THE UNIVERSITY OF SYDNEY

Advanced Machine Learning

(COMP 5328)

School of Computer Science
Introduction to Machine Learning Problems

Tongliang Liu

Acknowledgement of Country - ON CAMPUS

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Before we begin the proceedings, I would like to acknowledge and pay respect to the traditional owners of the land on which we meet: [the Gadigal people of the Eora Nation]. It is upon their ancestral lands that the University of Sydney is built.

As we share our own knowledge, teaching, learning and research practices within this university may we also pay respect to the knowledge embedded forever within the Aboriginal Custodianship of Country.

Acknowledgement of Country - ONLINE

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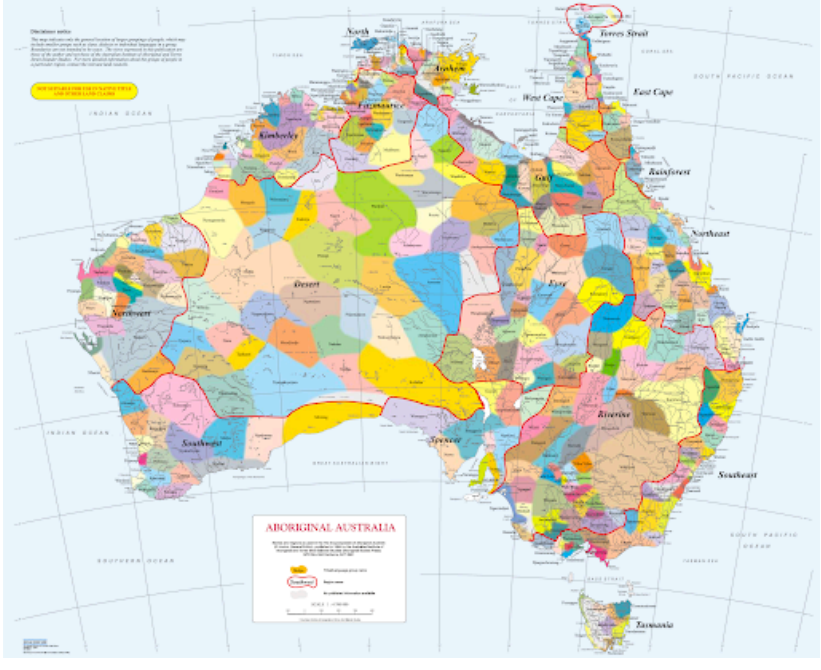
I wish to acknowledge all the Traditional Owners of all the lands on which we meet. I would like to show my respect to all Aboriginal people and acknowledge the Elders in the past and in the present.



Kinship Module AIATSIS Map

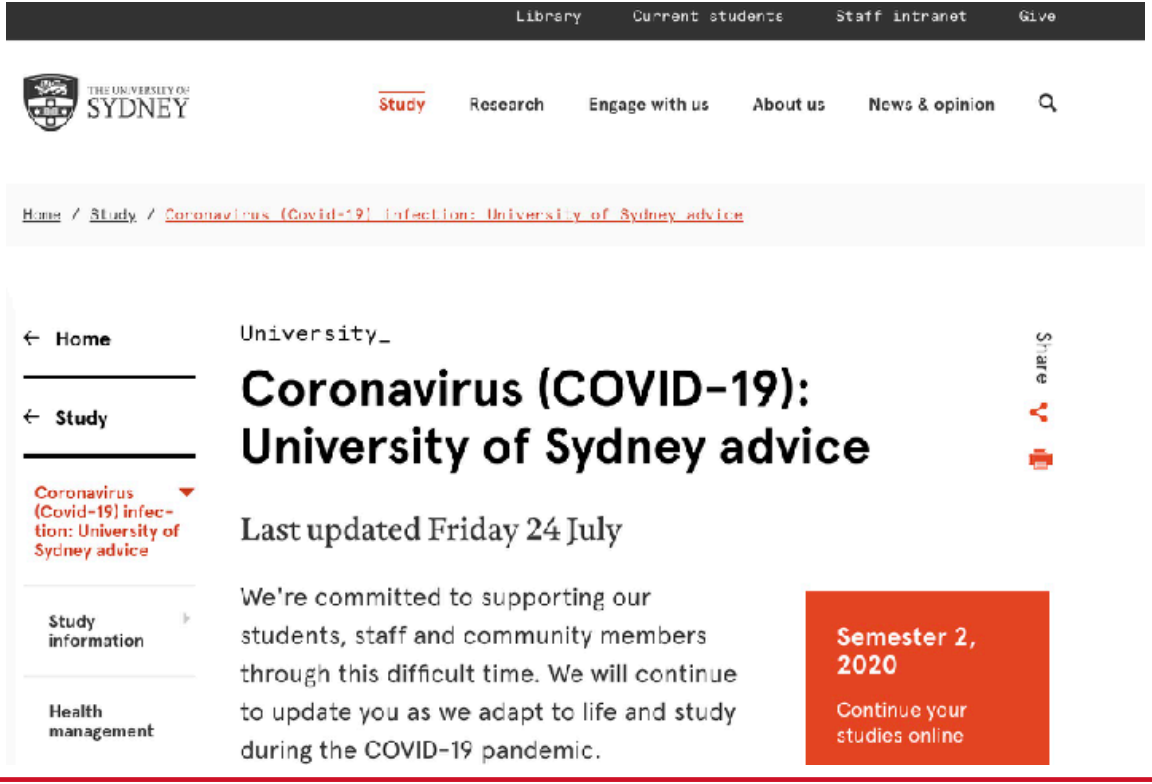
WHS INDUCTION

School of Computer Science

THE UNIVERSITY OF SYDNEY

COVID-19 USYD Advice

Seek advice about COVID-19 from the University webpage: https://www.sydney.edu.au/study/coronavirus-infection-university-of-sydney-advice.html



School of CS Safety Contacts

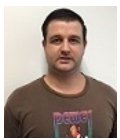
CHIEF WARDEN

Name: Greg Ryan
Mobile: : +61 411 406 322

FIRST AID OFFICERS

Name: Julia Ashworth
Location: 2E-Reception
Phone: 9351 3423

Name: Will Calleja
Location: 1 West
Phone: 9036 9706
0422 001 964



Name: Katie Yang
Location: 2E-237
Phone: 9351 4918

Orally REPORT all INCIDENTS & HAZARDS to your SUPERVISOR

OR the admin team

Undergraduates: to Katie Yang
9351 4918

Coursework Postgraduates: to Cecille Faraizi
9351 6060
or Keiko Narushima
8627 0872

