CS499
Deep Learning
Lecture 1: applications of machine learning

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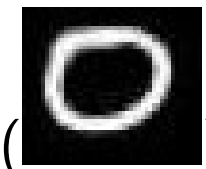
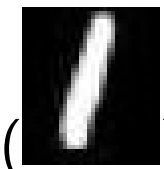
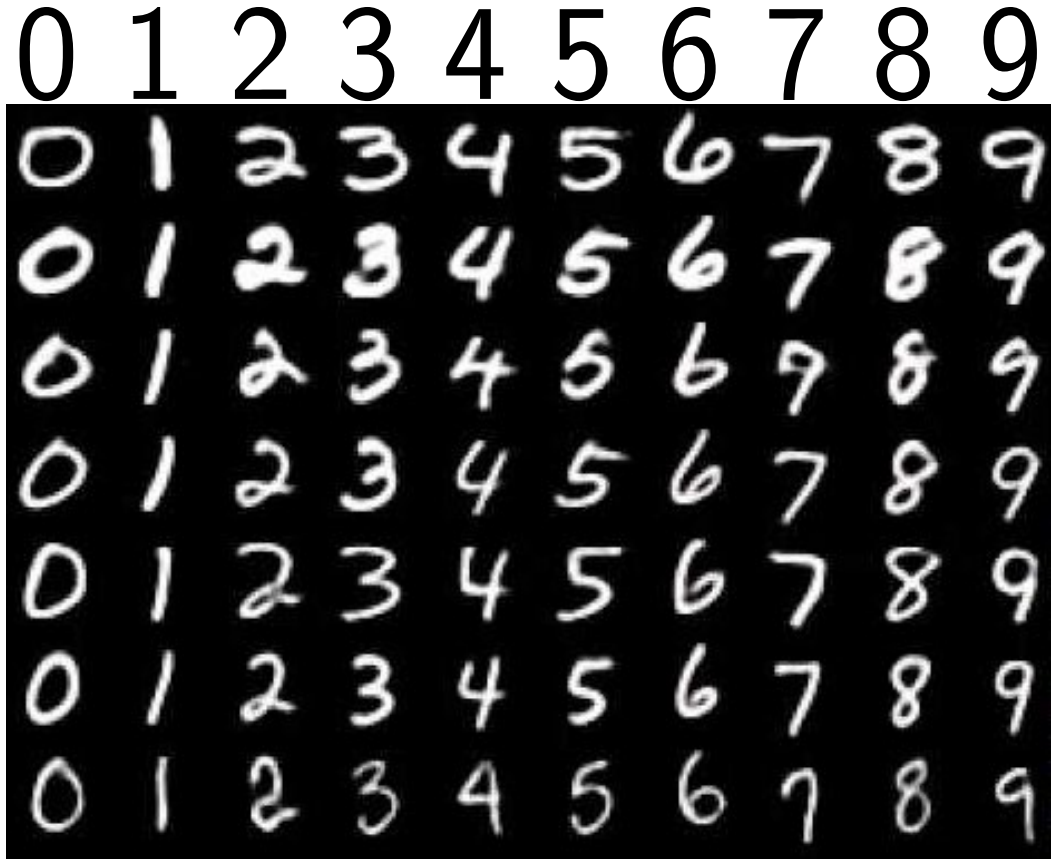
Machine learning intro: image classification example

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 $y \in \{0, 1, \ldots, 9\}$,
  – this is a classification problem with 10 classes.
  $f($  $) = 0$, $f($  $) = 1$
- 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.



