What is Machine Learning?

Pyowa

September 5, 2017

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 @david_body

Artificial Intelligence ⊇ Machine Learning ⊇ Deep Learning

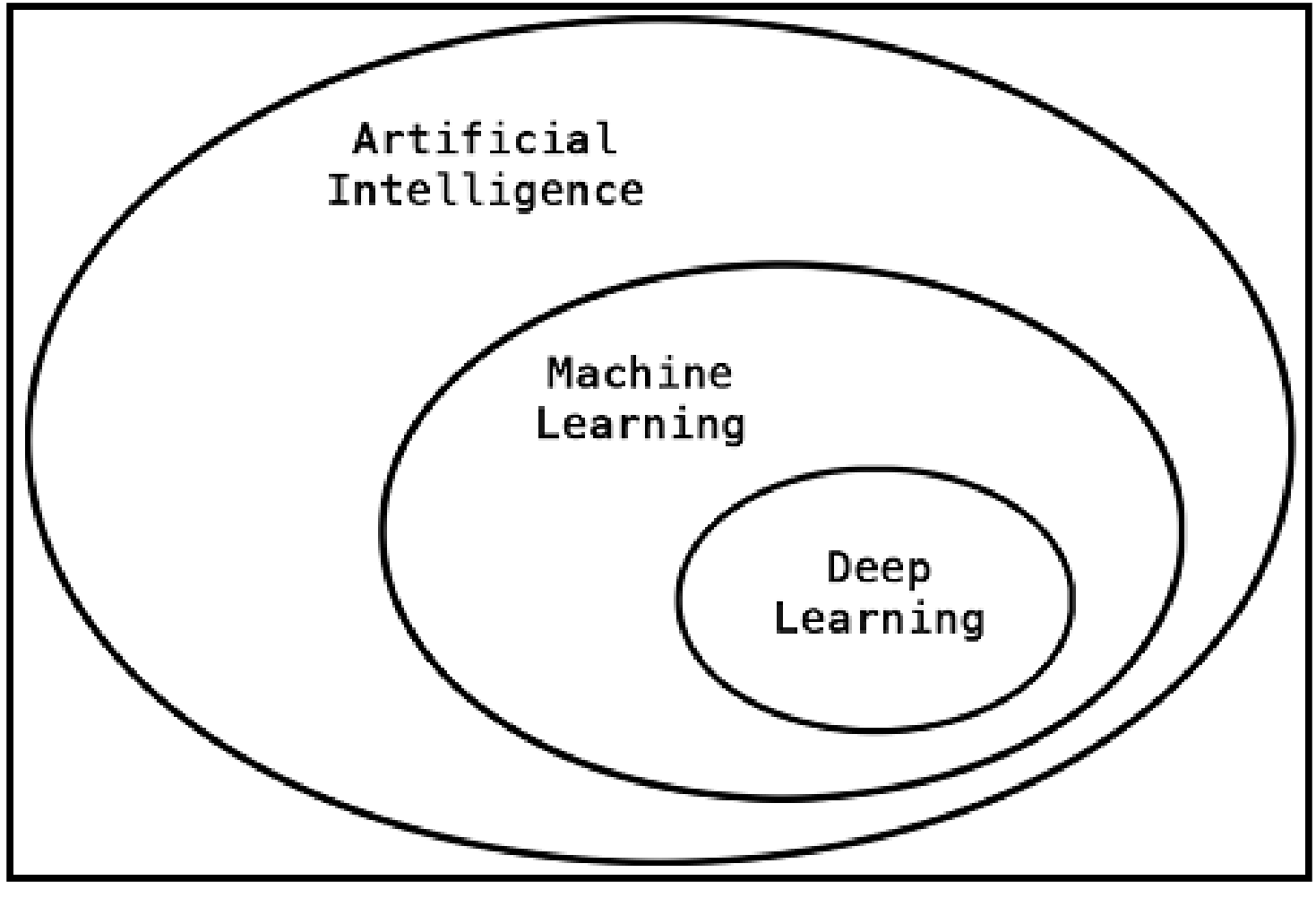


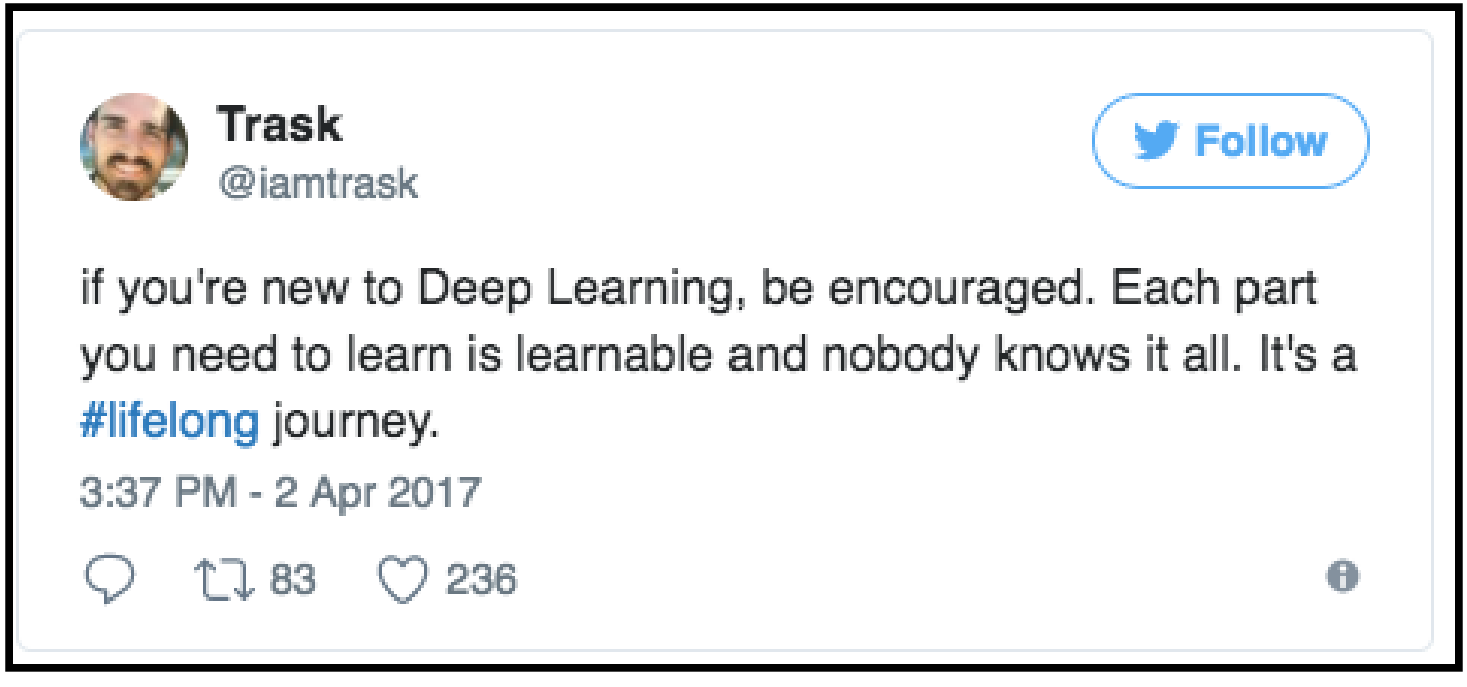
Image credit: François Chollet, Deep Learning with Python

Who am I?

- David W. Body
- Independent software developer
- Interested in data science & machine learning
- Love learning & teaching
- Available for contract & consulting work

Who are you?

- Software developers
- Data scientists / statisticians?
- Other?


Trask
@iamtrask
Follow
if you're new to Deep Learning, be encouraged. Each part you need to learn is learnable and nobody knows it all. It's a #lifelong journey.
3:37 PM - 2 Apr 2017
83
236

Outline

- The concept of machine learning
- Types of machine learning
- Machine learning techniques
  - Linear regression
  - Logistic regression for classification
  - Neural networks
- MNIST example
