

CS599

Deep Learning

Lecture 1: applications of machine learning

Toby Dylan Hocking
toby.hocking@nau.edu

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What is machine learning?

- Computer science: domain of study about efficient algorithms / computations.
- Artificial intelligence: sub-domain concerned with algorithms for accurate predictions/suggestions.
- Machine learning: sub-domain concerned with algorithms for large data.
- Machine learning is widely used in search engines, automatic translation, image analysis, ...

Computer science

Artificial intelligence

Machine learning:
linear models,
decision trees,
nearest neighbors, ...

Neural networks

Deep learning

Machine learning intro: image classification example

ML is all about learning predictive functions $f(x) \approx y$, where

- ▶ Inputs/features x can be easily computed using traditional algorithms, e.g. matrix of pixel intensities in an image.
- ▶ Outputs/labels y are what we want to predict, easy to get by asking a human, but hard to compute using traditional algorithms, e.g. image class.
- ▶ Input $x =$ image of digit, output $y \in \{0, 1, \dots, 9\}$,
 - this is a classification problem with 10 classes.



$$f(\textcircled{0}) = 0$$



$$f(\textcircled{1}) = 1$$

- ▶ Traditional/unsupervised algorithm: I give you a pixel intensity matrix $x \in \mathbb{R}^{16 \times 16}$, you code a function f that returns one of the 10 possible digits. Q: how to do that?

Supervised machine learning algorithms

I give you a training data set with paired inputs/outputs, e.g.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
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| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

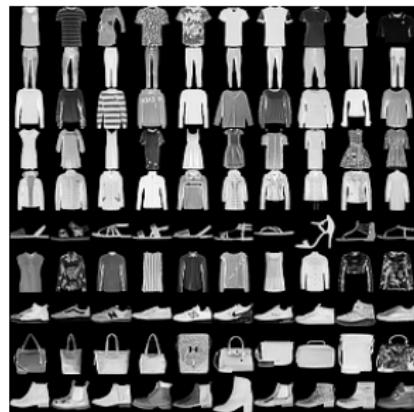
Your job is to code an algorithm that learns the function f from the training data. (you don't code f)
Source: github.com/cazala/mnist

Supervised machine learning algorithms

Can be used typically whenever a knowledgeable/skilled human can easily/quickly/consistently create a large database of labels.

Should be used if it is not easy to code the function f for predicting the labels by hand.

Advantages of supervised machine learning



- ▶ Input $x \in \mathbb{R}^{16 \times 16}$, output $y \in \{0, 1, \dots, 9\}$ types the same!
- ▶ Can use same learning algorithm regardless of pattern.
- ▶ Pattern encoded in the labels (not the algorithm).
- ▶ Useful if there are many un-labeled data, but few labeled data (or getting labels is long/costly).
- ▶ State-of-the-art accuracy (if there is enough training data).

Sources: github.com/cazala/mnist, github.com/zalandoresearch/fashion-mnist

Learning two different functions using two data sets

Figure from chapter by Hocking TD, *Introduction to machine learning and neural networks* for book *Land Carbon Cycle Modeling: Matrix Approach, Data Assimilation, and Ecological Forecasting* edited by Luo Y (Taylor and Francis, 2022).

Learning Algorithm Train data Learned function Predictions on test data

Learn(\quad) $\rightarrow g$

| Label 0 | Label 1 | Label 2 | Label 3 | Label 4 | Label 5 | Label 6 | Label 7 | Label 8 | Label 9 |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
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| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

$$\begin{aligned}g(\textcircled{0}) &= 0 \\g(\textcircled{1}) &= 1 \\g(\textcircled{1}) &= 1\end{aligned}$$

Learn(\quad) $\rightarrow h$



$$\begin{aligned}h(\textcircled{1}) &= 0 \\h(\textcircled{1}) &= 0 \\h(\textcircled{1}) &= 1\end{aligned}$$

Learn is a learning algorithm you have coded, which outputs g and

h. Q: what happens if you do $g(\text{靴})$, or $h(\text{靴})$?

