Machine Learning (summer)
I. Basic regression & classification (linear regression, regularization, CV, conditional random fields & structured output)
II. The breadth of ML ideas (boosting, loss functions, learning embeddings, deep learning, active learning, etc)
III. Bayesian Modeling and Learning (Bayesian regression & classification, GPs, graphical models, inference, EM)

Robotics (winter)
I. Kinematics & Dynamics (inv. Kinematics, operational space control, Euler-Lagrange eqns., PID control)
II. Planning & Optimization (path planning, PRM, RRT, trajectory optimization)
III. Control Theory (optimal control, HJB eqns., LQG, Riccati eqns., controllability, stability, Lyapunov)
IV. Mobile Robotics (state estimation, Bayesian filtering, particles, Kalman, SLAM)

Optimization (summer)
I. Basics (gradient & 2nd order methods, convergence, monotonicity, line search)
II. Constrained Optimization (KKT conditions, penalties, log barrier, aug. Lagrangian, primal-dual, LP/OP simplex, discrete optimization)
III. Global & Black-box Optimization (Bayesian formulation, UCB-GP, MCMC, stochastic search)

Autonomous Systems (winter)
I. Advanced AI topics (Decision Theory, decision theoretic models (Bandits, (P)OMDP, multi-agent), solvers (UCB, MCTS, dynamic programming, reductions (CSP, inference, LP/QP)))
II. Research Methodologies (Statistical Testing, Probability basics)
III. Meta-Problems (decision theoretic methods within learning, reasoning & optimization algorithms)

Contents

1 Modules
  1.1 Machine Learning (Modul 29470, 051200112) ................................................................. 2
  1.2 Robotics I (Modul 48600, 051200999) .............................................................................. 2
  1.3 Optimization (Modul 40680, 051200113) ........................................................................ 3
  1.4 Theoretical and Methodological Foundations of Autonomous Systems (Modul 48640, 051200987) 4
  1.5 Robotics II (Modul 48610, 051200888) ............................................................................ 4
  1.6 Reinforcement Learning (Modul 48580, 051200888) ....................................................... 5
  1.7 Vertiefungslinie Intelligent Systems (Modul 29340, 051901555) ................................. 6
1 Modules

1.1 Machine Learning (Modul 29470, 051200112)

Univ.-Prof.Dr. Marc Toussaint

1.1.1 Empfohlene Voraussetzungen

Solid knowledge in Linear Algebra, probability theory and optimization. Fluency in at least one programming language.

1.1.2 Lernziele

Students will acquire an in depth understanding of Machine Learning methods. The concepts and formalisms of Machine Learning are understood as generic approach to a variety of disciplines, including image processing, robotics, computational linguistics and software engineering. This course will enable students to formalize problems from such disciplines in terms of probabilistic models and the derive respective learning and inference algorithms.

1.1.3 Inhalt

Exploiting large-scale data is a central challenge of our time. Machine Learning is the core discipline to address this challenge, aiming to extract useful models and structure from data. Studying Machine Learning is motivated in multiple ways: 1) as the basis of commercial data mining (Google, Amazon, Picasa, etc), 2) a core methodological tool for data analysis in all sciences (vision, linguistics, software engineering, but also biology, physics, neuroscience, etc) and finally, 3) as a core foundation of autonomous intelligent systems (which is my personal motivation for research in Machine Learning).

This lecture introduces to modern methods in Machine Learning, including discriminative as well as probabilistic generative models. A preliminary outline of topics is:

- motivation and history
- probabilistic modeling and inference
- regression and classification methods (kernel methods, Gaussian Processes, Bayesian kernel logistic regression, relations)
- discriminative learning (logistic regression, Conditional Random Fields)
- feature selection
- boosting and ensemble learning
- representation learning and embedding (kernel PCA and derivatives, deep learning)
- graphical models
- inference in graphical models (MCMC, message passing, variational)
- learning in graphical models
- structure learning and model selection
- relational learning

Please also refer to the course web page: http://ipvs.informatik.unistuttgart.de/mlr/marc/teaching/13-MachineLearning/

1.1.4 Literatur

- Pattern Recognition and Machine Learning by Bishop, C. M.. Springer 2006. online: http://research.microsoft.com/en-us/um/people/cmbishop (especially chapter 8, which is fully online)

1.2 Robotics I (Modul 48600, 051200999)

Univ.-Prof.Dr. Marc Toussaint
1.2.1 Empfohlene Voraussetzungen

Solid knowledge in linear algebra, probability theory and optimization. Fluency in at least one programming language.

1.2.2 Lernziele

Students will acquire the basic methodologies to model, control and navigate robots, including trajectory planning, control of dynamic systems and object manipulation.