School Manager: Priyanka Magotra
8627 4295

Places

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- Lecture:
  - Every Friday, 6 to 8pm, Online
- Labs:
  - Every Friday, 8 to 9pm (from Week 2 and skip Week 4);
  - Or Every Monday, 5 to 6pm (from Week 3);
  - Or Every Tuesday, 5 to 6pm (from Week 3)
    - Online
    - Go to the lab you are scheduled for
    - If for some reason you miss it, you can attend a later lab session *if there is space and the tutor agrees*, but ask the tutor before taking a seat
- Do not miss classes, except for illness, emergencies, etc
- Get help from staff if you feel you are falling behind

Using your Zoom environment

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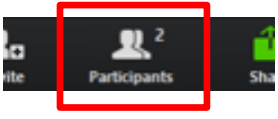
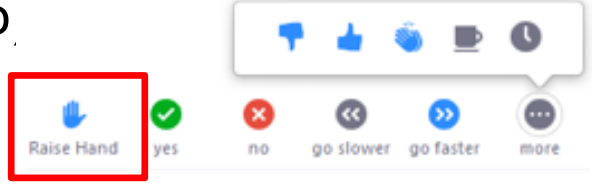
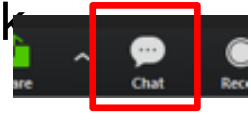
'Yes/No' (View > Participants > yes/no)





1. Have you managed to check-in? (Zoom: yes/no)
2. If no, look at the **Zoom > chat** for the link



1. If the link doesn't work for you, write in chat and we can help

Kinship Module AIATSIS Map

Tips for online learning

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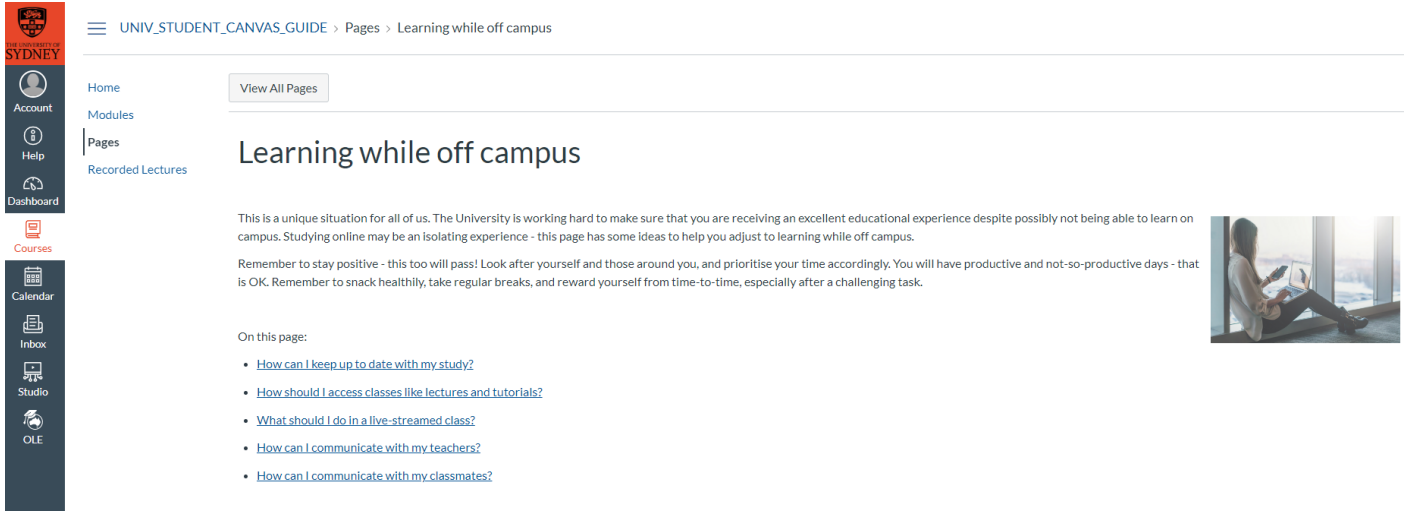
For tips and guides on learning online and the tools you will use, refer to **Learning while off campus** resources in **Canvas**:



Team

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- Lecturer:
  - Dr Tongliang Liu (coordinator)
- Teaching Assistant:
  - Yu Yao (yyao0814@uni.sydney.edu.au)
- Tutors:
  - **Nicholas James** (nicholas.james@sydney.edu.au),
  - **Xuefeng Li** (xuefeng.li1@unsw.edu.au),
  - **Songhua Wu** (sowu4341@uni.sydney.edu.au),
  - **Yu Yao**

Resources

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- Canvas
  - Login using Unikey and password
  - Link to the unit website: https://www.sydney.edu.au/units/COMP5328
    - list of learning outcomes, etc
  - Official schedule
  - Copies of slides
  - Lab instructions
  - Assignment instructions
  - Lecture videos
    - We intend to record the lectures, but the technology is not reliable
  - *Submit official assignments in Canvas*;
  - See your grades; etc
  - Discussion board

Resources

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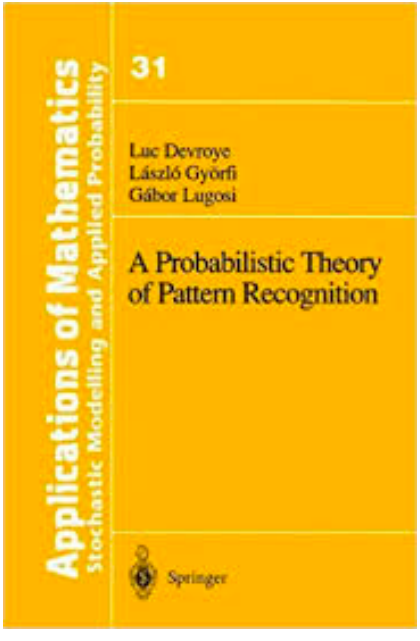
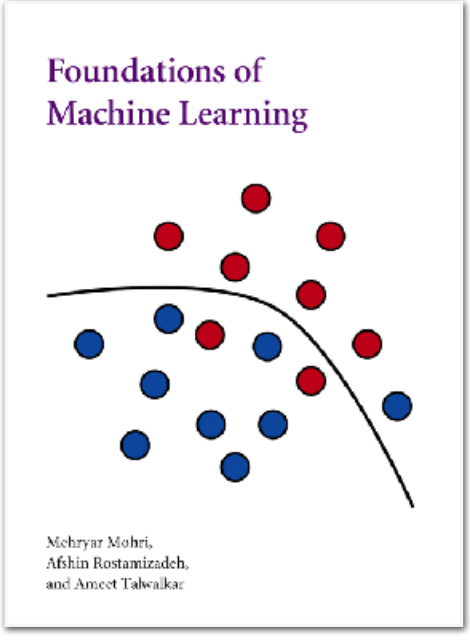
- Discussion board on Canvas:
- **General** (student helpline 1800 793 864 or contact the admin team) and **Technical**