Your job is to code an algorithm that learns the function f from the training data. (you don't code f)

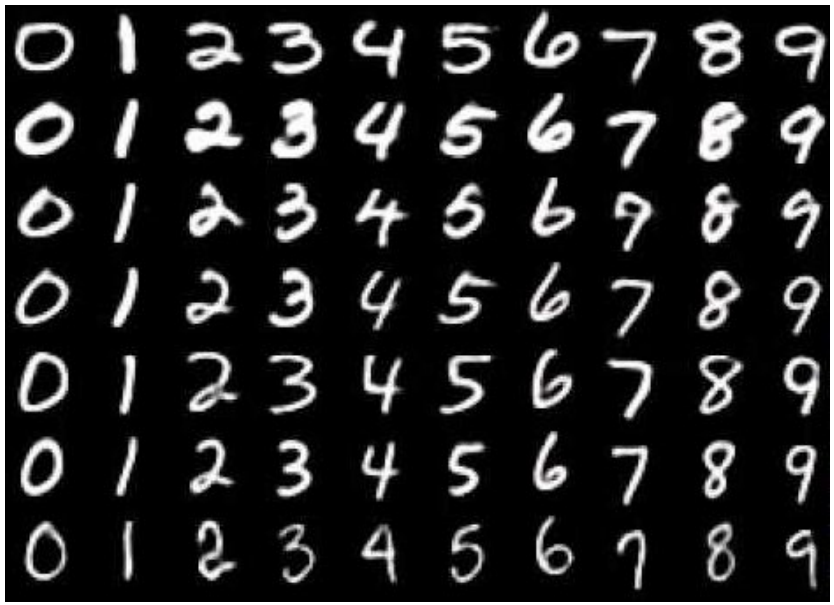
Source: github.com/cazala/mnist

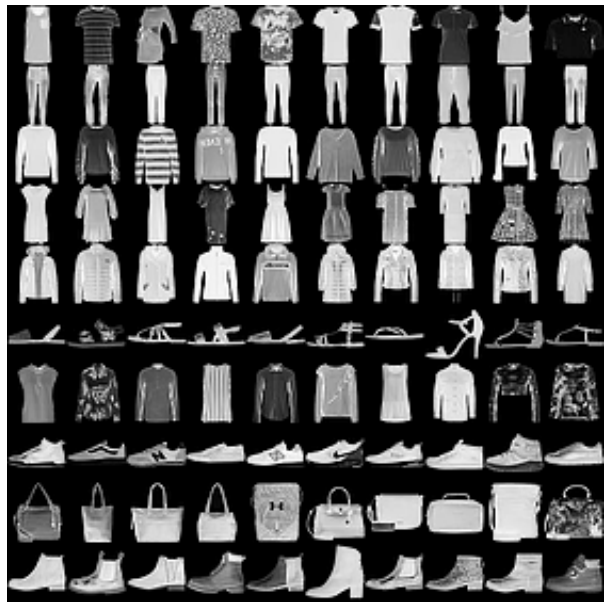
Supervised machine learning algorithms

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



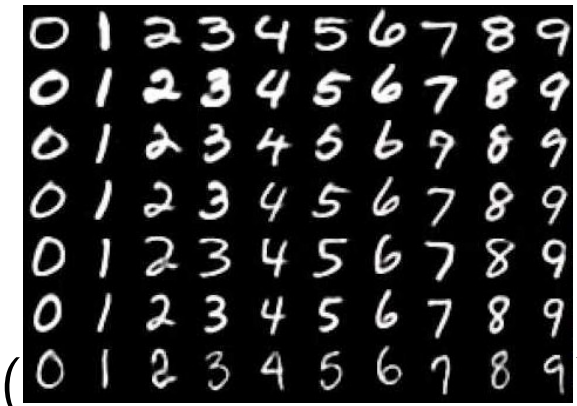
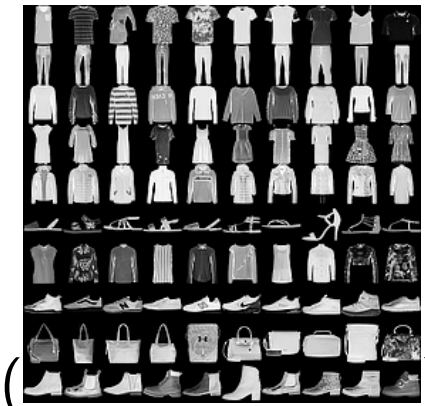


