

Overview

Daniel Hsu

COMS 4772

About COMS 4772

- ▶ “Advanced machine learning”

About COMS 4772

- ▶ “Advanced machine learning”
 - ▶ But actually: “machine learning theory”

About COMS 4772

- ▶ “Advanced machine learning”
 - ▶ But actually: “machine learning theory”
- ▶ Website:
<http://www.cs.columbia.edu/~djhsu/coms4772-f16/>

About COMS 4772

- ▶ “Advanced machine learning”
 - ▶ But actually: “machine learning theory”
- ▶ Website:
<http://www.cs.columbia.edu/~djhsu/coms4772-f16/>
 - ▶ Course information, policies, academic rules of conduct, etc.

About COMS 4772

- ▶ “Advanced machine learning”
 - ▶ But actually: “machine learning theory”
- ▶ Website:
<http://www.cs.columbia.edu/~djhsu/coms4772-f16/>
 - ▶ Course information, policies, academic rules of conduct, etc.
- ▶ Courseworks, Piazza: links on website

About you

- ▶ Satisfy all prerequisites:

About you

- ▶ Satisfy all prerequisites:
 - ▶ “machine learning”

About you

- ▶ Satisfy all prerequisites:
 - ▶ “machine learning”
 - ▶ multivariate calculus

About you

- ▶ Satisfy all prerequisites:
 - ▶ “machine learning”
 - ▶ multivariate calculus
 - ▶ linear algebra

About you

- ▶ Satisfy all prerequisites:
 - ▶ “machine learning”
 - ▶ multivariate calculus
 - ▶ linear algebra
 - ▶ probability theory

About you

- ▶ Satisfy all prerequisites:
 - ▶ “machine learning”
 - ▶ multivariate calculus
 - ▶ linear algebra
 - ▶ probability theory
 - ▶ algorithms

About you

- ▶ Satisfy all prerequisites:
 - ▶ “machine learning”
 - ▶ multivariate calculus
 - ▶ linear algebra
 - ▶ probability theory
 - ▶ algorithms
 - ▶ mathematical maturity

About you

- ▶ Satisfy all prerequisites:
 - ▶ “machine learning”
 - ▶ multivariate calculus
 - ▶ linear algebra
 - ▶ probability theory
 - ▶ algorithms
 - ▶ mathematical maturity
 - ▶ can read/write mathematical arguments, derivations, and proofs

About you

- ▶ Satisfy all prerequisites:
 - ▶ “machine learning”
 - ▶ multivariate calculus
 - ▶ linear algebra
 - ▶ probability theory
 - ▶ algorithms
 - ▶ mathematical maturity
 - ▶ can read/write mathematical arguments, derivations, and proofs
- ▶ You have until next lecture to “page in” these topics.

About you

- ▶ Satisfy all prerequisites:
 - ▶ “machine learning”
 - ▶ multivariate calculus
 - ▶ linear algebra
 - ▶ probability theory
 - ▶ algorithms
 - ▶ mathematical maturity
 - ▶ can read/write mathematical arguments, derivations, and proofs
- ▶ You have until next lecture to “page in” these topics.
 - ▶ See Homework 0

About you (relative to this class)

- ▶ Read papers/notes (posted on website)

About you (relative to this class)

- ▶ Read papers/notes (posted on website)
- ▶ Attend lectures (mostly at blackboard, sometimes slides)

About you (relative to this class)

- ▶ Read papers/notes (posted on website)
- ▶ Attend lectures (mostly at blackboard, sometimes slides)
- ▶ Solve problem sets (~ 4)

About you (relative to this class)

- ▶ Read papers/notes (posted on website)
- ▶ Attend lectures (mostly at blackboard, sometimes slides)
- ▶ Solve problem sets (~ 4)
 - ▶ Write them up in \LaTeX or something of similar quality

About you (relative to this class)

- ▶ Read papers/notes (posted on website)
- ▶ Attend lectures (mostly at blackboard, sometimes slides)
- ▶ Solve problem sets (~ 4)
 - ▶ Write them up in \LaTeX or something of similar quality
- ▶ Work on theoretical research project

About you (relative to this class)

- ▶ Read papers/notes (posted on website)
- ▶ Attend lectures (mostly at blackboard, sometimes slides)
- ▶ Solve problem sets (~ 4)
 - ▶ Write them up in \LaTeX or something of similar quality
- ▶ Work on theoretical research project
 - ▶ E.g., new, interesting theoretical result