1.2.3 Inhalt

The lecture will give an introduction to robotics, focusing on essential theoretical foundations of planning and controlling motion, state estimation and eventually object manipulation. Exercises in simulations and on a real robot are a core element of this lecture to gain practical experience.

– motivation and history
– (inverse) kinematics
– path finding and trajectory optimization
– (non-)holonomic systems
– mobile robots
– sensor processing (vision, range sensors)
– simulation of robots and environments
– object grasping and manipulation

1.2.4 Literatur

1.3 Optimization (Modul 40680, 051200113)

Univ.-Prof. Dr. Marc Toussaint

1.3.1 Empfohlene Voraussetzungen

Solid basic knowledge in linear algebra and analysis. Basic programming skills.

1.3.2 Lernziele

Students will learn to identify, mathematically formalize, and derive algorithmic solutions to optimization problems as they occur in nearly all disciplines, e.g. Machine Learning, Combinatorial Optimization, Computer Vision, Robotics, Simulation. The focus will be on continuous optimization problems (including as they arise from relaxations of discrete problems), including convex problems, quadratic linear programming, but also non-linear black-box problems. The goal is to give an overview of the various approaches and mathematical formulations and practical experience with the basic paradigms.

1.3.3 Inhalt

Optimization is one of the most fundamental tools of modern sciences. Many phenomena – be it in computer science, artificial intelligence, logistics, physics, finance, or even psychology and neuroscience – are typically described in terms of optimality principles. The reason is that it is often easier to describe or design an optimality principle or cost function rather than the system itself. However, if systems are described in terms of optimality principles, the computational problem of optimization becomes central to all these sciences. This lecture aims give an overview and introduction to various approaches to optimization together with practical experience in the exercises. The focus will be on continuous optimization problems and we will cover methods ranging from standard convex optimization and gradient methods to non-linear black box problems (evolutionary algorithms) and optimal global optimization. Students will learn to identify, mathematically formalize, and derive algorithmic solutions to optimization problems as they occur in nearly all disciplines. A preliminary list of topics is:

– gradient methods, log-barrier, conjugate gradients, Rprop
Please also refer to the course web page: http://ipvs.informatik.unistuttgart.de/mlr/marc/teaching/13-Optimization/

1.3.4 Literatur

1.4 Theoretical and Methodological Foundations of Autonomous Systems (Modul 48640, 051200987)

Univ.-Prof. Dr. Marc Toussaint

1.4.1 Empfohlene Voraussetzungen

Solid knowledge in linear algebra, probability theory and optimization. Fluency in at least one programming language.

1.4.2 Lernziele

Students will acquire a conceptual overview of the challenges and research in intelligent autonomous systems. The course will emphasize the necessity of combining theory with integrated systems, namely the theoretical and computational foundations modeling and solving decision and behavioral problems and the integration in real-world autonomous systems that integrate perception, action and (on-board) computation. The course reflects the conceptual structure of the Major in Autonomous Systems by addressing the methodological foundations of (i) Computational Intelligence and Learning, (ii) Perception and Action, and (iii) System Integration.

1.4.3 Inhalt

This course discusses the challenges and research in intelligent autonomous systems. It introduces to the basic foundations in the relevant disciplines to enable a holistic view on autonomous systems. This is done using a coherent formalization for concepts which are usually introduced separately.

- motivation and history
- challenges in autonomous systems
- frameworks for modeling decision and behavioral problems
- computational methods for solving such problems: planning, decision making
- system integration
- classical Artificial Intelligence and modern probabilistic AI
- perception and image processing
- learning from data (basic regression and classification)
- learning applied in autonomous systems (Reinforcement Learning, adaptive control, system identification)

1.4.4 Literatur

1.5 Robotics II (Modul 48610, 051200888)

Dr. Vien Ngo

1.5.1 Empfohlene Voraussetzungen

Course Robotics I
1.5.2 Lernziele

Students will acquire in-depth knowledge of advanced theoretical topics in robotics as well as the state-of-the-art in autonomous robotics, in particular object manipulation, application of Machine Learning in robotics and control theory on modern (compliant) actuators.

1.5.3 Inhalt

This course combines the foundations of Reinforcement Learning with robotics and control theory and explores in depth advanced topics at the state-of-the-art in autonomous robotics. The course will focus on core topics such as analytical dynamics, stochastic control theory, and machine learning approaches to data-driven robotics. At the end of the course you will be equipped to read and understand relevant research papers to develop beyond this material on your own.