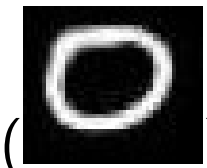
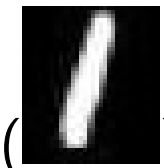
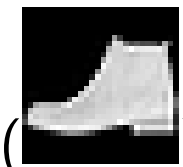
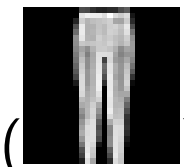
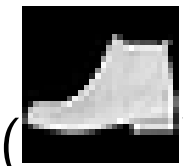
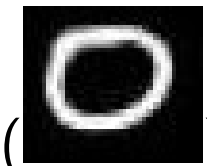
- Input $x \in \mathbb{R}^{16\times16}$, output $y \in \{0, 1, \ldots, 9\}$ types the same!
- Can use same learning algorithm regardless of pattern.
- Pattern encoded in the labels (not the algorithm).
- Useful if there are many un-labeled data, but few labeled data (or getting labels is long/costly).
- 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

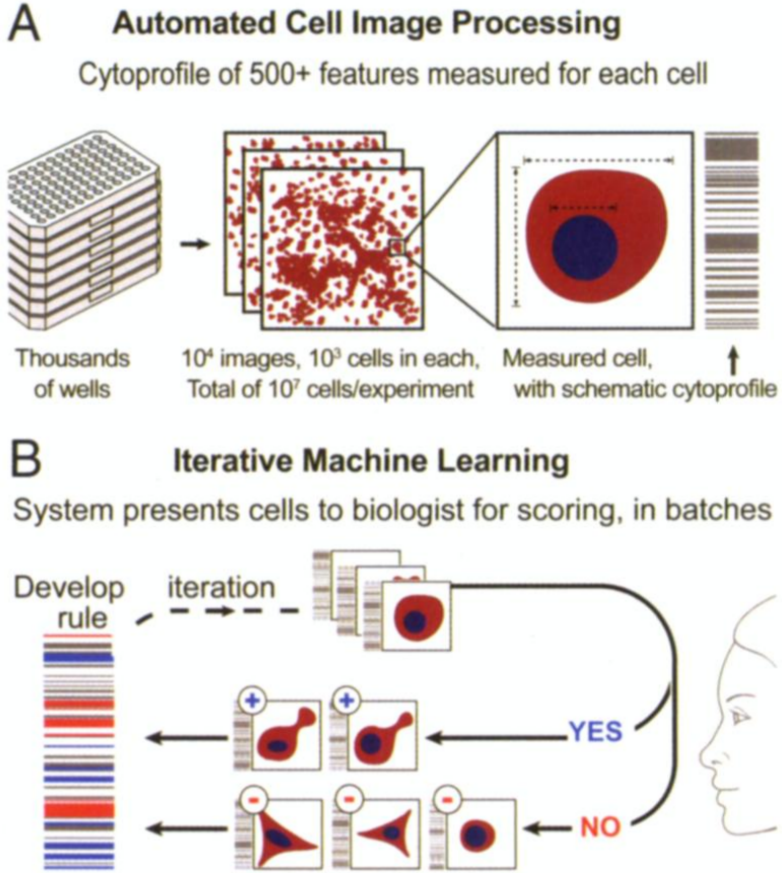
Say LEARN is a learning algorithm you have coded.

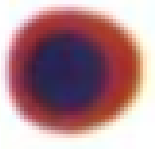
LEARN() $\rightarrow f$, LEARN() $\rightarrow g$

- Then we would expect $f($  $) = 0$, $f($  $) = 1$
- $g($  $) =$ shoe$/0$, $g($  $) =$ pants$/1$
- Q: what happens if you do $f($  $)$, or $g($  $)$?