- Mail technical questions tutors

Best books available





Assessment overview

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- Quiz: 0%
  - Week 4 (19/09) online, 8-9pm
  - Individual
  - Contents in the first three weeks

- Assignment 1: 25%
  - Due: Week 8 (22/10), 11:59pm
  - Groups of 2 or 3 students
  - Method comparison and analysis for feature noise

- Assignment 2: 25%
  - Due: Week 12 (19/11), 11:59pm
  - Groups of 2 or 3 students
  - Classification with noisy labels

- Final exam: 50%
  - December (date to be defined)

Late submissions

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- Consistent penalty of 5% per day late

e.g.,

a) A “good” assignment that would normally get 9/10, and is 2 days late, loses 10% of the full 10 marks, ie, new mark = 8/10.

b) An average assignment, that would normally get 5/10, that is 5 days late, loses 25% of the full 10 marks, ie new mark = 2.5/10

- Assignments more than 10 days late get 0.

Assessment overview

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In order to pass the course, the School requires at least 40% in the written exam, at least 40% in the other assessment components together and an overall final mark of 50 or more. This means that students who score less than 40% in the exam will fail the course regardless of their marks during the semester.

Expectations

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- Students attend scheduled classes, and devote an *extra* 6-9 hrs per week
  - doing assessments
  - preparing and reviewing for classes
  - revising and integrating the ideas
  - practice and self-assess
- Students are responsible learners
  - Participate in classes, constructively
    - Respect for one another (criticise ideas, not people)
    - Humility: none of us knows it all; each of us knows valuable things
  - Check Canvas site at least once a week!
  - Notify academics whenever there are difficulties
  - Notify group partners honestly and promptly about difficulties
  - Communicate respectively and efficiently with your group partners.

Topics

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Week	Topic
1	Introduction to ML Problems
2	Loss Functions and Convex Optimisation
3	Hypothesis Complexity and Generalisation
4	Dictionary Learning and NMF
5	Sparse Coding and Regularisation
6	Learning with Noisy Data
7	Domain Adaptation and Transfer Learning
8	Learning with Noisy Data II: Label Noise
9	Reinforcement Learning
10	Causal Inference
11	Multi-task Learning
12	Review

Assumed knowledge

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- Linear algebra, calculus
- Basics of probability and statistics
- Programming skills

Labs: Python

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- Python is a high-level programming language designed to enforce good coding practices.
- Interactive and very natural to use.
- Extremely versatile and excellent for prototyping.
- Great libraries for machine learning eg. scikit-learn, TensorFlow, Keras, Edward

www.python.org

Tutorial 1 (homework)

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- Check on canvas
- Introduction to (Python and) Convex Optimisation
- Bring questions to your tutor next week

Special Consideration (University Policy)

- If your performance on assessments is affected by illness or misadventure
- Follow proper bureaucratic procedures
  - Have professional practitioner sign special USYD form
  - Submit application for special consideration online, upload scans
  - Note you have only a quite short deadline for applying
  - http://sydney.edu.au/current_students/special_consideration/
- Also, notify the coordinator by email *as soon as anything begins to go wrong*
- There is a similar process if you need special arrangements eg for religious observance, military service, representative sports

Academic Integrity (University Policy)

- Please read the University policy on Academic Honesty carefully:
- http://sydney.edu.au/elearning/student/EI/academic_honesty.shtml
- All cases of academic dishonesty and plagiarism will be investigated
- There is a new process and a centralised University system and database
- Three types of offences:
  - Plagiarism – when you copy from another student, website or other source. This includes copying the whole assignment or only a part of it.
  - Academic dishonesty – when you make your work available to another student to copy (the whole assignment or a part of it). There are other examples of academic dishonesty.
  - Misconduct - when you engage another person to complete your assignment (or a part of it), for payment or not. This is a very serious matter and the Policy requires that your case is forwarded to the University Registrar for investigation.

Academic Integrity (University Policy)

- The penalties are severe and include:

1) a permanent record of academic dishonesty, plagiarism and misconduct in the University database and on your student file

2) mark deduction, ranging from 0 for the assignment to Fail for the course

3) expulsion from the University and cancelling of your student visa

- Do not confuse legitimate co-operation and cheating! You can discuss the assignment with another student, this is a legitimate collaboration, but you cannot complete the assignment together – everyone must write their own code or report, unless the assignment is group work.
- When there is copying between students, note that both students are penalised – the student who copies and the student who makes his/her work available for copying

Academic Integrity (University Policy)

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- We will use the similarity detection software TurnItIn and MOSS to compare your assignments with these of other students (current and previous) and the Internet
  - Turnitin is for text documents: http://www.turnitin.com/en_us/higher-education
  - MOSS is for programming code: https://theory.stanford.edu/~aiken/moss/
- These tools are extremely good!
  - e.g. MOSS cannot be fooled by changing the names of the variables or changing the order of the conditions in if-else statements
- Examples of plagiarism in programming code:
  - http://www.upenn.edu/academicintegrity/ai_computercode.html

Academic Integrity (University Policy)

