Machine Learning for Artificial Intelligence in Medicine Applications

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About Me
Hsuan-Tien Lin

- Professor, Dept. of CSIE, National Taiwan University
- Chief Data Science Consultant, Appier
- Co-author of textbook “Learning from Data: A Short Course”
- Instructor of the NTU-Coursera Mandarin-teaching ML Massive Open Online Courses
  - “Machine Learning Foundations”:
    www.coursera.org/course/ntumlone
  - “Machine Learning Techniques”:
    www.coursera.org/course/ntumltwo
researched on quite a few ML-related topics, but . . .

limited first-hand experience in ML for AI in Medicine Applications

- Peng et al., . . . for fast disease diagnosis, NeurIPS 2018: building family-medicine doctor-bot
- Chou and Lin, ML for interactive verification, PAKDD 2014: effective use of doctor’s time on screening X-ray scans
- Jan et al., Cost-sensitive classification on pathogen species of bacterial meningitis . . ., BIBM 2011: leveraging doctor’s domain knowledge (to be introduced)
- Lin and Li. Analysis of SAGE results with combined learning techniques. In ECML/PKDD Discovery Challenge 2015: using machine learning properly on small medical data

will talk more about general wisdom (hopefully), less about specific techniques
Outline

ML for (Modern) AI

ML for AI in Medicine Application: My Own Story

Suggestions to Medicine Researchers on Using ML-driven AI
intelligence: thinking and acting smartly

- humanly
- rationally

artificial intelligence: computers thinking and acting smartly

- humanly
- rationally

humanly ≈ smartly ≈ rationally
—are humans rational? :-)

From Intelligence to Artificial Intelligence

Hsuan-Tien Lin (NTU)
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](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.

**Car Acting **Humanly **to save my (and passengers’) life, stay on track**

**Car Acting **Rationally **avoid the crowd and crash the owner for minimum total loss**

which is smarter?
—depending on where I am, maybe? :-(
### Thinking Humanly
- Cognitive modeling — now closer to Psychology than AI

### Acting Humanly
- Dialog systems
- Humanoid robots
- Computer vision

### Thinking Rationally
- Formal logic — now closer to Theoreticians than AI practitioners

### Acting Rationally
- Recommendation systems
- Cleaning robots
- Cross-device ad placement

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

**Traditional Definition**
humanly $\approx$ intelligently $\approx$ rationally

**My Definition**
intelligently $\approx$ easily
is your smart phone ‘smart’? :-)

user-needs-driven AI is important
AI Milestones

- first AI winter: AI cannot solve ‘combinatorial explosion’ problems
- second AI winter: expert system failed to scale

reason of winters: expectation mismatch
What’s Different Now?

More Data
- cheaper storage
- Internet companies

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

Faster Computation
- cloud computing
- GPU computing

Healthier Mindset
- reasonable wishes
- key breakthroughs

**data-enabled** AI: mainstream nowadays
Machine Learning and AI

Easy-to-Use

Acting Humanly

Machine Learning

Acting Rationally

machine learning: core behind modern (data-enabled) AI
ML Connects (Big) Data and AI

From Big Data to Artificial Intelligence

big data → ML → artificial intelligence

ingredient → tools/steps → dish

(Photos Licensed under CC BY 2.0 from Andrea Goh on Flickr)

ML Scientist ≡ restaurant chef
Bigger Data Towards Better AI

best route by shortest path

best route by current traffic

best route by predicted travel time

big data can make machine look smarter
human learning/analysis

domain knowledge (HI)

big data

model

expert system

ML

human sometimes faster learner on initial (smaller) data

industry: black plum is as sweet as white

often important to leverage human learning, especially in the beginning
AI: Now and Next

**2010–2015**
AI becomes **promising**, e.g.
- initial success of **deep learning** on ImageNet
- mature tools for SVM (**LIBSVM**) and others

**2016–2020**
AI becomes **competitive**, e.g.
- super-human performance of **alphaGo** and others
- all big technology companies become **AI-first**

**2021–**
AI becomes **necessary**
- “You’ll not be replaced by AI, but by humans who know how to use AI”
  (Sun, Chief AI Scientist of Appier, 2018)
Outline

ML for (Modern) AI

ML for AI in Medicine Application: My Own Story

Suggestions to Medicine Researchers on Using ML-driven AI
What is the Status of the Patient?