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.



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

Machine learning for image segmentation (LabelMe)

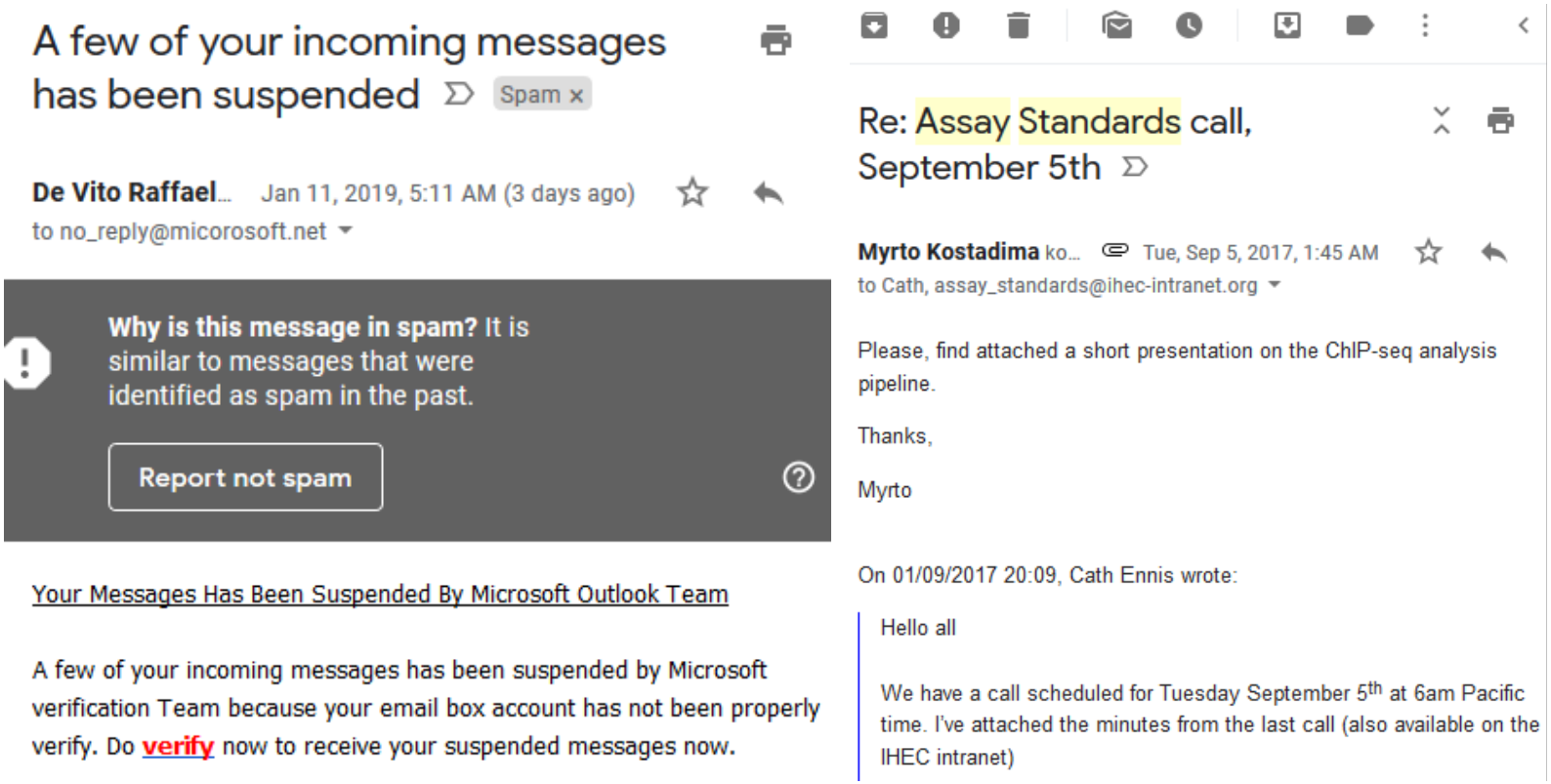
Figure 1. A screenshot of the labeling tool in use. The user is shown an image along with possibly one or more existing annotations, which are drawn on the image. The user has the option of annotating a new object by clicking along the boundary of the desired object and

Machine learning for image segmentation

Russell *et al.* 2007.