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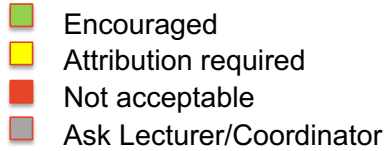
- All these are cases of plagiarism and academic dishonesty we have seen in our school and the student excuses are not acceptable:
  - *Plagiarism means presenting another person's work as one's own work by presenting, copying or reproducing it without appropriate acknowledgement of the source.*
  - *I sat the test and then posted the questions and solutions to my friends whose test was later in the week. I only wanted to help them understand the concepts that are examinable.*
  - *I posted parts of my code on my web page (group discussion forum) because my solution was cool (or I wanted to help them). I didn't expect them to copy it.*
  - *I tried to do the assignment on my own but I had problems with the extension part that I couldn't fix, so I submitted my core part and his extension part. I didn't cheat.*
  - *I finished my assignment but my friend had family problems. I felt sorry for her, so I gave her my assignment as an example. She said she only wanted to have a look and promised not to copy it.*
  - *The test has finished but the tutor hasn't collected the papers yet. I showed my answer to my friend. I didn't expect him to copy it.*
  - *He is my best friend. I had no choice but to let him copy my assignment.*

Academic Integrity (University Policy)

- Plagiarism and any form of academic dishonesty will be dealt with, and the penalties are severe
- We use plagiarism detection systems such as MOSS and TurnItIn that are extremely good. If you cheat, the chances you will be caught are very high.
- If someone asks you to see or copy your assignment, or to complete the assignment instead of them, just say: *I can't do this. This is against the University policy. I will not risk my future by doing this*.

Be smart and don't risk your future by engaging in plagiarism and academic dishonesty!

Academic Integrity Practice Source of help



Lecturer	Teaching Assistants / Tutors	Classmates	Online forums/ Online tutors	Students outside course/UoS	Hired coders Tutorial Company outside University	Relatives	Other

- A student needs to gain an understanding of high level knowledge/skills
- A student needs to gain skills to find, evaluate and apply existing knowledge/solutions

Academic Integrity Practice
Types of help

- Encouraged
- Attribution required
- Not acceptable
- Ask Lecturer/Coordinator

Understanding General Concepts	Explained using similar material (not assignment)	Sharing approach/ concept to derive assignment solution	Designing code/ solution	Implementing code/solution

- A student needs to gain an understanding of fundamental knowledge/ skills
- It is important to master the knowledge/skills themselves
- Students are encourage to obtain help through relevant teaching material and practices

Self-test

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- When is the first assessment due?
- How much work will you be devoting to this unit, each week?
- Do you need to buy a book?
- What do you do if you get sick during semester?
- What help can you use when answering assessments?
- How do you find out about assignment instructions?
- How do you submit your work?
- What is Turnitin?
- What language will you be coding in?

Disability Services

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Do you have a disability?

- You may not think of yourself as having a 'disability' but the definition under the **Disability Discrimination Act** is broad and includes temporary or chronic medical conditions, physical or sensory disabilities, psychological conditions and learning disabilities.
- The types of disabilities we see include:
  - anxiety, arthritis, asthma, asperger's disorder, ADHD, bipolar disorder, broken bones, cancer, cerebral palsy, chronic fatigue syndrome, crohn's disease, cystic fibrosis, depression, diabetes, dyslexia, epilepsy, hearing impairment, learning disability, mobility impairment, multiple sclerosis, post traumatic stress, schizophrenia , vision impairment, and much more.
- Students needing assistance must register with Disability Services –
  - it is advisable to do this as early as possible.
- http://sydney.edu.au/study/academic-support/disability-support.html

Do you have a disability?

You may not think of yourself as having a ‘disability’ but the definition under the **Disability Discrimination Act (1992)** is broad and includes temporary or chronic medical conditions, physical or sensory disabilities, psychological conditions and learning disabilities.

The types of disabilities we see include:
Anxiety // Arthritis // Asthma // Autism // ADHD
Bipolar disorder // Broken bones // Cancer
Cerebral palsy // Chronic fatigue syndrome
Crohn’s disease // Cystic fibrosis // Depression
Diabetes // Dyslexia // Epilepsy // Hearing impairment // Learning disability // Mobility impairment // Multiple sclerosis // Post-traumatic stress // Schizophrenia // Vision impairment
and much more.

Students needing assistance must register with Disability Services. It is advisable to do this as early as possible. Please contact us or review our website to find out more.

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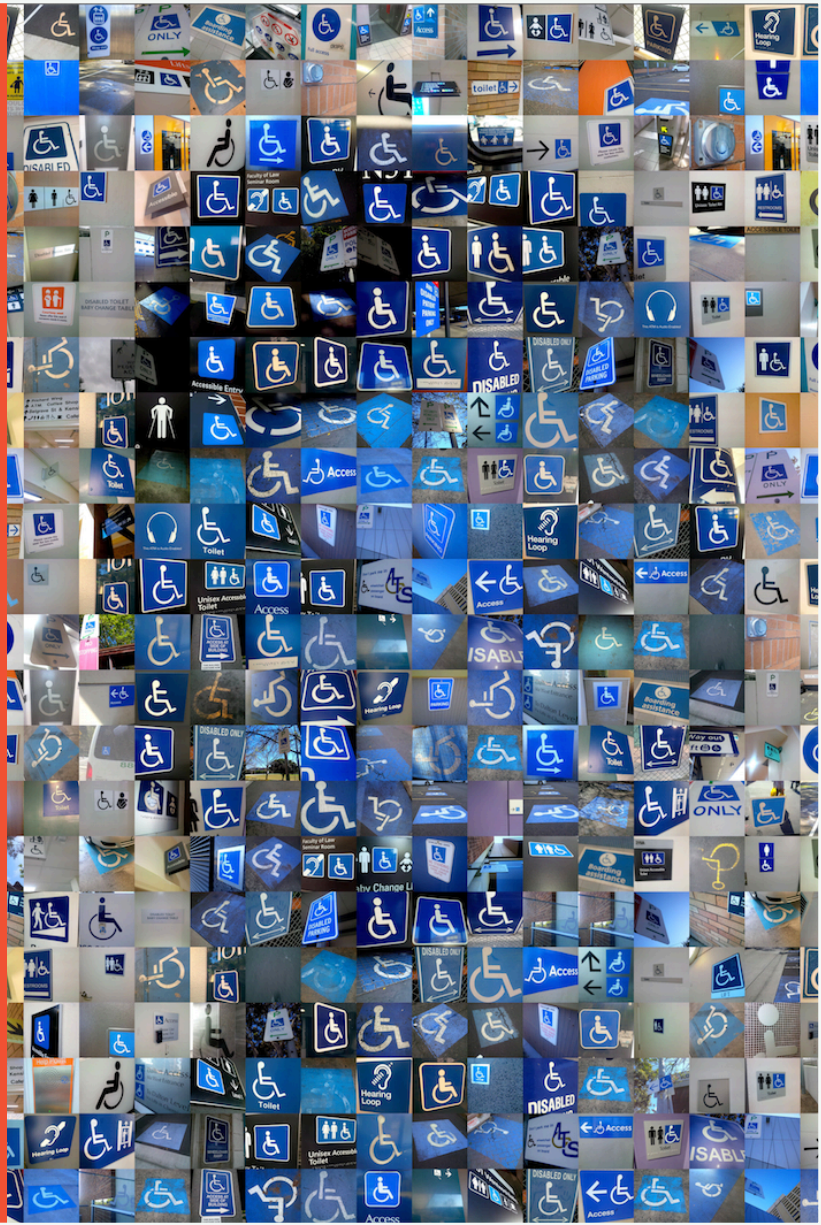
Disability Services Office
sydney.edu.au/disability



