

Machine Learning Foundations (機器學習基石)



Lecture 1: The Learning Problem

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Course Design (1/2)

Machine Learning: a mixture of theoretical and practical tools

理論角度

- theory oriented
- derive everything **deeply** for solid understanding
- less interesting to general audience

理論的、深刻的、實際的

方法角度

- techniques oriented
- flash over the sexiest techniques **broadly** for shiny coverage
- too many techniques, hard to choose, hard to use properly

大扯

our approach: foundation oriented

基礎

Course Design (2/2)

Foundation Oriented ML Course

- mixture of philosophical illustrations, key theory, core techniques, usage in practice, and hopefully jokes :-)
—what every machine learning user should know
- story-like:
 - When Can Machines Learn? (illustrative + technical)
 - Why Can Machines Learn? (theoretical + illustrative)
 - How Can Machines Learn? (technical + practical)
 - How Can Machines Learn Better? (practical + theoretical)

allows students to learn 'future/untaught' techniques or study deeper theory easily

Course History

NTU Version

- 15-17 weeks (2+ hours)
- highly-praised with English and blackboard teaching



Coursera Version

- 8 weeks of 'foundation' (this course) + 7 weeks of 'techniques' (coming course)
- Mandarin teaching to reach more audience in need
- slides teaching improved with Coursera's quiz and homework mechanisms

goal: try making Coursera version even better than NTU version

Fun Time

Which of the following description of this course is true?

- ① the course will be taught in Taiwanese
- ② the course will tell me the techniques that create the android Lieutenant Commander Data in Star Trek
- ③ the course will be 15 weeks long
- ④ the course will be story-like

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Reference Answer: ④

- ① no, my Taiwanese is unfortunately not good enough for teaching (yet)
- ② no, although what we teach may serve as foundations of those (future) techniques
- ③ no, unless you choose to join the next course
- ④ yes, let's begin the story

Roadmap

① When Can Machines Learn?

Lecture 1: The Learning Problem

- Course Introduction
- What is Machine Learning
- Applications of Machine Learning
- Components of Machine Learning
- Machine Learning and Other Fields

② Why Can Machines Learn?

③ How Can Machines Learn?

④ How Can Machines Learn Better?

From Learning to Machine Learning

學習
learning: acquiring skill
累積
with experience accumulated from observations
經驗



machine learning: acquiring skill
with experience accumulated/computed from data



What is skill?

A More Concrete Definition

skill

\Leftrightarrow improve some performance measure (e.g. prediction accuracy)

machine learning: improving some performance measure
with experience **computed** from data



An Application in Computational Finance



Why use machine learning?

Yet Another Application: Tree Recognition



- ‘define’ trees and hand-program: **difficult**
- learn from data (observations) and recognize: a **3-year-old can do so**
- ‘ML-based tree recognition system’ can be **easier to build** than hand-programmed system

ML: an alternative route to
build complicated systems

The Machine Learning Route

ML: an **alternative route** to build complicated systems

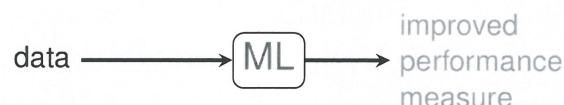
Some Use Scenarios

- when human cannot program the system manually
—navigating on Mars
- when human cannot ‘define the solution’ easily
—speech/visual recognition
- when needing rapid decisions that humans cannot do
—high-frequency trading
- when needing to be user-oriented in a massive scale
—consumer-targeted marketing

Give a **computer** a fish, you feed it for a day;
teach it how to fish, you feed it for a lifetime. :-)

Key Essence of Machine Learning

machine learning: improving some performance measure
with experience **computed** from data



- ① exists some ‘underlying pattern’ to be learned
—so ‘performance measure’ can be improved
- ② but no programmable (easy) definition
—so ‘ML’ is needed
- ③ somehow there is data about the pattern
—so ML has some ‘inputs’ to learn from

key essence: help decide whether to use ML

Fun Time

Which of the following is best suited for machine learning?

- ① predicting whether the next cry of the baby girl happens at an even-numbered minute or not
- ② determining whether a given graph contains a cycle
- ③ deciding whether to approve credit card to some customer
- ④ guessing whether the earth will be destroyed by the misuse of nuclear power in the next ten years

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Reference Answer: ③

- ① no pattern
- ② programmable definition
- ③ pattern: customer behavior;
definition: not easily programmable;
data: history of bank operation
- ④ arguably no (or not enough) data yet

Daily Needs: Food, Clothing, Housing, Transportation



① Food (Sadilek et al., 2013)

- data: Twitter data (words + location)
- skill: tell food poisoning likeliness of restaurant properly

② Clothing (Abu-Mostafa, 2012)

- data: sales figures + client surveys
- skill: give good fashion recommendations to clients

③ Housing (Tsanas and Xifara, 2012)

- data: characteristics of buildings and their energy load
- skill: predict energy load of other buildings closely

④ Transportation (Stallkamp et al., 2012)

- data: some traffic sign images and meanings
- skill: recognize traffic signs accurately

ML is everywhere!