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

Machine learning for spam filtering (Gmail)



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

Machine learning for translation (google books)

LE COMTE

DE

MONTE-CRISTO

PAR

ALEXANDRE DUMAS

ABRIDGED AND ANNOTATED

BY

EDGAR EWING BRANDON, A.M.

Professor of French in Miami University

NEW YORK

HENRY HOLT AND COMPANY

1900

THE

COUNT OF MONTE-CRISTO.

BY

ALEXANDRE DUMAS.

WITH

Twenty Illustrations,

DRAWN ON WOOD BY M. VALENTIN,

AND EXECUTED BY THE MOST EMINENT ENGLISH ENGRAVERS,
UNDER THE SUPERINTENDENCE OF MR. CHARLES HEATH.

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:

— Edmond Dantès!

Want: $f($ $)=$

" 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 alon 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)

— 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:
— Edmond Dantès!

Machine learning for translation (google translate)

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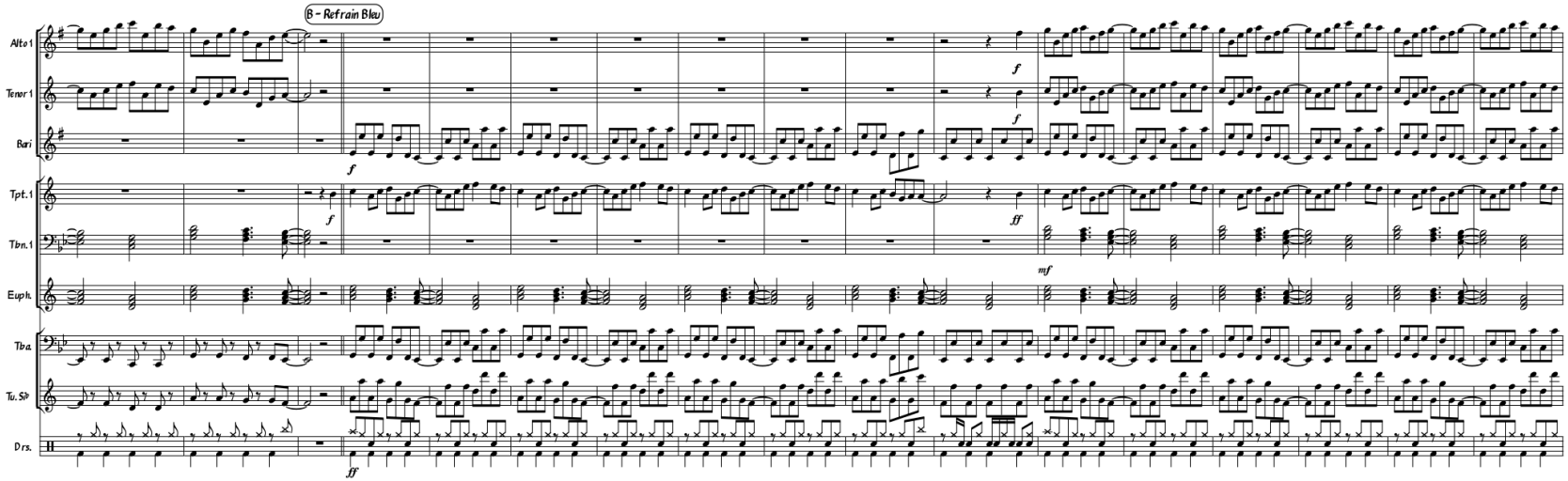
“Edmond Dantès!”