Assistance

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- There are a wide range of support services available for students: –https://sydney.edu.au/campus-life/health-wellbeing-success.html
- Please make contact, and get help
- You are not required to tell anyone else about this
- If you are willing to inform the unit coordinator or TA, they may be able to work with other support to reduce the impact on this unit
  - eg provide advice on which tasks are most significant

Other support

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- Learning support
  - http://sydney.edu.au/study/academic-support/learning-support.html
- International students
  - http://sydney.edu.au/study/academic-support/support-for-international-students.html
- Aboriginal and Torres Strait Islanders
  - http://sydney.edu.au/study/academic-support/aboriginal-and-torres-strait-islander-support.html
- Student organisation (can represent you in academic appeals etc)
  - http://srcusyd.net.au/ or http://www.supra.net.au/
- Please make contact, and get help
- You are not required to tell anyone else about this
- If you are willing to inform the unit coordinator, they may be able to work with other support to reduce the impact on this unit
  - eg provide advice on which tasks are most significant

Advice

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- Metacognition
  - Pay attention to the learning outcomes
  - Self-check that you are achieving each one
  - Think how each assessment task relates to these
- Time management
  - Watch the due dates
  - Start work early, submit early
- Networking and community-formation
  - Make friends and discuss ideas with them
  - Know your tutor, lecturer, coordinator
  - Keep them informed, especially if you fall behind
    - Don’t wait to get help
- Enjoy the learning!

Ask questions sooner!

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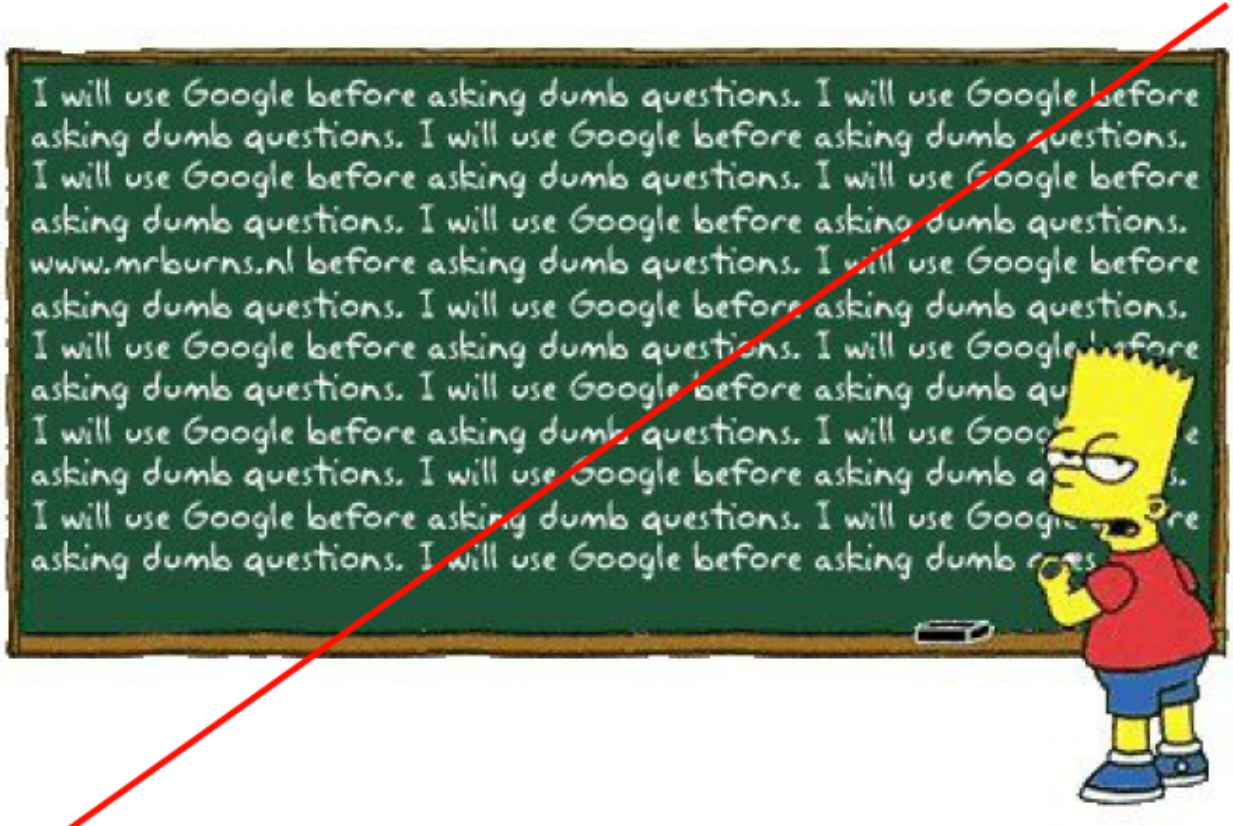

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Let's talk about some machine learning problems

Google
Baidu 百度
amazon.com
TOYOTA
SONY
SIEMENS
腾讯 Tencent
IBM Research
商汤 sensetime
Microsoft Research
Alibaba Group
CSIRO
HRI Europe Honda Research Institute
facebook
YAHOO!
CommonwealthBank
RioTinto

No Free Lunch Theorem

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- The "No Free Lunch" theorem states that there is no one model that works best for every problem.
- There are numerous applications. We cannot learn their solutions independently.
- We should know how machine learning algorithms works. How can we improve them?