Education



- data: students' records on quizzes on a Math tutoring system
- skill: predict whether a student can give a correct answer to another quiz question

A Possible ML Solution

answer correctly \approx [recent strength of student > difficulty of question]

- give ML 9 million records from 3000 students
- ML determines (reverse-engineers) strength and difficulty automatically

key part of the world-champion system from
National Taiwan Univ. in KDDCup 2010

推薦電影

Entertainment: Recommender System (1/2)



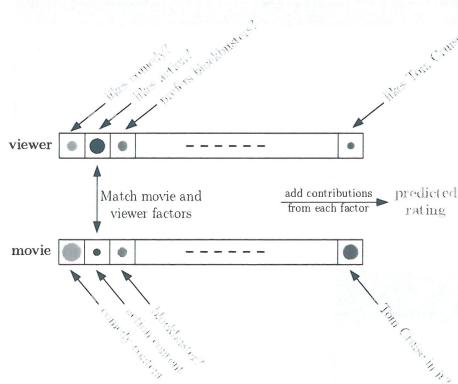
- data: how many users have rated some movies
- skill: predict how a user would rate an unrated movie

A Hot Problem

- competition held by Netflix in 2006
 - 100,480,507 ratings that 480,189 users gave to 17,770 movies
 - 10% improvement = **1 million dollar prize**
- similar competition (movies → songs) held by Yahoo! in KDDCup 2011
 - 252,800,275 ratings that 1,000,990 users gave to 624,961 songs

How can machines learn our preferences?

Entertainment: Recommender System (2/2)



A Possible ML Solution

- pattern:
rating ← viewer/movie factors
- learning:
known rating
→ learned factors
→ unknown rating prediction

key part of the **world-champion** (again!)
system from National Taiwan Univ.
in KDDCup 2011

Fun Time

Which of the following field cannot use machine learning?

- ① Finance
- ② Medicine
- ③ Law
- ④ none of the above

Fun Time

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- ① Finance
- ② Medicine
- ③ Law
- ④ none of the above

Reference Answer: ④

- ① predict stock price from data
- ② predict medicine effect from data
- ③ summarize legal documents from data
- ④ :-) Welcome to study this hot topic!

Components of Learning: Metaphor Using Credit Approval

Applicant Information

age	23 years
gender	female
annual salary	NTD 1,000,000
year in residence	1 year
year in job	0.5 year
current debt	200,000

unknown pattern to be learned:
 'approve credit card good for bank?'

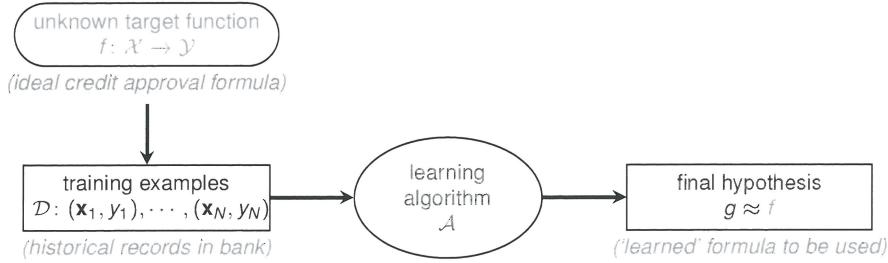
Formalize the Learning Problem

Basic Notations

- input: $\mathbf{x} \in \mathcal{X}$ (customer application)
- output: $y \in \mathcal{Y}$ (good/bad after approving credit card)
- unknown pattern to be learned \Leftrightarrow target function
 $f: \mathcal{X} \rightarrow \mathcal{Y}$ (ideal credit approval formula)
- data \Leftrightarrow training examples: $\mathcal{D} = \{(\mathbf{x}_1, y_1), (\mathbf{x}_2, y_2), \dots, (\mathbf{x}_N, y_N)\}$
 (historical records in bank)
- hypothesis \Leftrightarrow skill with hopefully good performance:
 $g: \mathcal{X} \rightarrow \mathcal{Y}$ ('learned' formula to be used)

$\{(\mathbf{x}_n, y_n)\}$ from $f \rightarrow \boxed{\text{ML}} \rightarrow g$

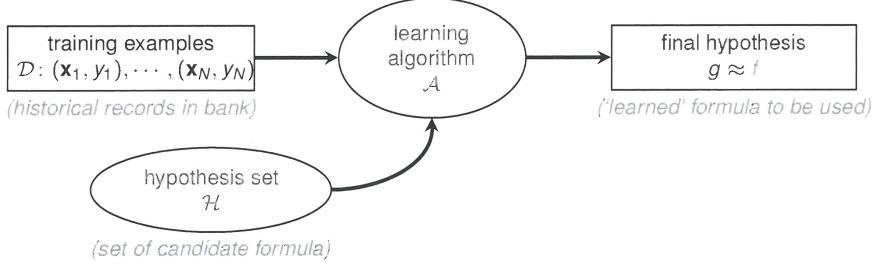
Learning Flow for Credit Approval



- **target f unknown**
(i.e. no programmable definition)
- hypothesis g hopefully $\approx f$
but possibly **different** from f
(perfection 'impossible' when f unknown)

What does g look like?