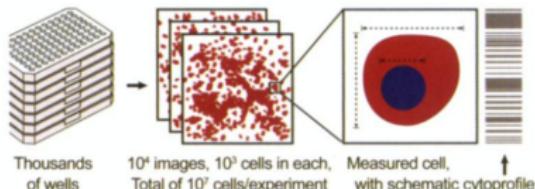


Machine learning for cell image classification (CellProfiler)

Jones *et al.* PNAS 2009. Scoring diverse cellular morphologies in image-based screens with iterative feedback and machine learning.

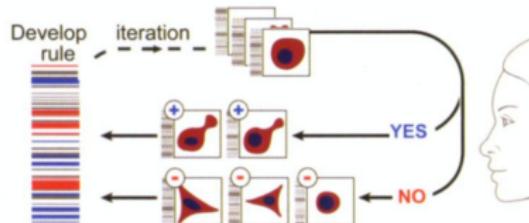
A Automated Cell Image Processing

Cytoprofile of 500+ features measured for each cell



B Iterative Machine Learning

System presents cells to biologist for scoring, in batches



- ▶ Input x = image of cell,
- ▶ Output $y \in \{\text{yes}, \text{no}\}$ (binary classification),

- ▶ $f(\text{ }) = \text{yes}$,
- ▶ $f(\text{ }) = \text{no}$.

Machine learning for image segmentation (LabelMe)



Figure 1. A screenshot of the labeling tool in use. The user is shown an image along with possibly one or more existing annotations, which are drawn on the image. The user has the option of annotating a new object by clicking along the boundary of the desired object and labeling it. Labels will be added to the image and the system will ask for the name of the object.

Machine learning for image segmentation

Paper cup



Rock



Statue



Chair



Russell *et al.* 2007.

Q: What are the types/dimensions of x, y, f in this example?

Machine learning for spam filtering (Gmail)

A few of your incoming messages has been suspended ➔ Spam

De Vito Raffael... Jan 11, 2019, 5:11 AM (3 days ago) ★ ↗
to no_reply@micorosoft.net

Why is this message in spam? It is similar to messages that were identified as spam in the past.

Report not spam

Re: Assay Standards call, September 5th

Myrto Kostadima ko... Tue, Sep 5, 2017, 1:45 AM ★ ↗
to Cath, assay_standards@ihec-intranet.org

Please, find attached a short presentation on the ChIP-seq analysis pipeline.

Thanks,
Myrto

Your Messages Has Been Suspended By Microsoft Outlook Team

A few of your incoming messages has been suspended by Microsoft verification Team because your email box account has not been properly verify. Do [verify](#) now to receive your suspended messages now.

On 01/09/2017 20:09, Cath Ennis wrote:

Hello all

We have a call scheduled for Tuesday September 5th at 6am Pacific time. I've attached the minutes from the last call (also available on the IHEC intranet)

Want: $f(\text{email message}) \in \{0, 1\}$ – binary classification, spam=1 or not=0.

Machine learning for translation (google books)

LE COMTE
DE
COUNT OF MONTE-CRISTO.
MONTE-CRISTO
BY
ALEXANDRE DUMAS

ABRIDGED AND ANNOTATED
BY
EDGAR EWING BRANDON, A.M.
Professor of French in Miami University

Twenty Illustrations,
DRAWN ON WOOD BY M. VALENTIN,
AND EXECUTED BY THE MOST EMINENT ENGLISH ENGRAVERS,
UNDER THE SUPERINTENDENCE OF MR. CHARLES HEATH.



NEW YORK
HENRY HOLT AND COMPANY
1900

IN TWO VOLUMES.
VOL. II.

LONDON:
CHAPMAN AND HALL, 186 STRAND.

1846.

Machine learning for translation (google translate)

— Fernand! lui cria-t-il, de mes noms, je n'aurais besoin de t'en dire qu'un seul pour te foudroyer; mais ce nom, tu le devines, n'est-ce pas? ou plutôt tu te le rappelles? car, malgré tous mes chagrins, toutes mes tortures, je te montre aujourd'hui un visage que le bonheur de la vengeance rajeunit, un visage que tu dois avoir vu bien souvent dans tes rêves depuis ton mariage... avec Mercédès, ma fiancée!