- H7N9-infected
- cold-infected
- healthy

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

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**are all mis-prediction costs equal?**
Patient Status Prediction

error measure = society cost

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<th>H7N9</th>
<th>cold</th>
<th>healthy</th>
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<td>100</td>
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<tr>
<td>healthy</td>
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- H7N9 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

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<tr>
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<tr>
<td>regular</td>
<td>well-studied</td>
<td>well-studied</td>
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<tr>
<td>cost-sensitive</td>
<td>known (Zadrozny et al., 2003)</td>
<td>ongoing (our works, among others)</td>
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</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? :-)

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Hsuan-Tien Lin (NTU)
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:

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<th>LM</th>
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Issue 2: is cost-sensitive classification really useful?
Cost-Sensitive vs. Traditional on Bacteria Data

(Jan et al., BIBM 2011)

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

Hsuan-Tien Lin (NTU)
Machine Learning for Artificial Intelligence in Medicine Applications
Issue 3: Error Rate of Cost-Sensitive Classifiers

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)*

### Cost

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<th>wine</th>
<th>glass</th>
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### Error

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*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 inputing 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
ML for (Modern) AI

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Suggestions to Medicine Researchers on Using ML-driven AI
Is Logistic Regression Part of ML?

No

• developed in 1958, **even** before “ML” named
• applied on medicine research **long before “ML” popularized**
  (e.g. [https://www.ncbi.nlm.nih.gov/pubmed/11576808](https://www.ncbi.nlm.nih.gov/pubmed/11576808))

Yes

• wikipedia: “Logistic regression is an **important ML algorithm**.”
• special case of modern deep learning approaches
• widely included in ML tool boxes

my biased opinion:

LogReg **analysis**: not (typical) ML;
LogReg **algorithm**: (typical) ML

but **both important for modern AI**
Shall We Replace Our Logistic Regression Model with Fancy ML Models?

Yes
- ML may provide more opportunities for better solving your problem
  - consider more factors
  - leverage non-linear relationship
- learn → analyze (ML) v.s. analyze → regress

No
- LogReg: safe first-hand choice in ML anyway—philosophy of linear first
- not really replacing, but worth comparing
- super big ML jungle: risky if lost

Concrete suggestions:
- compare with (“try”) some mature ML models
- consult/collaborate with ML specialist if using advanced ML models
Suggestions to Medicine Researchers on Using ML-driven AI

Some Mature ML Models Recommended

Random Forest
- voting of many (random) decision trees
- analysis: feature importance
- benefit: robust and efficient in general

Gradient Boosted Decision Tree
- optimized combination of decision trees
- analysis: feature importance
- benefit: accurate for many applications

(RBF-) Support Vector Machine
- optimized combination of key examples
- analysis: key examples (support vectors)
- benefit: robust for mid-sized data

suggested reading:

A Practical Guide to Support Vector Classification
Can We Explain ML Predictions?

courtesy of my Appier colleague
Jen-Yee Hong, M.D.

Yes

• for simple models like LogReg using statistics tools or feature importance
• ongoing research to explain complex ML models with some initial success on visual data

No

• not generally applicable to every ML model nowadays

explainable ML is getting more important
Can We Trust ML Predictions?

courtesy of my Appier colleague
Jen-Yee Hong, M.D.

Yes
- ML can be more accurate if properly used

No
- non-ML-specialists may not properly use ML tools
- need more honest success stories before winning human trust

trust needs accumulation
Summary

- ML for (Modern) AI: tools + human knowledge ⇒ easy-to-use application
- ML Research for AI in Medicine Applications: collaborative to keep discovering new research directions
- Suggestions to Medicine Researchers on Using ML-driven AI: ML provides more opportunities but needs care

Thank you! Questions?