

Index

- Action space, 12
- Actor-critic methods
 - Compatible features, 380
 - Fisher information matrix, 384
 - Score function, 377
- Admissible input, 246
- Advantage function, 322, 382
 - For optimal policy, 337
- ARMA model, 12
- Asymptotic covariance, 281
- Asymptotic stability, 18
 - Exponential, 19
 - Global, 18
- Average-cost optimal control, 402
- Average-cost optimality equation, 245, 403
- Basis, 68
 - Linearly independent, 177, 325
 - Tabular, 163, 358
- Belief state, 410
- Bellman equation, 53
 - Fixed-policy, 56
- Bellman error, 63
- Central Limit Theorem (CLT), 222
 - Batch means method, 223
- Coercive, 20
- Compact, 395
- Comparison theorem, 21
- Compatible features, 380
- Condition number, 396
- Conditional expectation, 237, 323
- Continuously differentiable, 23
- Control variate, 230
- Controlled transition matrix, 245
- Convex, 91
 - Strict, 92
 - Strong, 92
- Cost to go, 52
 - Continuous time, 69
- Discount factor, 59
- Discounted cost, 402
- Disturbance rejection, 13
- Drift condition, 23
- Drift inequality, 19
- Dynamic programming, 54
- Dynamic programming (DP) equation, 53
- Eligibility vector, 163, 178, 327
- Empirical
 - Distribution, 162
 - Mean, 162
 - Pmf, 162
- Empirical risk, 161
- Equilibrium, 17
 - Region of attraction, 19
- Ergodic, 209, 213
 - Geometric, 235
- Euler approximation, 87
- Examples
 - Acrobot, 39
 - Bandits, 266
 - CartPole, 38
 - Frictionless pendulum, 28
 - Linear state space model, 208
 - M/M/1 queue, 211
 - M/M/1 value functions, 252, 322, 358
 - MagBall, 36
 - Mountain car, 34, 70, 118
 - Queueing game, 261
 - Queueing network, 73
 - Rover with partial information, 264
 - Rowing, 41
 - Speed scaling, 253
- Exercises
 - CartPole, 38
 - Criteria for instability, 239
 - Introduction to conditional expectation, 237
 - Inventory model, 275
 - MagBall, 36, 153
 - Pendulum, 47, 153
 - Perron–Frobenius theory, 241
 - Rover with full observations, 271
 - Rover with partial information, 277
 - Simulation theory and practice, 239

- Exercises (Cont.)
 - Speed scaling, 272
 - Tabular basis, 358
 - Zap zero, 358
- Exogenous, 11
- Expectation
 - Conditional, 237, 323
- Experience replay buffer, 162
- Exploration, 4, 31, 266
- Extremum seeking control, 114
- Feedback law, 9
- Feedforward control, 9
- Fixed-point equation, 53
- Fluid model, 248
- Fundamental matrix, 58, 241
- Galerkin, 163, 178
- Gradient descent
 - Acceleration, 155
 - Stochastic, 114
- Gradient flow, 90
 - Matrix gain, 150
- Graveyard state, 60, 401
- Grönwall inequality, 86
- Hamilton–Jacobi–Bellman equation, 69
- History state, 13
- HJB equation, 69
- Hurwitz, 27
- Indicator function, 395
- Inf-compact, 20
- Infimum, 396
- Information state, 410
- Input, 12
 - Admissible, 246
- Input space U , 12
- Integral control, 14
- Internal Model Principle, 14
- Inverse dynamic programming (IDP), 63
- Irreducible, 233
- Kac's theorem, 234
- L -smooth, 91
- Law of Large Numbers (LLN), 222
- Linear independence, 177, 325
- Linear quadratic regulator, 52
 - Continuous time, 77
- Linear state space model, 15, 208
 - Continuous time, 16
- Linearization, 29
- Lipschitz continuous, 85
- Load, 211
- LSTD Learning, 329
- LTI system, 12
 - Gain matrix, 15
- Lyapunov equation, 26
 - Continuous time, 27
- Lyapunov function, 19
 - Control, 63, 81
- Markov chain
 - ψ -irreducible, 233, 234
 - x^* -irreducible, 234
 - Aperiodic, 233
 - Communication diagram, 214
 - Ergodic, 213
 - Memoryless property, 205
 - Shift operator, 398
 - Spectral gap, 214
 - Transition kernel, 206
 - Transition matrix, 206
 - Uni-chain, 233
- Markov decision process, 245
- Markov property, 399
 - Strong, 400
- Martingale difference, 307
- Mean-field dynamics, 248
- Model predictive control, 62
- Monte Carlo, 222
 - Control variate, 230
- Neighborhood, 395
- Newton–Raphson algorithm, 284
- Newton–Raphson flow, 88
 - Regularized, 89, 301
- Nonlinear state space model, 12
 - Continuous time, 16
 - Markov, 205
- Observations, 9
- Occupancy pmf ω , 194
- ODE method, 84, 281
- Oja's algorithm, 151
- Optimal control
 - Hamiltonian, 70
 - Minimum principle, 70
 - Risk sensitive, 276
- Optimality equation
 - Average cost, 245, 403
- Optimization, 90
 - Stationary point, 47
- Ordinary differential equation (ODE), 84
 - ODE method, 84, 281
 - Vector field, 23
- Poisson's equation, 216
- Poisson's inequality, 20, 218
 - Continuous time, 24
- Policy, 9
 - H -greedy, 321
 - Linear optimal, 66
 - Markov, 13, 247
 - Stationary Markov, 247