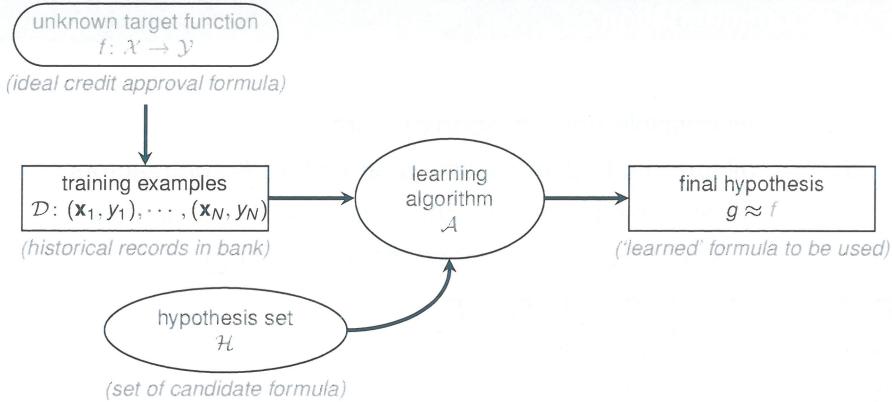
The Learning Model



- assume $g \in \mathcal{H} = \{h_k\}$, i.e. approving if
 - h_1 : annual salary > NTD 800,000
 - h_2 : debt > NTD 100,000 (really?)
 - h_3 : year in job ≤ 2 (really?)
- hypothesis set \mathcal{H} :
 - can contain **good or bad hypotheses**
 - up to \mathcal{A} to pick the 'best' one as g

learning model = \mathcal{A} and \mathcal{H}

Practical Definition of Machine Learning



machine learning:

use data to compute hypothesis g
that approximates target f

Fun Time

How to use the four sets below to form a learning problem for song recommendation?

$$\mathcal{S}_1 = [0, 100]$$

$$\mathcal{S}_2 = \text{all possible (userid, songid) pairs}$$

$$\mathcal{S}_3 = \text{all formula that 'multiplies' user factors \& song factors, indexed by all possible combinations of such factors}$$

$$\mathcal{S}_4 = 1,000,000 \text{ pairs of ((userid, songid), rating)}$$

$$① \mathcal{S}_1 = \mathcal{X}, \mathcal{S}_2 = \mathcal{Y}, \mathcal{S}_3 = \mathcal{H}, \mathcal{S}_4 = \mathcal{D}$$

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Reference Answer: ②

$$\mathcal{S}_4 \xrightarrow{\text{A on } \mathcal{S}_3} (g: \mathcal{S}_2 \rightarrow \mathcal{S}_1)$$

資料探勘

Machine Learning and Data Mining

Machine Learning

use data to compute hypothesis g that approximates target f

Data Mining

use (huge) data to find property that is interesting

- if ‘interesting property’ same as ‘hypothesis that approximate target’
—ML = DM (usually what KDDCup does)
- if ‘interesting property’ related to ‘hypothesis that approximate target’
—DM can help ML, and vice versa (often, but not always)
- traditional DM also focuses on efficient computation in large database

difficult to distinguish ML and DM in reality

Machine Learning and Artificial Intelligence

Machine Learning

use data to compute hypothesis g
that approximates target f

Artificial Intelligence

compute **something**
that shows intelligent behavior

審題

- $g \approx f$ is something that shows intelligent behavior
—ML can realize AI, among other routes
- e.g. chess playing
 - traditional AI: game tree
 - ML for AI: 'learning from board data'

ML is one possible route to realize AI

統計
統計

Machine Learning and Statistics

Machine Learning

use data to compute hypothesis g
that approximates target f

Statistics

use data to **make inference**
about an unknown process

- g is an inference outcome; f is something unknown
—statistics can be used to achieve ML
- traditional statistics also focus on **provable results with math assumptions**, and care less about computation

statistics: many useful tools for ML

Fun Time

Which of the following claim is not totally true?

- ① machine learning is a route to realize artificial intelligence
- ② machine learning, data mining and statistics all need data
- ③ data mining is just another name for machine learning
- ④ statistics can be used for data mining

Reference Answer: ③

While data mining and machine learning do share a huge overlap, they are arguably not equivalent because of the difference of focus.

Summary

① When Can Machines Learn?

Lecture 1: The Learning Problem

- Course Introduction
foundation oriented and story-like
- What is Machine Learning
use data to approximate target
- Applications of Machine Learning
almost everywhere
- Components of Machine Learning
 \mathcal{A} takes \mathcal{D} and \mathcal{H} to get g
- Machine Learning and Other Fields
related to DM, AI and Stats

- next: a simple and yet useful learning model (\mathcal{H} and \mathcal{A})

② Why Can Machines Learn?

③ How Can Machines Learn?

④ How Can Machines Learn Better?