Elements of Machine Learning Algorithms

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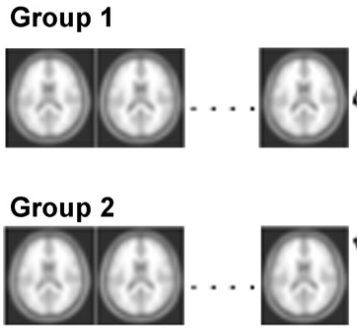
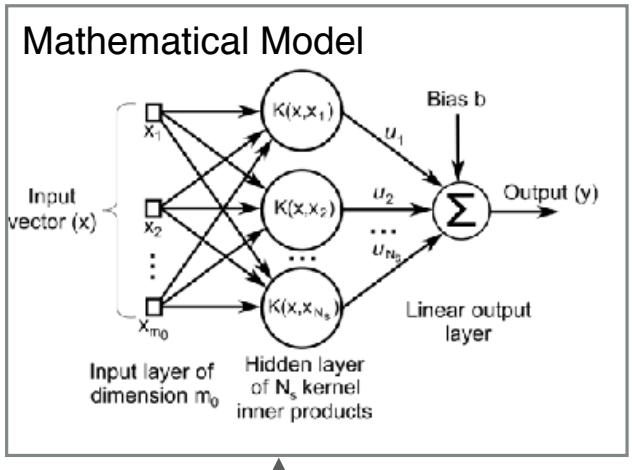
Input training data

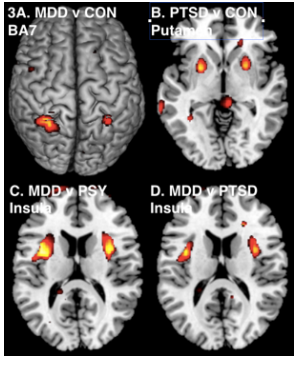


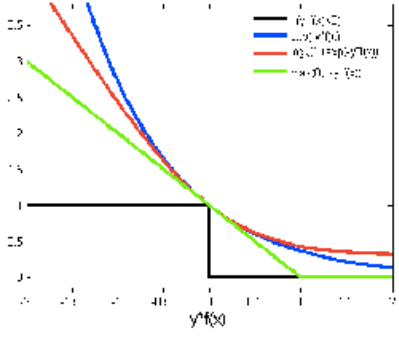
Data

Input predefined hypothesis/function class



Output hypothesis
Predictions/Patterns





Objective function

Optimisation method

Elements of Machine Learning Algorithms

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- I. Input training data
- II. Predefined hypothesis class
- III. Objective function
- IV. Optimisation method
- V. Output hypothesis

What is Machine Learning? (COMP5318)

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Informally: Making predictions from data

Formally: The construction of a statistical model that is an underlying distribution from which the data is drawn from.

What is Machine Learning? (COMP5328)

feature / instance / observation

target

- Input training data: $S = \{(X_1, Y_1), \ldots, (X_n, Y_n)\}$
- Input predefined hypothesis class: $H = \{h_1, h_2, \ldots\}$
- The objective function and optimisation method together make up a mapping: $\mathcal{A} : (\mathcal{X} \times \mathcal{Y})^n \to H$
- Output hypothesis: h_S
- The overall learning algorithm is a mapping:

latex \mapsto

$$\mathcal{A} : S \in (\mathcal{X} \times \mathcal{Y})^n \mapsto h_S \in H$$

Topics

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Week	Topic	Elements of ML
1	Introduction to ML Problems	
2	Loss Functions and Convex Optimisation	I, III, IV
3	Hypothesis Complexity and Generalisation	II, V
4	Dictionary Learning and NMF	I, II, IV, V
5	Sparse Coding and Regularisation	II, III, V
6	Learning with Noisy Data	I, III
7	Domain Adaptation and Transfer Learning	I, II
8	Learning with Noisy Data II: Label Noise	I, III, V
9	Reinforcement Learning	I, II, III, V
10	Causal Inference	I, II, III
11	Multi-task Learning	III, V
12	Review	

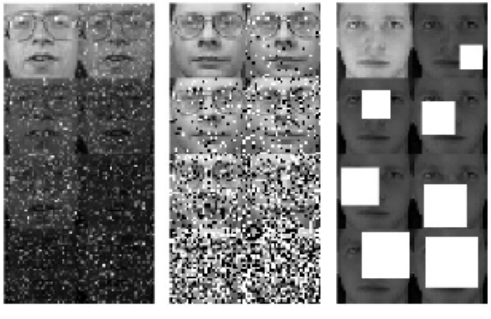
I. Input training data
II. Predefined hypothesis class
III. Objective function
IV. Optimisation method
V. Output hypothesis

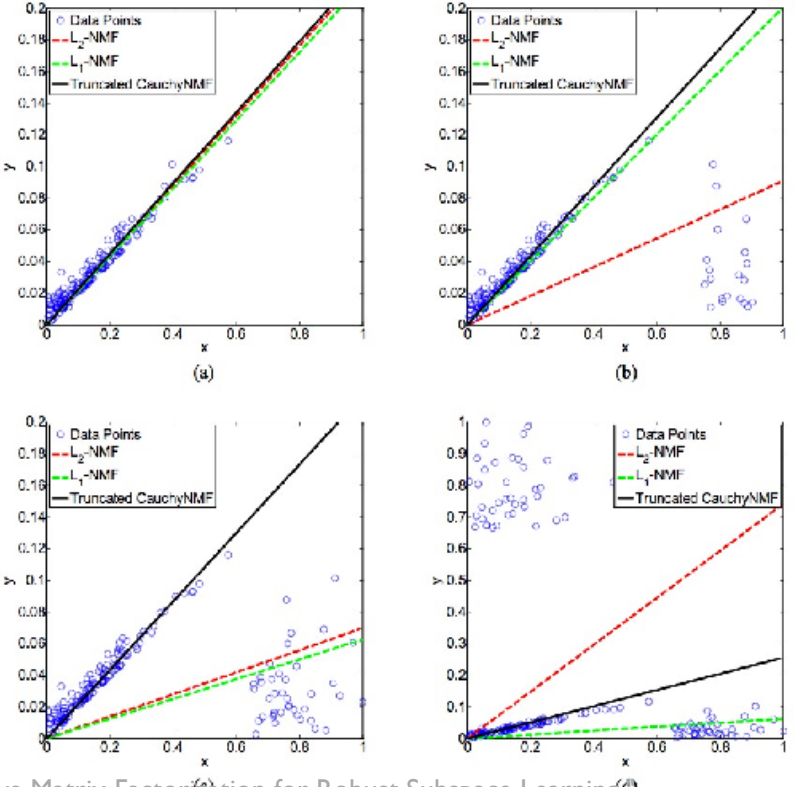
I. Input data: feature noise → robust model

