Machine Learning for Modern Artificial Intelligence

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Winbond Electronics Corp.
華邦電子高階主管講座
About Me

Professor
National Taiwan University

Co-author
Learning from Data

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(former Chief Data Scientist)
Appier Inc.

Instructor
NTU-Coursera MOOCs
ML Foundations/Techniques
Outline

ML for (Modern) AI

ML Research for Modern AI

ML for AI in Reality
intelligence: thinking and acting **smartly**
- humanly
- rationally

artificial intelligence: **computers** thinking and acting **smartly**
- humanly
- rationally

humanly ≈ **smartly** ≈ rationally
—are humans rational? 😊
What if your self-driving car decides one death is better than two—and that one is you? (The Washington Post http://wpo.st/ZK-51)

You’re humming along in your self-driving car, chatting on your iPhone 37 while the machine navigates on its own. Then a swarm of people appears in the street, right in the path of the oncoming vehicle.

<table>
<thead>
<tr>
<th>Car Acting Humanly</th>
<th>Car Acting Rationally</th>
</tr>
</thead>
<tbody>
<tr>
<td>to save my (and passengers’) life, stay on track</td>
<td>avoid the crowd and crash the owner for minimum total loss</td>
</tr>
</tbody>
</table>

which is smarter?—depending on where I am, maybe? 😊
(Traditional) Artificial Intelligence

<table>
<thead>
<tr>
<th>Thinking Humanly</th>
<th>Thinking Rationally</th>
</tr>
</thead>
<tbody>
<tr>
<td>• cognitive modeling —now closer to Psychology than AI</td>
<td>• formal logic—now closer to Theoreticians than AI practitioners</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acting Humanly</th>
<th>Acting Rationally</th>
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</thead>
<tbody>
<tr>
<td>• dialog systems</td>
<td>• recommendation systems</td>
</tr>
<tr>
<td>• humanoid robots</td>
<td>• cleaning robots</td>
</tr>
<tr>
<td>• computer vision</td>
<td>• character recognition</td>
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</tbody>
</table>

acting humanly or rationally: more academia/industry attention nowadays
Traditional vs. Modern [My] Definition of AI

Traditional Definition
humanly ≈ intelligently ≈ rationally

My Definition
intelligently ≈ easily
is your smart phone ‘smart’? 😊

modern artificial intelligence
= application intelligence
Examples of Application Intelligence

Siri
By Bernard Goldbach [CC BY 2.0]

iRobot
By Yuan-Chou Lo [CC BY-NC-ND 2.0]

Amazon Recommendations
By Kelly Sims [CC BY 2.0]

Vivino
From nordic.businessinsider.com
• first AI winter: AI cannot solve ‘combinatorial explosion’ problems
• second AI winter: expert system failed to scale

reason of winters: **expectation mismatch**
### AI: Now and Next

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>AI becomes promising</strong>, e.g.</td>
<td><strong>AI becomes competitive</strong>, e.g.</td>
<td><strong>AI becomes necessary</strong></td>
</tr>
</tbody>
</table>
| • initial success of **deep learning** on ImageNet | • super-human performance of **alphaGo** and others | • “You’ll not be replaced by AI, but **by humans who know how to use AI**”
| • mature tools for SVM (**LIBSVM**) and others | • all big technology companies become **AI-first** | (Sun, Chief AI Scientist of Appier, 2018) |
What’s Different Now?

**More Data**
- cheaper storage
- Internet companies

**Faster Computation**
- cloud computing
- GPU computing

**Better Algorithms**
- decades of research
- e.g. deep learning

**Healthier Mindset**
- reasonable wishes
- key breakthroughs

**data-enabled** AI: mainstream nowadays
Bigger Data Enable Easier-to-use AI

By deepanker70 on https://pixabay.com/

**past**
- best route by shortest path

**present**
- best route by current traffic

**future**
- best route by predicted travel time

big data *can* make machine look smarter
Machine Learning Connects Big Data and AI

From Big Data to Artificial Intelligence

big data → ML → artificial intelligence

ingredient

tools/steps

dish

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many possibilities when using the right tools
ML-based AI Applications (1/6): Medicine