- Policy improvement
 - Approximate, 104
 - Average cost, 404
 - Discounted cost, 320
- Polyak–Juditsky–Ruppert Averaging, 108, 282
- Positive definite, 396
- Principle of optimality, 53
 - Continuous time, 69
- Probability mass function (pmf), 206
- Probing signal, 98
- Q-function
 - Average cost, 246
 - Fixed policy, 320
 - Total cost, 54
- Q-learning
 - Asynchronous, 339
 - GQ, 183, 349
 - $Q(0)$, 338
 - Relative, 344
 - Synchronous, 339
 - Watkins, 339
- Quasistochastic approximation, 98
- Queue
 - CRW, 251
 - M/M/1, 211
 - MaxWeight policy, 75
- Random walk, 211
 - Reflected r.w., 211
- Reference signal, 9
- Relative value function, 216, 403
- Representer theorem, 166
- Reproducing kernel Hilbert space, 166
- Riccati equation, 66, 77
- Risk-sensitive optimal control, 276
- Sample complexity, 290
- SARSA, 172, 321
- Score function, 231, 377
- Shift operator, 398
- Shortest path problem (SPP), 60, 402
- Simplex, 410
- Simultaneous perturbation stochastic approximation, 157
- Singular value, 396
- Span seminorm, 395
- Spectral gap, 214
- Split sampling, 229, 333
- Stable
 - Asymptotically stable, 18
 - Exponentially asymptotically stable, 19
 - Globally asymptotically stable, 18
 - in the sense of Lyapunov, 18
 - Ultimately bounded, 109, 125
- State, 12, 205
- State feedback, 13, 247
 - linear, 66
- State space X , 12
- State space model, 12
- Stochastic approximation
 - Algorithm, 280
 - Averaging, 282
 - Projection, 286
 - Restart, 286
 - SNR, 302
 - Zap, 301
- Stochastic gradient descent, 231, 294
 - Quasi, 114
- Stochastic Newton–Raphson, 302
- Sublevel set, 19
- Successive approximation, 54
 - Picard iteration, 85
- Sufficient statistic, 12, 205
- Supremum, 396
- Tabular basis, 163, 358
- TD-learning, 172, 327, 332
 - Advantage, 337
 - LSTD, 329
 - Off-policy, 172, 332
 - On-policy, 172, 332
 - Regenerative, 370, 374
 - Regenerative for a.c., 374
 - Relative, 335
 - State weighting, 366
- Temporal difference, 30, 68, 162, 328
- Total cost, 17
- Tracking, 9, 13
 - Regulation, 15
- Transition matrix, 206
 - Controlled, 245
- Uni-chain, 233
- Value function, 18
 - Continuous time, 69
 - Discounted cost, 59, 402
 - Finite horizon, 61
 - Optimal, 51
- Value Iteration, 54, 403
 - Average cost, 403
 - Boundary condition, 61
- Vector field, 23
 - Newton–Raphson, 88
- Workload
 - Virtual station, 76
 - Virtual w. process, 76
- Zap
 - Q-learning, 351
 - QSA, 112
 - SA, 301
 - Zero, 301