Le général, la tête renversée en arrière, les mains étendues, le regard fixe, dévora en silence ce terrible spectacle; puis, allant chercher la muraille comme point d'appui, il s'y glissa lentement jusqu'à la porte par laquelle il sortit à reculons, en laissant échapper ce seul cri lugubre, lamentable, déchirant:

Want: $f($ — Edmond Dantès! $) =$

“Fernand,” cried he, “of my hundred names I need only tell you one to overwhelm you! But you guess it now; do you not?—or, rather, you remember it? For, notwithstanding all my sorrows and my tortures, I shew you to-day a face which the happiness of revenge makes young again—a face you must often have seen in your dreams since your marriage with Mercédès, my betrothed!”

The general, with his head thrown back, hands extended, gaze fixed, looked silently at this dreadful apparition; then seeking the wall to support him, he glided along close to it until he reached the door, through which he went out backwards, uttering this single mournful, lamentable, distressing cry,—

“Edmond Dantès!”

Machine learning for translation (google translate)

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— Edmond Dantès!

Machine learning for translation (google translate)

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“Edmond Dantès!”

Machine learning for music transcription

- Want: $f(\text{mp3 file}) = \text{score for all instruments playing}$, e.g.



- Listening to mp3 then writing score is difficult! (but possible)
- Generating a real/recorded mp3 file based on score is also difficult (need skilled musicians to read/play).
- Easy to compute $\text{SYNTH(score)} = \text{synthesized mp3 file}$.
- Q: can we use synthesized mp3 files to train a ML algo?
- Listen to MP3s: recorded, synthesized.

Machine learning for recognizing cursive handwriting

Optical/intelligent character/word recognition

Want:

River Rafting Trip June 10 - 25, 1989
14 days on the Colorado River from
Lee's Ferry below Lake Powell to
Diamond Creek above Lake Mead,
Through the Grand Canyon.) =
f(

Machine learning for recognizing cursive handwriting

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River Rafting Trip June 10–25, 1989

14 days on the Colorado River from

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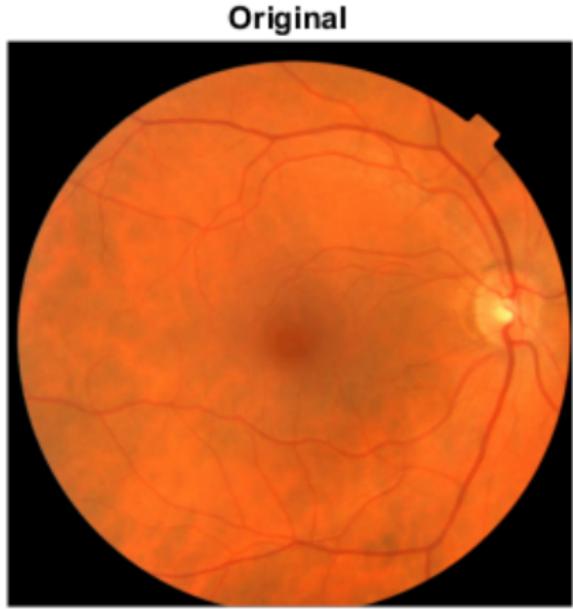
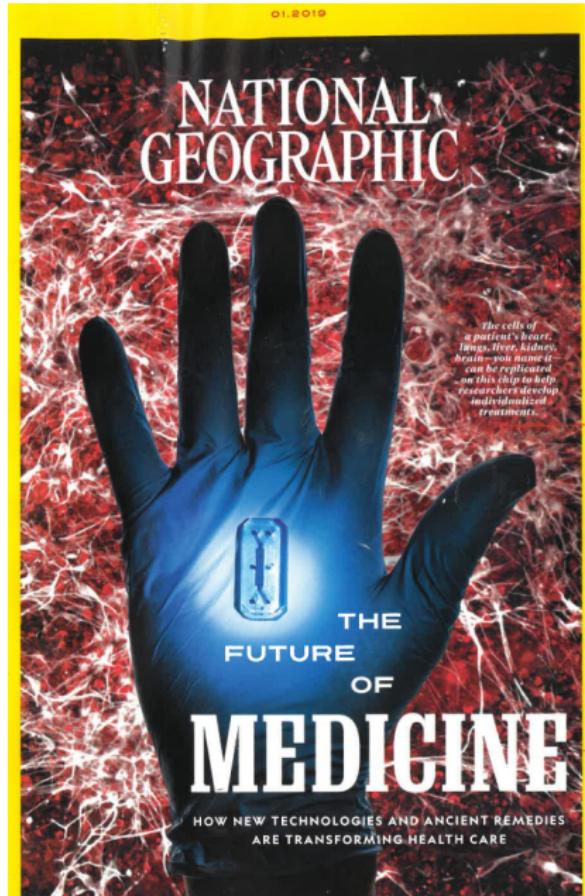
Machine learning for recognizing cursive handwriting