Data → ML → AI

For computer-assisted diagnosis

- Data:
  - Patient status
  - Past diagnosis from doctors

- AI: Dialogue system that efficiently identifies disease of patient

My student’s earlier work as intern @ HTC DeepQ
for 4G LTE communication

- **data:**
  - *channel information* (the channel matrix representing mutual information)
  - *configuration* (precoding, modulation, etc.) that reaches the highest throughput

- **AI:** predict **best configuration to the base station** in a new environment

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By JulianVilla26; licensed under CC BY-SA 4.0 via Wikimedia Commons

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my student’s earlier work as intern @ MTK
ML-based AI Applications (3/6): Education

- data: students’ records on quizzes on a Math tutoring system
- AI: 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
ML-based AI Applications (4/6): Entertainment

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

*world-champion* (again!) from National Taiwan Univ. in KDDCup 2011
ML-based AI Applications (5/6): Manufacturing

- **Data**: PCB images of normal and abnormal PCBs & maybe human-marked faulty locations
- **AI**: predict **which PCBs are faulty**

ongoing research for smart factory

By Raimond Spekking; licensed under CC BY-SA 4.0 via Wikimedia Commons
ML-based AI Applications (6/6): Security

face recognition

- **data**: faces and non-faces
- **AI**: predict which boxes contain faces

mature ML technique, but often need tuning for different application intelligence needs
Good AI Needs Both ML and Non-ML Techniques

**Non-ML Techniques**

- Monte C. Tree Search
  \[ \approx \text{move simulation in brain} \]

**ML Techniques**

- Deep Learning
  \[ \approx \text{board analysis in human brain} \]
- Reinforcement Learn.
  \[ \approx (\text{self})\text{-practice in human training} \]

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**good AI: important to use the right techniques—ML & others, including human**

(H.-T. Lin (NTU))
Full Picture of ML for Modern AI

- **Human learning/analysis**
  - **Big data**
  - **Method**
  - **ML**
  - **AI**

- **Domain knowledge**
  - **Expert system**

**Industry:** black plum is as sweet as white
Example: Tropical Cyclone Intensity Estimation

Meteorologists can ‘feel’ & estimate TC intensity from image

Better than current system & ‘trial-ready’
(Chen et al., KDD ’18; Chen et al., Weather & Forecasting ’19)
Outline

ML for (Modern) AI

ML Research for Modern AI

ML for AI in Reality
Cost-Sensitive Multiclass Classification
What is the Status of the Patient?

By DataBase Center for Life Science; licensed under CC BY 4.0 via Wikimedia Commons

? COVID19 cold healthy

Pictures Licensed under CC BY-SA 3.0 from 1RadicalOne on Wikimedia Commons

• a classification problem —grouping ‘patients’ into different ‘status’

are all mis-prediction costs equal?
Patient Status Prediction

error measure = society cost

<table>
<thead>
<tr>
<th>actual</th>
<th>COVID19</th>
<th>cold</th>
<th>healthy</th>
</tr>
</thead>
<tbody>
<tr>
<td>COVID19</td>
<td>0</td>
<td>1000</td>
<td>100000</td>
</tr>
<tr>
<td>cold</td>
<td>100</td>
<td>0</td>
<td>3000</td>
</tr>
<tr>
<td>healthy</td>
<td>100</td>
<td>30</td>
<td>0</td>
</tr>
</tbody>
</table>

- COVID19 mis-predicted as healthy: very high cost
- cold mis-predicted as healthy: high cost
- cold correctly predicted as cold: no cost

human doctors consider costs of decision; how about computer-aided diagnosis?
## Our Works

<table>
<thead>
<tr>
<th></th>
<th>binary</th>
<th>multiclass</th>
</tr>
</thead>
<tbody>
<tr>
<td>regular</td>
<td>well-studied</td>
<td>well-studied</td>
</tr>
<tr>
<td>cost-sensitive</td>
<td>known (Zadrozny et al., 2003)</td>
<td>ongoing (our works, among others)</td>
</tr>
</tbody>
</table>

### selected works of ours

- cost-sensitive SVM (Tu and Lin, ICML 2010)
- cost-sensitive one-versus-one (Lin, ACML 2014)
- cost-sensitive deep learning (Chung et al., IJCAI 2016)