The input data are contaminated by noise. How can we deal?

high-quality data

low quality data



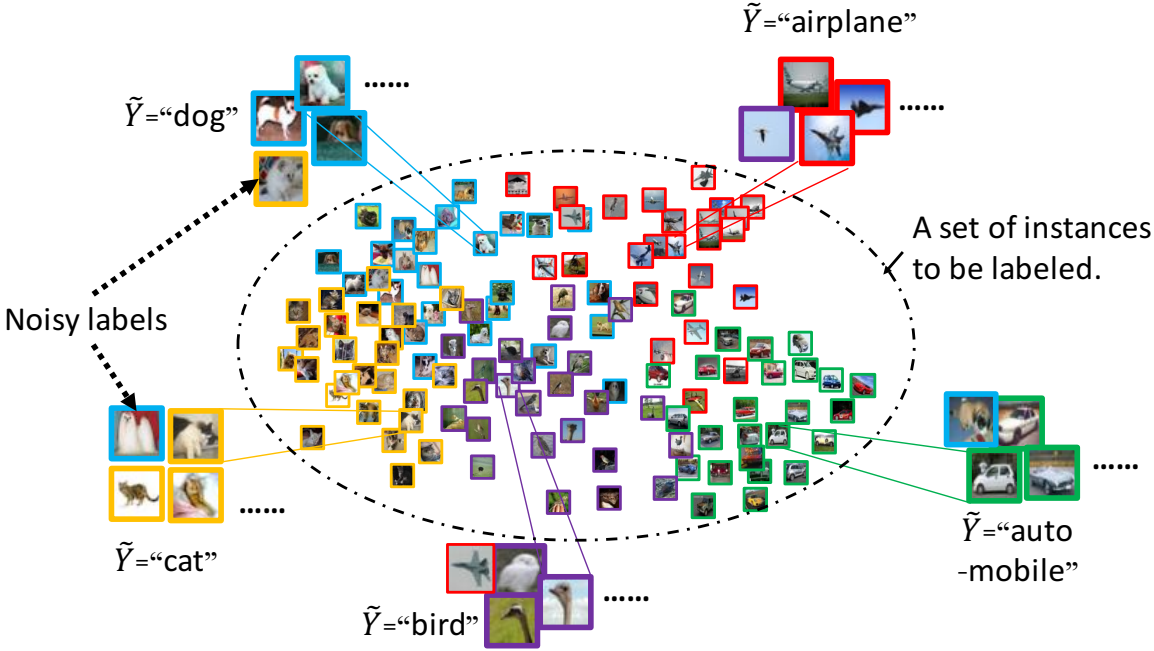


Guan, Naiyang, et al. "Truncated Cauchy Non-negative Matrix Factorization for Robust Subspace Learning." IEEE Transactions on Pattern Analysis and Machine Intelligence (2017).

I. Input data: label noise

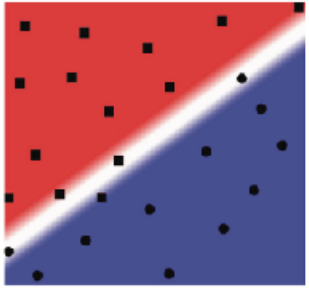
e.g. → transition matrix

The labels of the input training data are noisy or contaminated. How can we deal?

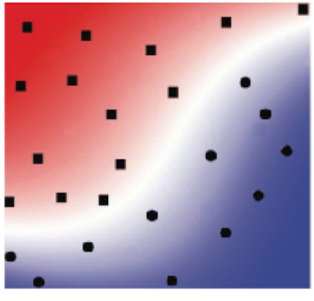


Yu, Xiyu, et al. "An Efficient and Provable Approach for Mixture Proportion Estimation Using Linear Independence Assumption." Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition. 2018.

II. Input Predefined Hypothesis class



Linear SVM

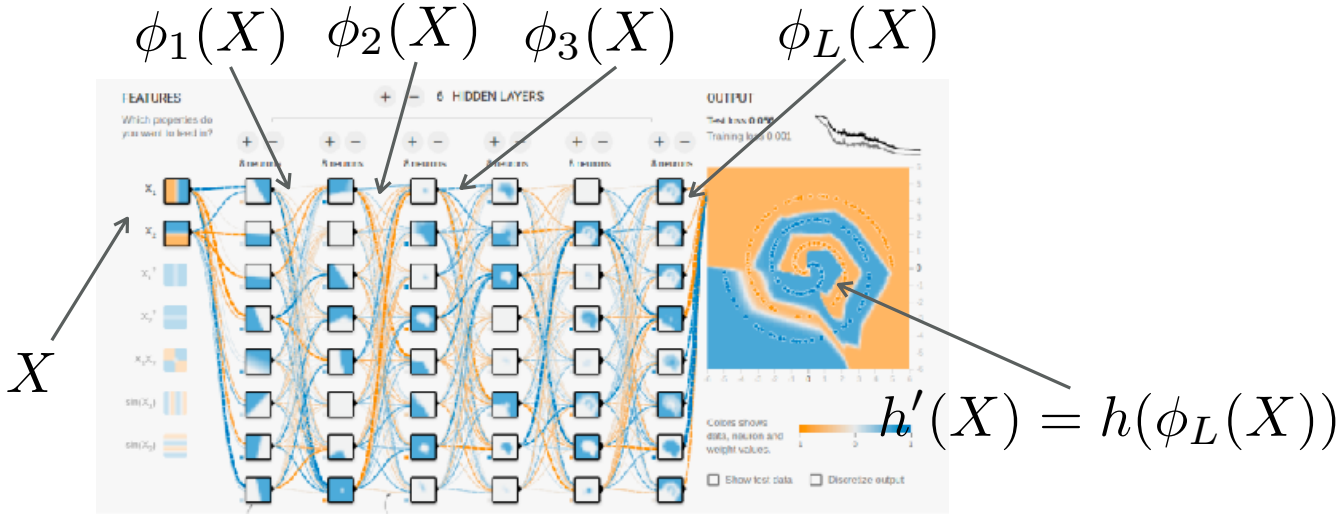


Kernel SVM

How to find a proper predefined hypothesis class?