It was a success, good job.
Mike (NICEST MAN ON THE PLANET) gets up early,
flies on coffee water, helped at every
turn and besides this - he gives a
message to get the woman - we all
love it - its' heaven! Finally since
Mike passed away, GREAT! Cindy is his
counterpart - she is indispensable. Mike
handles everything; helps where ever needed
and is a caring, lovely person.

Q: sometimes you hear about "AI more accurate than human" – what does that mean, if the human is defining the labels?

Q: Can AI be more accurate at reading this than my grandmother, who wrote it?

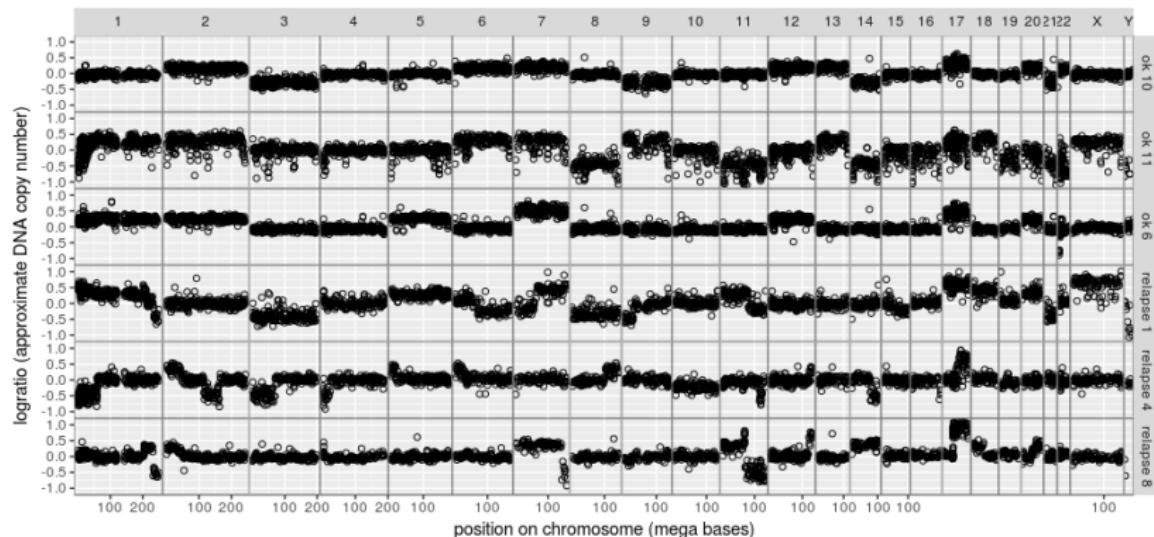
Machine learning for medical diagnosis



f()=

Thanks to artificial intelligence and machine learning, diagnostic tools can be trained to read tissue samples and radiologic scans. Google researchers fed more than a quarter-million patients' retinal scans into algorithms that recognize patterns—and the technology "learned" to spot which patterns predict a patient has high blood pressure or is at increased risk for heart attack or stroke. In some comparisons, digital tools produced more accurate analyses than did human pathologists, dermatolo-

Machine learning for medical diagnosis 2



- ▶ Each row is a genomic profile from a cancer patient.
- ▶ Each column is a different chromosome.
- ▶ Approximate copy number plotted against chrom position.
- ▶ Want $f(\text{profile}) \in \{\text{ok}, \text{relapse}\}$.
- ▶ Can you determine an f by visual inspection?

Machine learning for other applications

I have mostly presented machine learning applications which I believe are good for the future of humanity. (e.g. google translate makes it easier for people to communicate/understand each other)

Q: what are some other applications of machine learning which are good/bad for the future of humanity? Why?