Machine learning for music transcription

- Want: f(mp3 file)=score for all instruments playing, e.g.

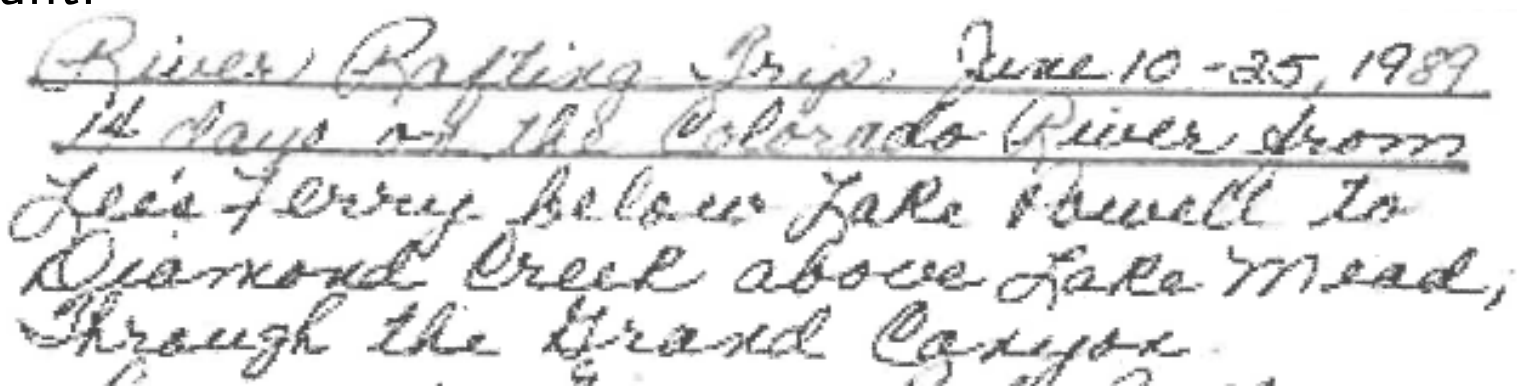


- Listening to mp3 then writing score is difficult! (but possible)
- Generating a real/recorded mp3 file based on score is also difficult (need skilled musicians to read/play).
- Easy to compute SYNTH(score)=synthesized mp3 file.
- Q: can we use synthesized mp3 files to train a ML algo?
- Listen to MP3s: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

Machine learning for recognizing cursive handwriting

Optical/intelligent character/word recognition

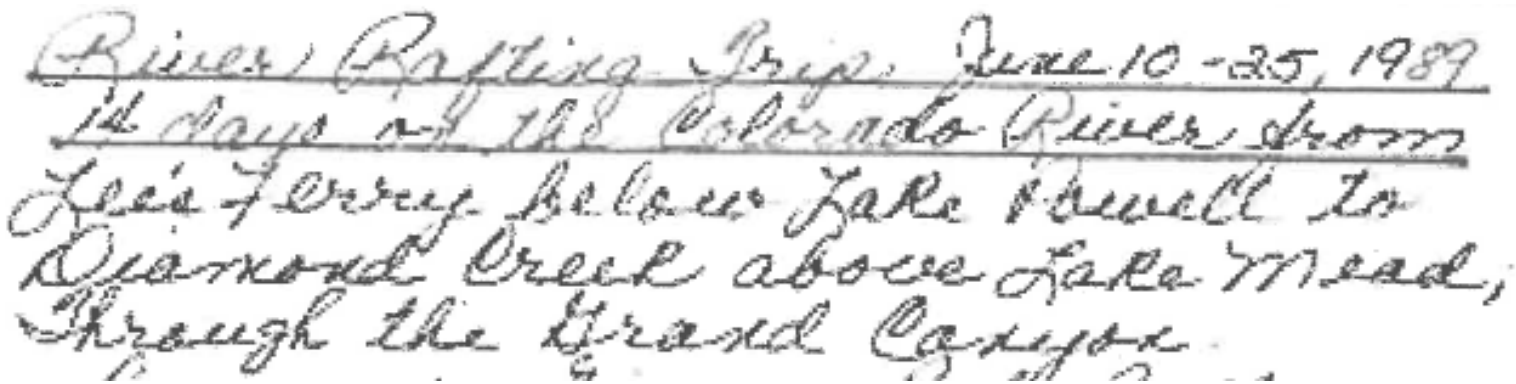
Want:

