Machine Learning B: Material for Exam

This document contains an overview of relevant topics for the MLB exam. The exam will include multiple-choice questions and questions that require a written explanation. You do not have to reproduce proofs, but you should understand the consequences of theorems and be familiar with the basic mathematical notations. It is also not necessary to memorize implementation details of algorithms, but you should be able to give a high-level description of important algorithms (e.g. Q-learning, SARSA, general genetic algorithms,...). Details from applications will not be asked, but you should know possible applications for the discussed algorithms.

1 Reinforcement Learning

1.1 Theory
- The reinforcement learning model
- Markov property and Markov decision processes
- Value and Q-functions
- Bellman equations and optimality
- Policy improvement
- Existence and uniqueness of optimal solutions

1.2 Dynamic Programming
- Policy evaluation, policy improvement and relation to theory
- Policy Iteration
- Value Iteration
- Pros and Cons

1.3 Monte-Carlo Methods
- Monte Carlo policy evaluation
- On-policy MC control
- Exploration / Exploitation
- Pros and Cons

1.4 Temporal Difference Learning
- Temporal difference updates
- Relation to DP and MC
- SARSA
- Q-learning
- On- vs. Off-policy learning
- Pros and Cons
1.5 Eligibility Traces
- Definition of eligibility traces (replacing vs. accumulating traces)
- Forward-view of TD(λ)
- Backward-view of TD(λ)
- Relation to TD(0) and MC methods
- SARSA(λ)
- (Watkins) Q(λ) and special treatment of exploratory actions
- Pros and Cons

1.6 Function Approximation
- Generalization
- Online RL with function approximation
- Linear methods (tile coding, RBFs)
- Nonlinear methods (neural networks)
- Risks of gradient descent learning
- Convergence guarantees of online RL with function approximation
- Self-play learning
- Pros and Cons

1.7 Policy Gradient Methods
- What is a policy gradient?
- Comparison to value-learning
- Advantage over value learning (local improvements, continuous environments)
- Limitations (local maxima, number of required samples)
- Basic idea of PEGASUS

1.8 Biological RL
- Conditioning and blocking paradigm
- Basal ganglia as the brain’s center for RL
- Correspondence of dopamine and TD error
2 Genetic Algorithms

2.1 Basics
- Basic evolutionary algorithm
- Selection schemes (roulette, rank-based, tournament) and their properties
- Reproduction operators (mutation, cross-over) for binary, real-valued and permutation genomes
- Strengths and weaknesses of GAs
- Comparison between RL and GAs

2.2 Theory
- What is a schema?
- Main message of the schema theorem

2.3 Applications
- Evolution of neural networks
- Fitness calculation for behavior learning
- Evolutionary robotics
  - Problems of evolution on physical robots
  - Problems of evolution in simulations