Mohri, Mehryar, Afshin Rostamizadeh, and Ameet Talwalkar. Foundations of machine learning. MIT press, 2012.

II. Input Predefined Hypothesis class



Deep learning helps find a proper hypothesis class?
It is also widely believed that deep learning learns a good representation $\phi_L(X)$.

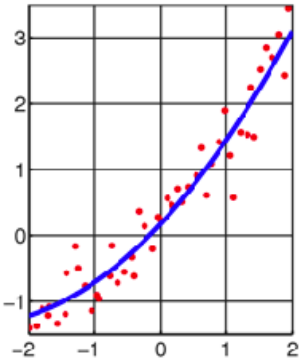
Zhang, Jingwei, et al. "An Information-Theoretic View for Deep Learning." arXiv preprint arXiv:1804.09060 (2018).

III. Objective function

An objective is a numerical value to be minimised or maximised.

The objective function indicates how much each variable contributes to the value to be optimised in the problem.

The objective function of Least squares:



$$\arg\min_{h} \frac{1}{n} \sum_{i=1}^{n} (y - h(x))^2$$

III. Objective function

$$\arg\min_{h} \frac{1}{n} \sum_{i=1}^{n} (y - h(x))^2$$

- Why the objective function of Least squares is defined in this way?
- What is the best regressor?
- Can we obtain the best regressor?

III. Objective function

- Given a classification task, we should firstly defined which hypothesis or classifier is the best.
- One intuitive way to defined the best classifier: the classifier that has the minimum classification error on the all possible data generated from the task.

Best classifier

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- For a given data point (X, Y), the classification error for a hypothesis h is measured by the 0-1 loss function:

$$1_{\{Y \neq \text{sign}(h(X))\}} = \begin{cases} 0 & Y = \text{sign}(h(X)) \\ 1 & Y \neq \text{sign}(h(X)) \end{cases}$$

- The best classifier can be mathematically defined as:

$$\arg\min_h \frac{1}{|D|} \sum_{i \in D} 1_{\{Y_i \neq \text{sign}(h(X_i))\}}$$

where D is the set of indices of **all possible data** points of the task, and $|D|$ denotes the size of the set D.

The law of large numbers

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LLN describes the result of performing the same experiment a large number of times.

The average of the results obtained from a large number of independent trials should converge to the expected value.

$$\frac{1}{|D|}\sum_{i\in D} 1_{\{Y_i \neq \text{sign}(h(X_i))\}} \xrightarrow{|D|\to\infty} \mathbb{E}\left[1_{\{Y \neq \text{sign}(h(X))\}}\right]$$

Best classifier

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- The best classifier can be mathematically defined as:

$$\arg\min_h \mathbb{E}[1_{\{Y \neq \text{sign}(h(X))\}}]$$

don't know all the data

- Some problems: 1, the distribution of data is unknown. We cannot calculate the expectation. 2, the objective function is not convex or smooth, hard to optimise. 3, what kind of hypothesis *h* should we employ to fit the data?

not smooth ⇒ no derivative
not convex ⇒ no global maximum

III. Objective function

- Given a classification task, we want to find a classifier such that the following is minimised:

$$\mathbb{E}[1_{\{Y \neq \text{sign}(h(X))\}}]$$

- We don't have the distribution of data. Fortunately, we have some examples (or a training sample) draw from the distribution:

$$S = \{(X_1, Y_1), \ldots, (X_n, Y_n)\}$$

- Because of the law of large numbers, we can use

$$\frac{1}{n}\sum_{i=1}^{n} 1_{\{Y \neq \text{sign}(h(X))\}}$$

(unbiased estimator)

good approximation?
↓
quality of samples
↓
#

to estimate $\mathbb{E}[1_{\{Y \neq \text{sign}(h(X))\}}]$

III. Objective function

- The estimator is unbiased because

optimise Expectation
↓
optimise average error.

$$\frac{1}{n}\sum_{i=1}^{n} 1_{\{Y_i \neq \text{sign}(h(X_i))\}} \xrightarrow{n\to\infty} \mathbb{E}[1_{\{Y \neq \text{sign}(h(X))\}}]$$

- This also explains why big data is very helpful.

IV. Optimisation method

- How to obtain the hypothesis that minimises the objective function, i.e.,

$$\arg\min_{h} \frac{1}{n} \sum_{i=1}^{n} 1_{\{Y_i \neq \text{sign}(h(X_i))\}}$$

- Pick one from the predefined hypothesis class *H* to minimise the objective, i.e.,

$$\arg\min_{h \in H} \frac{1}{n} \sum_{i=1}^{n} 1_{\{Y_i \neq \text{sign}(h(X_i))\}}$$

IV. Convex optimisation

- Pick one from the predefined hypothesis class *H* to minimise the objective, i.e.,

surrogate function versus 0-1 loss function

$$\arg\min_{h \in H} \frac{1}{n} \sum_{i=1}^{n} \ell(X_i, Y_i, h)$$

where the loss function ℓ is a convex surrogate for the 0-1 loss function.

An iterative updating method

Let $$f(h) = \frac{1}{n}\sum_{i=1}^{n} \ell(X_i, Y_i, h)$$

$$h_{k+1} = h_k + \eta d_k \ .$$

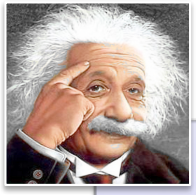
By Taylor's theorem, we have

$$f(h_{k+1}) = f(h_k) + \eta \nabla f(h_k)^\top d_k + o(\eta) \, .$$

For positive but sufficiently small η,
$f(h_{k+1})$ is smaller than $f(h_k)$,
if the direction d_k is chosen so that

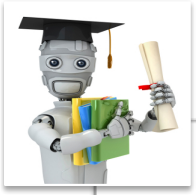
$\nabla f(h_k)^\top d_k < 0$, $f(h_{k+1}) < f(h_k)$ when $\nabla f(h_k) \neq 0.$

V. Output hypothesis h_S



Human

- Experience
- Choose a rule
- Do classification



Machine

- A sample
- Choose a hypothesis
- Do classification

Human vs Machine learning

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- As human grows older, more reliable decision will be made. How about machine?
- Human can be trained to be qualified for a job. How about machine?

Generalisation error of h_S

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- Informally: generalisation error is defined by the difference between training and test error.
- Formally: will be introduced in Week 3.
- Generally: the more the training data, the smaller the generalisation error.

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Thank you!