About you (relative to this class)

- ▶ Read papers/notes (posted on website)
- ▶ Attend lectures (mostly at blackboard, sometimes slides)
- ▶ Solve problem sets (~ 4)
 - ▶ Write them up in \LaTeX or something of similar quality
- ▶ Work on theoretical research project
 - ▶ E.g., new, interesting theoretical result
 - ▶ E.g., simplify an existing, complex result in a non-trivial way

About you (relative to this class)

- ▶ Read papers/notes (posted on website)
- ▶ Attend lectures (mostly at blackboard, sometimes slides)
- ▶ Solve problem sets (~4)
 - ▶ Write them up in \LaTeX or something of similar quality
- ▶ Work on theoretical research project
 - ▶ E.g., new, interesting theoretical result
 - ▶ E.g., simplify an existing, complex result in a non-trivial way
 - ▶ E.g., *high quality* survey paper that unifies several papers

About you (relative to this class)

- ▶ Read papers/notes (posted on website)
- ▶ Attend lectures (mostly at blackboard, sometimes slides)
- ▶ Solve problem sets (~4)
 - ▶ Write them up in \LaTeX or something of similar quality
- ▶ Work on theoretical research project
 - ▶ E.g., new, interesting theoretical result
 - ▶ E.g., simplify an existing, complex result in a non-trivial way
 - ▶ E.g., *high quality* survey paper that unifies several papers
 - ▶ Cannot “just” implement an algorithm and run some experiments

About you (relative to this class)

- ▶ Read papers/notes (posted on website)
- ▶ Attend lectures (mostly at blackboard, sometimes slides)
- ▶ Solve problem sets (~4)
 - ▶ Write them up in \LaTeX or something of similar quality
- ▶ Work on theoretical research project
 - ▶ E.g., new, interesting theoretical result
 - ▶ E.g., simplify an existing, complex result in a non-trivial way
 - ▶ E.g., *high quality* survey paper that unifies several papers
 - ▶ Cannot “just” implement an algorithm and run some experiments
 - ▶ Project report / presentation (possibly a poster session) at end of semester (maybe during “final exam” time)

About you (relative to this class)

- ▶ Read papers/notes (posted on website)
- ▶ Attend lectures (mostly at blackboard, sometimes slides)
- ▶ Solve problem sets (~4)
 - ▶ Write them up in \LaTeX or something of similar quality
- ▶ Work on theoretical research project
 - ▶ E.g., new, interesting theoretical result
 - ▶ E.g., simplify an existing, complex result in a non-trivial way
 - ▶ E.g., *high quality* survey paper that unifies several papers
 - ▶ Cannot “just” implement an algorithm and run some experiments
 - ▶ Project report / presentation (possibly a poster session) at end of semester (maybe during “final exam” time)
- ▶ Abide by course policies, academic rules of conduct

About you (relative to this class)

- ▶ Read papers/notes (posted on website)
- ▶ Attend lectures (mostly at blackboard, sometimes slides)
- ▶ Solve problem sets (~4)
 - ▶ Write them up in \LaTeX or something of similar quality
- ▶ Work on theoretical research project
 - ▶ E.g., new, interesting theoretical result
 - ▶ E.g., simplify an existing, complex result in a non-trivial way
 - ▶ E.g., *high quality* survey paper that unifies several papers
 - ▶ Cannot “just” implement an algorithm and run some experiments
 - ▶ Project report / presentation (possibly a poster session) at end of semester (maybe during “final exam” time)
- ▶ Abide by course policies, academic rules of conduct
 - ▶ See website

About you (relative to this class)

- ▶ Read papers/notes (posted on website)
- ▶ Attend lectures (mostly at blackboard, sometimes slides)
- ▶ Solve problem sets (~4)
 - ▶ Write them up in \LaTeX or something of similar quality
- ▶ Work on theoretical research project
 - ▶ E.g., new, interesting theoretical result
 - ▶ E.g., simplify an existing, complex result in a non-trivial way
 - ▶ E.g., *high quality* survey paper that unifies several papers
 - ▶ Cannot “just” implement an algorithm and run some experiments
 - ▶ Project report / presentation (possibly a poster session) at end of semester (maybe during “final exam” time)
- ▶ Abide by course policies, academic rules of conduct
 - ▶ See website
 - ▶ Violators reported to the Dean’s office, get failing grade for assignment and/or course