**why are people not using those cool ML works for their AI? 😊**
### Issue 1: Where Do Costs Come From?

#### A Real Medical Application: Classifying Bacteria

- by human doctors: different treatments ⇔ serious costs
- cost matrix averaged from two doctors:

```
   Ab  Ecoli  HI  KP  LM  Nm  Psa  Spn  Sa  GBS
---  ---  ---  ---  ---  ---  ---  ---  ---  ---
 Ab  0    1   10   7   9   9   5   8   9   1
 Ecoli 3    0   10   8   10  10  5  10  10  2
 HI   10   10   0   3   2   2  10   1   2  10
 KP   7    7   3   0   4   4   6   3   3   8
 LM   8    8   2   4   0   5   8   2   1   8
 Nm  3    10   9   8   6   0   8   3   6   7
 Psa 7    8  10   9   9   7   0   8   9   5
 Spn 6    10   7   7   4   4   9   0   4   7
 Sa   7    10   6   5   1   3   9   2   0   7
 GBS 2    5  10   9   8   6   5   6   8   0
```

### issue 2: is cost-sensitive classification really useful?
Cost-Sensitive vs. Traditional on Bacteria Data

Are cost-sensitive algorithms great?

Cost-sensitive algorithms perform better than regular algorithms

Jan et al. (Academic Sinica)

Cost-Sensitive Classification on SERS

October 31, 2011 15 / 19

(Jan et al., BIBM 2011)

cost-sensitive better than traditional; but why are people still not using those cool ML works for their AI? 😊
The Problem

- cost-sensitive classifier: low cost but high error rate
- traditional classifier: low error rate but high cost
- how can we get the blue classifiers?: low error rate and low cost

cost-and-error-sensitive: more suitable for real-world medical needs
Improved Classifier for Both Cost and Error

(Jan et al., KDD 2012)

<table>
<thead>
<tr>
<th>Cost</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>iris</td>
<td>iris</td>
</tr>
<tr>
<td>wine</td>
<td>wine</td>
</tr>
<tr>
<td>glass</td>
<td>glass</td>
</tr>
<tr>
<td>vehicle</td>
<td>vehicle</td>
</tr>
<tr>
<td>vowel</td>
<td>vowel</td>
</tr>
<tr>
<td>segment</td>
<td>segment</td>
</tr>
<tr>
<td>dna</td>
<td>dna</td>
</tr>
<tr>
<td>satimage</td>
<td>satimage</td>
</tr>
<tr>
<td>usps</td>
<td>usps</td>
</tr>
<tr>
<td>zoo</td>
<td>zoo</td>
</tr>
<tr>
<td>splice</td>
<td>splice</td>
</tr>
<tr>
<td>ecoli</td>
<td>ecoli</td>
</tr>
<tr>
<td>soybean</td>
<td>soybean</td>
</tr>
</tbody>
</table>

now, are people using those cool ML works for their AI? 😊
Lessons Learned from Research on Cost-Sensitive Multiclass Classification

1. more realistic (generic) in academia
   ≠ more realistic (feasible) in application
   e.g. the ‘cost’ of inputting a cost matrix?
   😊

2. cross-domain collaboration important
   e.g. getting the ‘cost matrix’ from domain experts

3. not easy to win human trust
   —humans are somewhat multi-objective

See Page 16 of the Slides for Sources of the Pictures
Tropical Cyclone Intensity Estimation
Experienced Meteorologists Can ‘Feel’ and Estimate Tropical Cyclone Intensity from Image

Can ML do the same/better?

- lack of **ML-ready datasets**
- lack of **model that properly utilizes domain knowledge**

issues addressed in our latest works

(Chen et al., KDD ’18; Chen et al., Weather & Forecasting ’19)
Recall: Flow behind Our Proposed Model

- TC images
- human learning/analysis
- domain knowledge (HI)
- CNN
- polar rotation invariance
- current weather system
- intensity estimation
- ML

is proposed **CNN-TC** better than current weather system?
### Results

#### RMS Error

<table>
<thead>
<tr>
<th>Model</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADT</td>
<td>11.75</td>
</tr>
<tr>
<td>AMSU</td>
<td>14.40</td>
</tr>
<tr>
<td>SATCON</td>
<td>9.66</td>
</tr>
<tr>
<td>CNN-TC</td>
<td>9.03</td>
</tr>
</tbody>
</table>

**CNN-TC** much better than current weather system (SATCON)

why are people not using this cool ML model? 😊
Lessons Learned from Research on Tropical Cyclone Intensity Estimation

1. Again, **cross-domain collaboration** important
   e.g. even from ‘organizing data’ to be ML-ready

2. Not easy to claim **production ready**
   —can ML be used for ‘**unseenly-strong** TC’?

3. Good AI system requires **both human and machine learning**
   —still an ‘art’ to blend the two
ML for AI in Reality

Outline

ML for (Modern) AI

ML Research for Modern AI

ML for AI in Reality
What is the best AI project for (my precious big) data?