Topics:
- Analytical dynamics (Lagrange, Hamilton, Gauss formulations; contact analysis)
- Stochastic optimal control (focus on nonlinear systems)
- Inverse optimal control (maximum margin and maximum entropy)
- Imitation learning (inverse reinforcement learning)
- Policy search (model based and model free)
- Model learning (forward and inverse models)

1.5.4 Literatur

1.6 Reinforcement Learning (Modul 48580, 051200888 )

Dr. Vien Ngo

1.6.1 Empfohlene Voraussetzungen

Solid knowledge in linear algebra, probability theory and optimization. Rough knowledge of Artificial Intelligence. Fluency in at least one programming language.

1.6.2 Lernziele

Students will acquire a deep understanding of Reinforcement Learning methods. Reinforcement Learning addresses the problem of learning optimal behavior (strongly related to optimal control) from data. This course will enable students to apply Reinforcement Learning algorithms in simulated domains and real robotic systems.

1.6.3 Inhalt

Reinforcement Learning considers how an agent, interacting with a world, can improve or learn optimal behavior based on own experience or teacher demonstration. This branch of Artificial Intelligence and Machine Learning has become increasingly important as a foundation of robust intelligent systems and robotics. Optimal exploration (behavior that optimizes the agent's information gain) is a particularly interesting aspect of Reinforcement Learning. This lecture will introduce to the theory of Reinforcement Learning and then discuss state-of-the-art algorithms in this area. motivation and historyMarkov Decision Processes and Bellman's optimality principle relations to stochastic optimal control theory basic model-free RL methods (TD-Learning, Q-learning, etc) model-based RL methods theory of optimal exploration (Bayesian RL, R-max) relational RL inverse RL, learning from demonstration and instruction information theoretic formulations of RL modern policy search methods (and applications in robotics)

1.6.4 Literatur

- (Main background) R. Sutton and A. Barto, Reinforcement Learning, 1998. This book is freely available online.
- (For robotics application) S. Thrun, W. Burgard, D. Fox, Probabilistic Robotics, 2006.
1.7 Vertiefungslinie Intelligent Systems (Modul 29340, 051901555)

Univ.-Prof. Dr.-Ing. Andrs Bruhn
Univ.-Prof. Dr. Marc Toussaint

1.7.1 Empfohlene Voraussetzungen

Grundlegende Kenntnisse in Mathematik und Bildverarbeitung (z.B. Mathematik für Informatiker und Softwaretechniker 080300100, Imaging Science 051900210)

1.7.2 Lernziele


The students have acquired specialised knowledge in the areas of computer vision, machine learning and robotics, and they are capable of understanding scientific papers and books from this field. They have the necessary knowledge to begin a Master's thesis in one of the aforementioned areas.

1.7.3 Inhalt

Es werden Vorlesungen bzw. Vorlesungen mit Übungen im Bereich Intelligente Systeme im Umfang von 8 SWS besucht, die im MINFKatalog (MINF 1-8) den entsprechenden Verwendungshinweis tragen und dort inhaltlich beschrieben werden. In dem Vertiefungsmodul Intelligente Systeme gehören hierzu die Veranstaltungen:

(i) 051900215 Computer Vision (Vorlesung mit Übungen, 4 SWS)
(ii) 051900211 Correspondence Problems in Computer Vision (Vorlesung mit Übungen, 4 SWS)
(iii) 051900205 Grundlagen der künstlichen Intelligenz (Vorlesung mit Übungen, 4 SWS)
(iv) 051200112 Maschine Learning (Vorlesung mit Übungen, 4 SWS)
(v) 051200113 Optimization (Vorlesung mit Übungen, 4 SWS)
(vi) 051200888 Reinforcement Learning (Vorlesung mit Übungen, 4 SWS)
(vii) 051200999 Robotics I: Introduction (Vorlesung mit Übungen, 4 SWS)
(viii) N/A Advanced Robotics (Vorlesung mit Übungen, 4 SWS)

Students have to attend lectures with and without exercises in the field of Intelligent Systems with a total of 8 SWS. These lectures have to be eligible from the MINF-catalogue (MINF 1-8) where their content is described. The lectures in the specialised module Intelligent Systems include:

(i) 051900215 Computer Vision (lecture with exercises, 4 SWS)
(ii) 051900211 Correspondence Problems in Computer Vision (lecture with exercises, 4 SWS)
(iii) 051900205 Grundlagen der künstlichen Intelligenz (lecture with exercises, 4 SWS)
(iv) 051200112 Maschine Learning (lecture with exercises, 4 SWS)
(v) 051200113 Optimization (lecture with exercises, 4 SWS)
(vi) 051200888 Reinforcement Learning (lecture with exercises, 4 SWS)
(vii) 051200999 Robotics I: Introduction (lecture with exercises, 4 SWS)
(viii) N/A Advanced Robotics (lecture with exercises, 4 SWS)
1.7.4 Literatur