Lehrstuhl für Angewandte Mechanik
TUM School of Engineering and Design
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ROBOTUM

Teamprojects

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The results achieved from the projects benefit the progress of the ROBOTUM student initiative. Nevertheless, all students of the ED and CIT schools can apply - there is no preferential treatment for ROBOTUM members.

Depending on the degree program, there are different guidelines for the coursework 'Semesterthesis - Teamproject' or 'Research Practice'

To apply for one of the team projects, please send us a CV, a current transcript of records and a short letter of motivation by **August 31, 2025** to philipp.radecker@tum.de with the subject line 'Application Teamproject ROBOTUM'.

1 Eigenmode aided Energy-efficient locomotion through Reinforcement Learning and Physics-informed Model Identification

In this project, students will develop energy efficient locomotion strategies for legged robots by combining physics informed model identification with reinforcement learning. A working implementation of all core components already exists for the double pendulum system, including learned dynamics, eigenmode discovery, and energy-based policy training. The goal of the project is to extend these methods to full legged locomotion.

Students will begin by learning the dynamics and energy function of a legged robot using differentiable models that incorporate physical structure. Suggested approaches include Lagrangian neural networks and other physics based architectures capable of capturing forward and backward dynamics.

Building on the learned models, students will identify eigenmodes of the system (low energy periodic behaviors) using reinforcement learning. Methods such as central pattern generators, Fourier analysis, or learned phase representations may be used to parameterize these motion patterns.

The eigenmodes will serve as priors for training locomotion policies that adapt to different tasks and terrains while minimizing energy expenditure. The final phase will focus on evaluating generalization and transfer to other robotic systems.

Recommended tools include JAX and Flax for model implementation and training, and Isaac Lab for simulation and control. This project offers a hands-on opportunity to apply structure aware learning, control theory, and energy optimization in the context of legged robotic systems.

2 Design and Implementation of a Time-Critical System for The Hardware Control and Sensing of a Tendon Driven Bipedal Robot

This project involves the design and implementation of a time-critical control and sensing system for a tendon driven bipedal robot. Students will work with an advanced hardware platform including Maxon HEJ 90 and HEJ 70 motors controlled via EtherCAT, an AES-ULTRA96-V2-G board for real-time execution, and a Jetson Nano Super for high-level control and perception.

The AES-ULTRA96-V2-G serves as the real-time computer, combining a general-purpose processor with programmable logic. It will manage time-critical tasks including sensor data acquisition via I2C and low-level motor control. Control loops will be executed using Simulink Real-Time, ensuring deterministic timing and synchronized operation across all joints.

Students will implement safety features such as joint limits, watchdogs, and emergency stop mechanisms. Communication between the Ultra96 and the Jetson will be handled via ROS 2, supporting modular system design and distributed control.

The Jetson Nano Super will handle computationally intensive perception and adaptive control tasks using its onboard GPU. System performance will be evaluated through latency and jitter analysis, closed-loop control tests, and stress tests under locomotion scenarios.

Deliverables include a fully functioning control pipeline, documented hardware-software interfaces, and a ROS 2 interface for extensibility. This project offers deep exposure to real-time systems, sensor fusion, low-level control, and modern robotics infrastructure.

3 Simulation and Reinforcement Learning Control of a Tendon Driven Underactuated Biped in Isaac Sim

This project focuses on the development and validation of a reinforcement learning based locomotion controller for a tendon driven underactuated biped, implemented in the Nvidia Isaac Sim environment. The primary objective is to achieve stable and energy efficient walking and running gaits, leveraging the compliant dynamics of the tendon system.

Students will construct a physically realistic simulation of the robot, modeling the compliant tendon actuation either as chains of rigid bodies or using other appropriate approximations supported by Isaac Sim. The robot model will be implemented as a USD file compatible with Isaac Sim, with integrated sensor models and actuation interfaces.

Using Isaac Lab, students will train a reinforcement learning policy that stabilizes bipedal locomotion while minimizing long-term energy expenditure. Emphasis will be placed on developing reward functions that promote both gait stability and energy efficiency, reflecting the advantages of the underactuated, compliant leg design.

A key part of the project will involve tracking mechanical energy flows within the simulation to validate energy reuse through passive dynamics. Students will perform quantitative analysis comparing energy consumption under different gait regimes and control policies.

Deliverables will include a functional Isaac Sim model of the biped, training results from Isaac Lab, visual demonstrations of the learned gaits, and documented energy calculations. The project offers experience in simulation, reinforcement learning, compliant system modeling, and quantitative analysis of locomotion efficiency.

4 Sim2Real Transfer for Locomotion: From Robust Policy Learning on TRON 1 to Deployment on Forrest

This project addresses the challenge of transferring locomotion policies from simulation to real hardware using the TRON 1 robotic system as the primary validation platform. Building on an existing training pipeline developed in the DODO Lab in collaboration with candidate PhD researcher Vasilije Rakcevic, students will investigate and implement state-of-the-art Sim2Real techniques to bridge the gap between idealized simulation and physical deployment.

The first phase involves a comprehensive review of Sim2Real challenges, including domain shift, sensor and actuator noise, contact model inaccuracies, and overfitting to simulation artifacts. Students will study and apply techniques such as domain randomization, curriculum learning, encoder regularization, adversarial domain adaptation, and hybrid fine-tuning strategies. The goal is to systematically improve the robustness and generalization of learned control policies.

Using TRON 1 hardware, students will develop real-world perturbation profiles and design transfer metrics to quantify trajectory fidelity, control divergence, and task success rates. Ablation studies will evaluate the effectiveness of each technique. Sensor and actuator interfaces will be tested for timing and fidelity to ensure compatibility with the simulation environment.

Once the methods are validated on TRON 1, the final phase will transfer the best-performing pipeline to the Forrest robot platform. Deliverables will include a modular toolkit for Sim2Real training and transfer, full documentation, and robust locomotion policies deployable across both systems. The project offers hands-on experience in modern reinforcement learning, robotic simulation, and real-world control validation.

5 Extending BirdBot: Enabling Active Push-Off in Energy-Efficient Bipedal Leg Mechanisms

This project aims to redesign the BirdBot mechanism to enable active ground push-off while preserving its energy efficient characteristics. The current BirdBot design relies entirely on the release of stored energy in global leg springs for ground contact force generation. While the leg can be pulled by motors, it cannot push against the ground unless the springs are first compressed, limiting control authority and dynamic range during locomotion.

Students will begin by thoroughly analyzing the mechanical principle of the current BirdBot leg, focusing on how energy is stored and released to achieve motion. This includes building simplified dummies or simulations to study timing, passive dynamics, and force transmission. The goal is to understand what makes the mechanism energy efficient and identify where actuation is mechanically decoupled from pushing.

Drawing inspiration from bipedal biological systems such as birds and humans, students will explore mechanical modifications that preserve passive return motion while enabling controlled active push-off. Potential design solutions may involve local spring actuation, controllable compliance, or alternative tendon routing. These concepts will be evaluated using simulations and rapid prototyping, focusing on feasibility, added complexity, and energy cost.

By the end of the project, students will propose and test key modifications to the Forrest robot's leg design that allow it to both pull and push effectively during stance. The result will be a mechanism that expands locomotion capabilities while maintaining the passive efficiency advantages of the original BirdBot design.