About the course staff

- ▶ Instructor: Prof. Daniel Hsu

About the course staff

- ▶ Instructor: Prof. Daniel Hsu
 - ▶ Website: <http://www.cs.columbia.edu/~djhsu/>

About the course staff

- ▶ Instructor: Prof. Daniel Hsu
 - ▶ Website: <http://www.cs.columbia.edu/~djhsu/>
 - ▶ Research in algorithmic statistics, machine learning

About the course staff

- ▶ Instructor: Prof. Daniel Hsu
 - ▶ Website: <http://www.cs.columbia.edu/~djhsu/>
 - ▶ Research in algorithmic statistics, machine learning
- ▶ Course assistants: Rob and Mark

About COMS 4772 (again)

- ▶ Techniques for designing/analyzing machine learning algorithms

About COMS 4772 (again)

- ▶ Techniques for designing/analyzing machine learning algorithms
 - ▶ Focus on simple statistical models of data

About COMS 4772 (again)

- ▶ Techniques for designing/analyzing machine learning algorithms
 - ▶ Focus on simple statistical models of data
 - ▶ E.g., “subpopulations” in genetic study panel

About COMS 4772 (again)

- ▶ Techniques for designing/analyzing machine learning algorithms
 - ▶ Focus on simple statistical models of data
 - ▶ E.g., “subpopulations” in genetic study panel
 - ▶ E.g., “communities” in a social network

About COMS 4772 (again)

- ▶ Techniques for designing/analyzing machine learning algorithms
 - ▶ Focus on simple statistical models of data
 - ▶ E.g., “subpopulations” in genetic study panel
 - ▶ E.g., “communities” in a social network
 - ▶ E.g., “topics” in a corpus of documents

About COMS 4772 (again)

- ▶ Techniques for designing/analyzing machine learning algorithms
 - ▶ Focus on simple statistical models of data
 - ▶ E.g., “subpopulations” in genetic study panel
 - ▶ E.g., “communities” in a social network
 - ▶ E.g., “topics” in a corpus of documents
 - ▶ Many omissions (e.g., PAC learning, Bayesian analysis)

About COMS 4772 (again)

- ▶ Techniques for designing/analyzing machine learning algorithms
 - ▶ Focus on simple statistical models of data
 - ▶ E.g., “subpopulations” in genetic study panel
 - ▶ E.g., “communities” in a social network
 - ▶ E.g., “topics” in a corpus of documents
 - ▶ Many omissions (e.g., PAC learning, Bayesian analysis)
- ▶ Role of theoretical analysis in machine learning

About COMS 4772 (again)

- ▶ Techniques for designing/analyzing machine learning algorithms
 - ▶ Focus on simple statistical models of data
 - ▶ E.g., “subpopulations” in genetic study panel
 - ▶ E.g., “communities” in a social network
 - ▶ E.g., “topics” in a corpus of documents
 - ▶ Many omissions (e.g., PAC learning, Bayesian analysis)
- ▶ Role of theoretical analysis in machine learning
 - ▶ Beyond worst-case analysis: also have model of “input” (data)

About COMS 4772 (again)

- ▶ Techniques for designing/analyzing machine learning algorithms
 - ▶ Focus on simple statistical models of data
 - ▶ E.g., “subpopulations” in genetic study panel
 - ▶ E.g., “communities” in a social network
 - ▶ E.g., “topics” in a corpus of documents
 - ▶ Many omissions (e.g., PAC learning, Bayesian analysis)
- ▶ Role of theoretical analysis in machine learning
 - ▶ Beyond worst-case analysis: also have model of “input” (data)
 - ▶ *Best case analysis*, but assumptions usually violated in practice

About COMS 4772 (again)

- ▶ Techniques for designing/analyzing machine learning algorithms
 - ▶ Focus on simple statistical models of data
 - ▶ E.g., “subpopulations” in genetic study panel
 - ▶ E.g., “communities” in a social network
 - ▶ E.g., “topics” in a corpus of documents
 - ▶ Many omissions (e.g., PAC learning, Bayesian analysis)
- ▶ Role of theoretical analysis in machine learning
 - ▶ Beyond worst-case analysis: also have model of “input” (data)
 - ▶ *Best case analysis*, but assumptions usually violated in practice
 - ▶ Often lags practice, but not always (e.g., boosting, *k*-means++)