$f($  $)=$

Machine learning for recognizing cursive handwriting

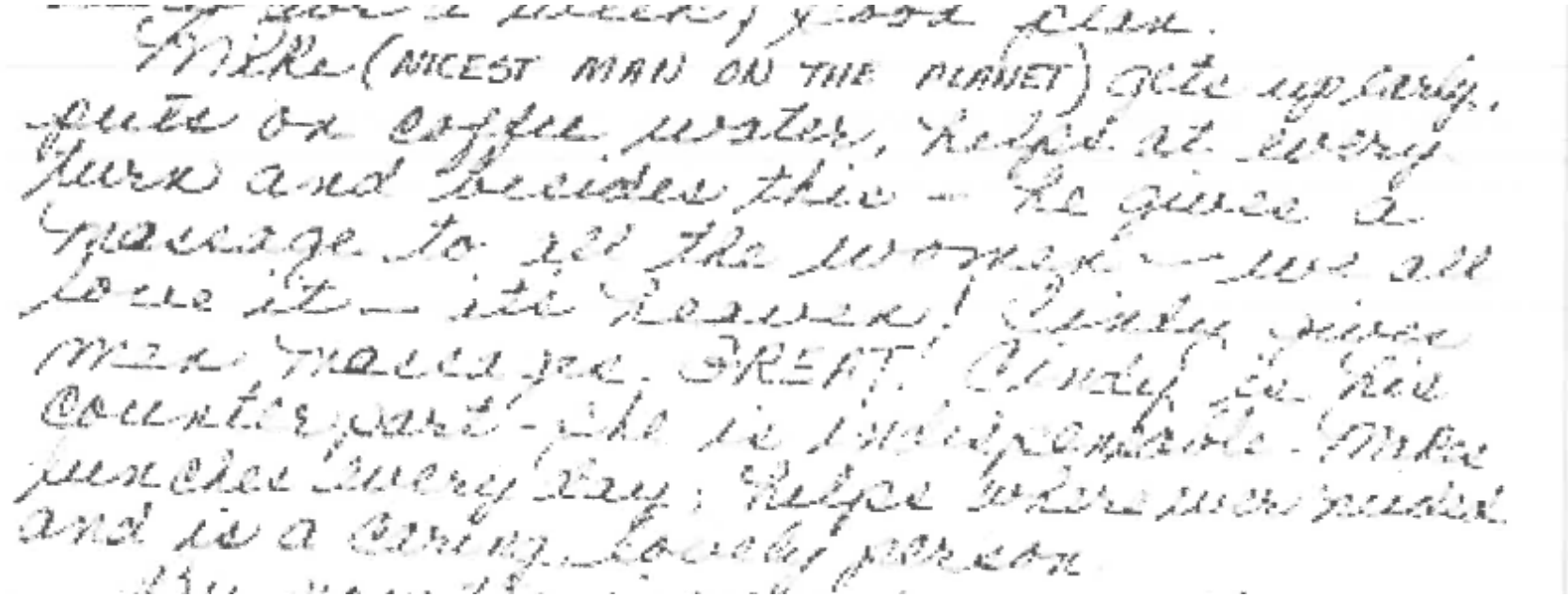
Optical/intelligent character/word recognition

Want:

$f($  $)=$

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

Machine learning for recognizing cursive handwriting



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?

