**Research Statement (describe your research, interests and future work at IAS in 500 words; do not write a letter)**

* Machine Learning for Robotics (especially Reinforcement Learning, Imitation, and Model Learning)
* Robot Grasping and Manipulation
* Robot Control, Learning for Control
* Robot Table Tennis
* The IAS Lab aims at endowing robots with the ability to learn new tasks and adapt their behavior to their environment. To accomplish this goal, IAS focuses on the intersection between Machine Learning, Robotics and Biomimetic Systems.-->**Biomimetics** or **biomimicry** is the imitation of the models, systems, and elements of nature for the purpose of solving complex [human](http://en.wikipedia.org/wiki/Human) problems.
* Resulting research topics range from algorithm development in machine learning over robot grasping/manipulation and robot table tennis to biomimetic motor control/learning and brain-robot interfaces.
* The goal of bringing advanced motor skills to robotics using techniques from machine learning and control.

# Research Overview

* Creating robots that can learn to accomplish many different tasks triggered by environmental context or higher-level instruction.

### Motor Skill Learning : three layers of abstraction

* Learning to Execute:
  + An essential problem in robotics is the accurate execution of desired movements using only low-gain controls such that the robot will accomplish the desired task while not harming human beings in its environment.
  + Following a trajectory with little feedback requires the accurate prediction of the needed torques, which cannot be achieved using classical methods for sufficiently complex robots.
  + However, learning such models is hard as the joint-space can never be fully explored and the learning algorithm has to cope with a never-ending data stream in real time.
  + We have developed learning methods both for accomplishing tasks represented in [operational space](http://www.ausy.tu-darmstadt.de/Research/LearningOperationalSpaceControl) as well as in [joint-space](http://www.ausy.tu-darmstadt.de/Research/LearningModelsForControl).
  + OPERATIONAL SPACE - Learning Operational Space Control (OSC)
    - Its potential for dynamically consistent control, compliant control, force control, and hierarchical control has not been exhausted to date.
    - Applications of OSC range from end-effector control of manipulators up to balancing and gait execution for humanoid robots
    - the practical use of operational space control becomes in-creasingly difficult in the presence of unmodeled nonlinearities, leading to reduced accuracy or even unpredictable and unstable null-space behavior in the robot system.
    - Learning methods do not easily provide the highly structured knowledge required in traditional operational space control laws, e.g., Jacobians, inertia matrices, and Coriolis/centripetal and gravity forces, since all these terms are not always instantly observable. They are therefore not suitable for formulating supervised learning as traditionally used in learning control approaches.
    - we have designed novel approaches to learning operational space control that avoid extracting such structured knowledge and rather aim at learning the operational space control law directly, i.e., we pose OSC as a direct inverse model learning problem.
    - A first important insight for this project is that a physically correct solution to the inverse problem with redundant degrees-of-freedom does exist when learning of the inverse map is performed in a suitable piecewise linear way.
    - The second crucial component for our work is based on the insight that many operational space controllers can be understood in terms of a constrained optimal control problem.
    - The cost function associated with this optimal control problem allows us to formulate a learning algorithm that automatically synthesizes a globally consistent desired resolution of redundancy while learning the operational space controller. From the machine learning point of view, this learning problem corresponds to a reinforcement learning problem that maximizes an immediate reward. We employ an expectation-maximization policy search algorithm in order to solve this problem.
  + JOINT-SPACE - Learning Models for Control
    - Bringing anthropomorphic robots into human daily life requires backdrivable robots with compliant control in order to ensure the safe interaction with human beings. controllers allow the robot to automatically adapt its shape to changes in its environment. To achieve accurate but compliant tracking, it is essential to predict the torques required for the current movement accurately.
    - It is well-known that for sufficiently complex robots (e.g., humanoids, service robots), the standard rigid body dynamics (RBD) models no longer describe the dynamics properly, and data-driven approximate methods become a promising alternative.
    - Machine learning techniques has a multitude of advantages ranging from higher precision torque prediction to adaptation to altered dynamics with online learning.
    - Online learning of robot dynamics poses a tremendous technical challenge as the learning method has to deal with an endless stream of data while learning needs to take place in real-time.
    - While modern machine learning approaches such as Gaussian process regression and support vector regression, yield significantly higher accuracy than traditional RBD models, their computational requirements can become prohibitively costly as they grow with number of data points.
    - One possibility for reducing the computational cost is the partitioning of the data such that only the regionally interesting data is included in a local regression and, subsequently, combining these local predictions into a joint prediction.
    - Another possibility is to employ sparsification methods in combination with an incremental model learning approach [5]. The main idea is to find a sparse representation of the data - called dictionary - which can be used for model learning.
* Learning new Elementary Tasks:
* Learning to Compose Complex Tasks:

**OTHERS**

* IAS members maintain a presence at the Max Planck Institute for Intelligent Systems in Tuebingen and there will always be opportunities there as well.
* Computational Learning for Autonomous Systems (CLAS) and Intelligent Autonomous Systems (IAS)