About COMS 4772 (again)

- ▶ Techniques for designing/analyzing machine learning algorithms
 - ▶ Focus on simple statistical models of data
 - ▶ E.g., “subpopulations” in genetic study panel
 - ▶ E.g., “communities” in a social network
 - ▶ E.g., “topics” in a corpus of documents
 - ▶ Many omissions (e.g., PAC learning, Bayesian analysis)
- ▶ Role of theoretical analysis in machine learning
 - ▶ Beyond worst-case analysis: also have model of “input” (data)
 - ▶ *Best case analysis*, but assumptions usually violated in practice
 - ▶ Often lags practice, but not always (e.g., boosting, k -means++)
 - ▶ Framework for reasoning about machine learning algorithms

About COMS 4772 (again)

- ▶ Techniques for designing/analyzing machine learning algorithms
 - ▶ Focus on simple statistical models of data
 - ▶ E.g., “subpopulations” in genetic study panel
 - ▶ E.g., “communities” in a social network
 - ▶ E.g., “topics” in a corpus of documents
 - ▶ Many omissions (e.g., PAC learning, Bayesian analysis)
- ▶ Role of theoretical analysis in machine learning
 - ▶ Beyond worst-case analysis: also have model of “input” (data)
 - ▶ *Best case analysis*, but assumptions usually violated in practice
 - ▶ Often lags practice, but not always (e.g., boosting, *k*-means++)
 - ▶ Framework for reasoning about machine learning algorithms
 - ▶ Suggest new algorithmic techniques

About COMS 4772 (tentative list of topics)

1. High-dimensional data

About COMS 4772 (tentative list of topics)

1. High-dimensional data
 - ▶ concentration of measure, random linear maps

About COMS 4772 (tentative list of topics)

1. High-dimensional data

- ▶ concentration of measure, random linear maps
- ▶ applications: least squares regression, k -means clustering, Gaussian mixtures

About COMS 4772 (tentative list of topics)

1. High-dimensional data
 - ▶ concentration of measure, random linear maps
 - ▶ applications: least squares regression, k -means clustering, Gaussian mixtures
2. Low-rank matrix approximation

About COMS 4772 (tentative list of topics)

1. High-dimensional data
 - ▶ concentration of measure, random linear maps
 - ▶ applications: least squares regression, k -means clustering, Gaussian mixtures
2. Low-rank matrix approximation
 - ▶ PCA, SVD, NMF, power iteration

About COMS 4772 (tentative list of topics)

1. High-dimensional data

- ▶ concentration of measure, random linear maps
- ▶ applications: least squares regression, k -means clustering, Gaussian mixtures

2. Low-rank matrix approximation

- ▶ PCA, SVD, NMF, power iteration
- ▶ applications: Gaussian mixtures, k -means clustering, planted partition models, topic models

About COMS 4772 (tentative list of topics)

1. High-dimensional data

- ▶ concentration of measure, random linear maps
- ▶ applications: least squares regression, k -means clustering, Gaussian mixtures

2. Low-rank matrix approximation

- ▶ PCA, SVD, NMF, power iteration
- ▶ applications: Gaussian mixtures, k -means clustering, planted partition models, topic models

3. Higher-order interactions

About COMS 4772 (tentative list of topics)

1. High-dimensional data

- ▶ concentration of measure, random linear maps
- ▶ applications: least squares regression, k -means clustering, Gaussian mixtures

2. Low-rank matrix approximation

- ▶ PCA, SVD, NMF, power iteration
- ▶ applications: Gaussian mixtures, k -means clustering, planted partition models, topic models

3. Higher-order interactions

- ▶ higher-order tensors, tensor decompositions, power iteration

About COMS 4772 (tentative list of topics)

1. High-dimensional data

- ▶ concentration of measure, random linear maps
- ▶ applications: least squares regression, k -means clustering, Gaussian mixtures

2. Low-rank matrix approximation

- ▶ PCA, SVD, NMF, power iteration
- ▶ applications: Gaussian mixtures, k -means clustering, planted partition models, topic models

3. Higher-order interactions

- ▶ higher-order tensors, tensor decompositions, power iteration
- ▶ applications: Gaussian mixtures, ICA, latent Dirichlet allocation