**Theory and Methods for Statistical Inference**

**Instructor**

Yuan SHEN

**Course description**  
The course will start with relevant mathematical tools, including probability theory, graphical models, information theory, and then introduce detection and estimation theory, information geometry and its applications, asymptotic statistics, and contemporary inference algorithms. In the final part of the course, a brief overview of high-dimensional statistics and the state of the art will be presented. The course will also highlight projects that allow students to apply the theory and methods in applications.

**Prerequisites**  
Calculus、Linear Algebra、Probability Theory、Mathematical Statistics

**Time and Location**

Unless otherwise specified the lectures are Wednesday 9:50 am to 12:15 pm in New Hydraulic Building 325.

Online course: Tencent Meeting, Meeting ID: 502 6018 4195

**Prerequisites**

Calculus, Linear Algebra, Probability

**Grading policy**

- Homework (30%): 5 x 6%

- Final Exam (35%)

- Project (30%)

- Participation (5%)

### Weekly Schedule

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| 1 | Bayesian and Non-Bayesian Hypothesis Testing | Part I  Decision Making and Estimation |
| Likelihood Ratio Test and Operating Characteristic |
| Randomized Tests and Efficient Frontier |
| 2 | Mismatch Bayes Risk and Minimax Hypothesis Testing |
| Bayes Parameter Estimation |
| Linear Least-Squares Estimation |
| 3 | Non-Bayesian Estimation and the Cramér-Rao Bound |
| Maximum Likelihood Estimation (ML) |
| Exponential Families |
| 4 | Sufficient Statistics |
| Generalized Bayesian Decision Theory | Part II  Inference and Information |
| Discrete Information Theory |
| 5 | Information Projection |
| Information Geometry of ML |
| Maximum Entropy Distributions |
| 6 | Expectation-Maximization (EM) Algorithm |
| Information Geometry of EM |
| Conjugate Priors |
| 7 | Typical Sequences | Part III  Large Deviations and Asymptotic Analysis |
| Cramér’s Theorem |
| Method of Types and Sanov’s Theorem |
| 8 | Dominant Atypical Behavior |
| Asymptotics of Hypothesis Testing |
| Asymptotics of Parameter Estimation |
| 9 | Modeling |
| Asymptotics of Model Capacity |
| Model Selection |
| 10 | Graphical Models | Part IV  Exact Inference Algorithms |
| Elimination and MAP Elimination Algorithms |
| Sum-Product and Max-Product Algorithms |
| 11 | Hidden Markov Model (HMM) |
| Forward-Backward and Viterbi Algorithms |
| EM algorithm on HMM |
| 12 | Gaussian Belief Propagation |
| Kalman Filtering and Smoothing |
| Junction Tree Algorithm |
| 13 | Loopy Belief Propagation | Part V  Approximate Inference Algorithms |
| Variational Inference |
| 14 | Rejection Sampling and MCMC |
| Importance Sampling and Particle Filtering |
| 15 | Final Exam |  |

**Reference textbook**

Lecture notes [1] D. J. C. MacKay, Information Theory, Inference, and Learning Algorithms, Cambridge University Press, 2003 [2] T. M. Cover and J. A. Thomas, Elements of Information Theory, Wiley, 2nd ed., 2006 [3] K. P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012 [4] D. Koller and N. Friedman, Probabilistic Graphical Models: Principles and Techniques, MIT Press, 2009