My Polite Answer

good start already 😊, any more thoughts that you have in mind?

My Honest Answer

I don’t know.

or a slightly longer answer:
if you don’t know, I don’t know.
A Similar Scenario

What is the best AI project for (my precious big) data?
how to find a research topic for my thesis?

My Polite Answer

good start already 😊, any more thoughts that you have in mind?

My Honest Answer

I don’t know.

or a slightly longer answer:
I don’t know, but perhaps you can start by thinking about motivation and feasibility.
Finding AI Projects ≈ Finding Research Topics

- **motivation**: what are you interested in?
- **feasibility**: what can or cannot be done?

### motivation
- something publishable? oh, possibly **just for people in academia 😊**
- something that **improves xyz performance**
- something that inspires deeper study
—helps **generate** questions

### feasibility
- **modeling**
- **computational**
- budget
- timeline
—helps **filter** questions

**tip**: important for **first AI project** to be of **high success possibility**
Should I use ML (or my precious Deep Learning) for my AI project?

**My Polite Answer**

let’s understand more about the constraints of your project, shall we 😊?

**My Honest Answer**

I don’t know.

or a slightly longer answer:

if you don’t know, I don’t know.
Necessary Conditions for Using ML

1. exists some “underlying pattern” to be learned
   —so “AI goal” possible
2. but no programmable (easy) definition
   —so “ML” is needed
3. somehow there is enough data about the pattern
   —so ML has some “inputs” to learn from

necessary, but not sufficient, for using ML
Human Learning versus Machine Learning

**Human Learning**
- subjective
- produce domain knowledge
- fast basic solution

**Machine Learning**
- objective
- leverage computing power
- continuous improvement

**tip:** use humans as much as possible first before going to machines
What is the best machine learning model for (my precious big) data and AI?

**My Polite Answer**
the best model is **data-dependent**, let’s chat about your data first

**My Honest Answer**
I don’t know.

or a slightly longer answer:
I don’t know about **best**, but perhaps you can start by thinking about **simple models**.
What is the best machine learning model for (my precious big) data and AI?

What is the most sophisticated machine learning model for (my precious big) data and AI?

- myth: my AI works best with most sophisticated model
- sophisticated model:
  - time-consuming to train and predict
  - difficult to tune or modify
  - hard to “simplify” nor “analyze”

sophisticated model shouldn’t be first choice
What is the first machine learning model for (my precious big) data and AI?

Simple model first:
- efficient to train and predict
- easy to tune or modify
- somewhat “analyzable”
- little risk

My KISS Principle:
Keep It Simple, Stupid Safe
How to Get my AI Project Started?

Old Me
I don’t know. 😊

New Me
I know one key factor!

let’s see what the key factor is
Todos in AI Project

- (big) data
- machine learning
- artificial intelligence

**Data**
- gathering
- cleaning
- storing
- ...

**Techniques**
- modeling
- computation
- non-ML tech.
- ...

**Usage**
- evaluation
- deployment
- scalability
- ...

Key first step: set up evaluation criteria
Evaluation Criteria Guide AI Project Planning

suggest improvement opportunities

**data**
- hint
- preparation steps

**techniques**
- assist
- model/tech. choices

**usage**
- define
- acceptance goals

**tip:** always start with reasonable & measurable criteria to describe prioritized AI goal
Summary

- ML for (Modern) AI: tools + human knowledge ⇒ easy-to-use application
- ML Research for Modern AI: need to be more open-minded
  —in methodology, in collaboration, in KPI
- ML for AI in Reality:
  - motivated/feasible project with measurable criteria
  - human and/or simple model first

Thank you! Questions?

H.-T. Lin (NTU)