS registration deadline</td>
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<td></td>
<td>Supervised lab course during the whole</td>
<td>Individual supervision</td>
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<td>semester</td>
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<tr>
<td>Mon Jan 24</td>
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<td>• Seminar presentation</td>
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<td>• Deadline for the summary</td>
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<tr>
<td>Tue Jan 25</td>
<td>Seminar presentation</td>
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<tr>
<td>Wed Apr 06</td>
<td>• Lab demonstration</td>
<td>• Lab demonstration</td>
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<td>• Deadline for the lab documentation</td>
<td>• Deadline for the lab</td>
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<td>documentation</td>
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Questions?