

Qiuzhen PhD Qualification Exam Syllabus (Artificial Intelligence)

Machine Learning Theory

1. Supervised Learning and PAC Learning Theory
2. VC dimension, Sauer's Lemma, and the Fundamental Theorem of Statistical Learning Theory (relationship between sample complexity and VC dimension)
3. Model selection and Bias-Variance Trade-off
4. Linear regression and logistic regression models
5. Decision tree models
6. k -Nearest Neighbors algorithm
7. Support Vector Machines (SVM) and Kernel methods
8. Compressed sensing

Reference Books:

1. *Understanding Machine Learning: From Theory to Algorithms* by Shai Shalev-Schwartz and Shai Ben-David
2. *Foundations of Machine Learning* by Mehryar Mohri, Afshin Rostamizadeh, and Ameet Talwalkar

Deep Learning and Reinforcement Learning

1. Fundamentals of Deep Learning: Neural network architectures, training methods, approximation and generalization analysis.
2. Vision Tasks: Feature extraction, image restoration, 3D reconstruction, optical flow estimation, recognition and segmentation.
3. Unsupervised Learning: Autoencoders, contrastive learning, implicit regularization in networks, transfer learning, and meta-learning.
4. Visual Generative Models: Generative Adversarial Networks (GANs), variational autoencoders (VAEs), diffusion models, flow based models, expressiveness analysis.
5. Reinforcement Learning: Bellman equation, Q-learning, policy gradient methods

Reference Books:

1. *Bengio, Yoshua, Ian Goodfellow, and Aaron Courville. Deep learning. Vol. 1. Cambridge, MA, USA: MIT press, 2017.*
2. *Bishop, Christopher M., and Hugh Bishop. Deep learning: Foundations and concepts. Springer Nature, 2023.*
3. *Bishop, Christopher M., and Nasser M. Nasrabadi. Pattern recognition and machine learning. Vol. 4. No. 4. New York: springer, 2006.*

4. *Szeliski, Richard. Computer vision: algorithms and applications. Springer Nature, 2022.*

Optimization Methods in Artificial Intelligence

1. Theory of convex sets and convex functions
2. Subgradient theory and important properties of convex functions
3. Gradient descent, stochastic gradient descent, and stochastic coordinate descent algorithms
4. Momentum acceleration methods and adaptive learning rate techniques

Reference Books:

1. *Lectures on Convex Optimization* by Y. Nesterov
2. *First-Order Methods in Optimization* by A. Beck
- 3.

Natural Language Processing

1. Statistical modeling assumptions and methods for natural language processing tasks
2. Mathematical principles of Word2Vec
3. Principles and implementation of self-attention in Transformer
4. Principles, limitations and improvements of large model pre-training alignment methods
5. Basic principles of Scaling Laws
6. Principles, limitations and improvements of knowledge base reasoning methods based on Embedding

Reference Books:

1. *Speech and Language Processing* by Dan Jurafsky and James H. Martin
2. *Neural Network Methods in Natural Language Processing* by Yoav Goldberg

Introduction and Course Selection Guide for the Artificial Intelligence Curriculum at Qiuzhen College

Graduate core courses:

Machine Learning Theory (机器学习理论)

Advanced Deep Learning (高等深度学习)

Optimization Methods for AI (人工智能中的优化方法)

Natural Language Understanding (自然语言理解)

Note: The above four courses are the core courses of the qualification exam in the AI direction. Among these courses, students are recommended to take Natural Language Understanding after completing Machine Learning Theory and Advanced Deep Learning.

Students are recommended to complete these courses within the first three semesters of their graduate study.