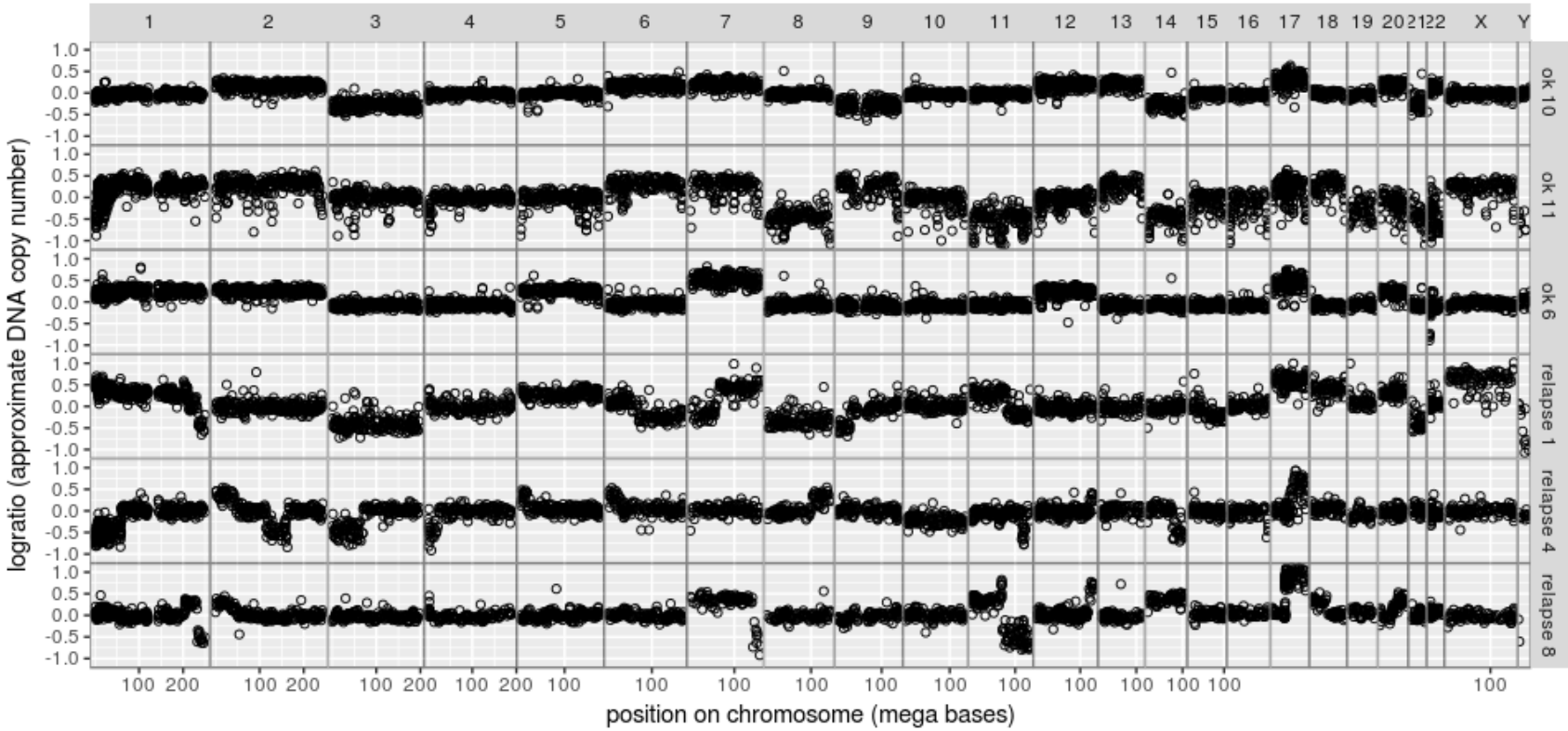
Machine learning for medical diagnosis

Original

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?