- Dangers of machine learning
- Where to go from here

Machine learning allows computers to ”learn” or improve their decisions or predictions without being explicitly programmed.

Machine Learning is a new programming paradigm

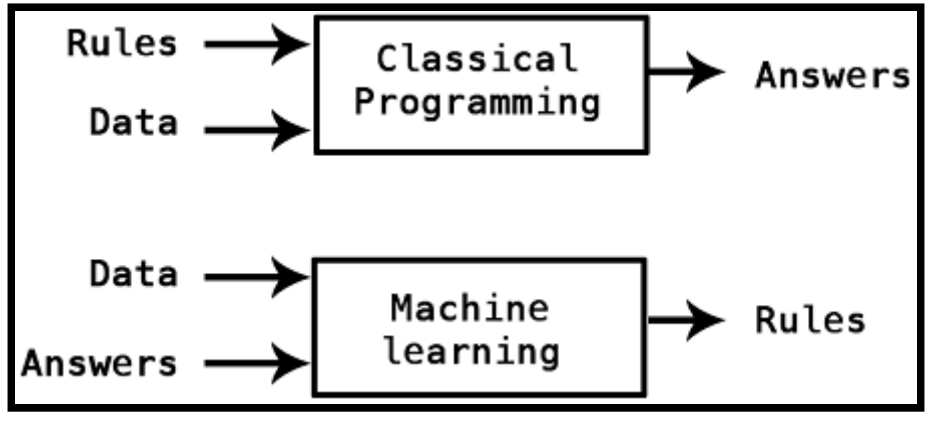


Image credit: François Chollet, Deep Learning with Python

Types of machine learning

- Supervised learning
- Unsupervised learning
- Reinforcement learning

Types of machine learning problems

- Regression
- Classification
- Clustering

Machine learning techniques

- Linear regression
- Logistic regression for classification
- Neural networks

Amy Hoy
@amyhoy

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by today's definition, y=mx+b is an artificial intelligence bot that can tell you where a line is going

9:44 AM - 29 Mar 2017

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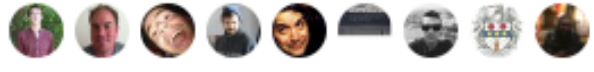

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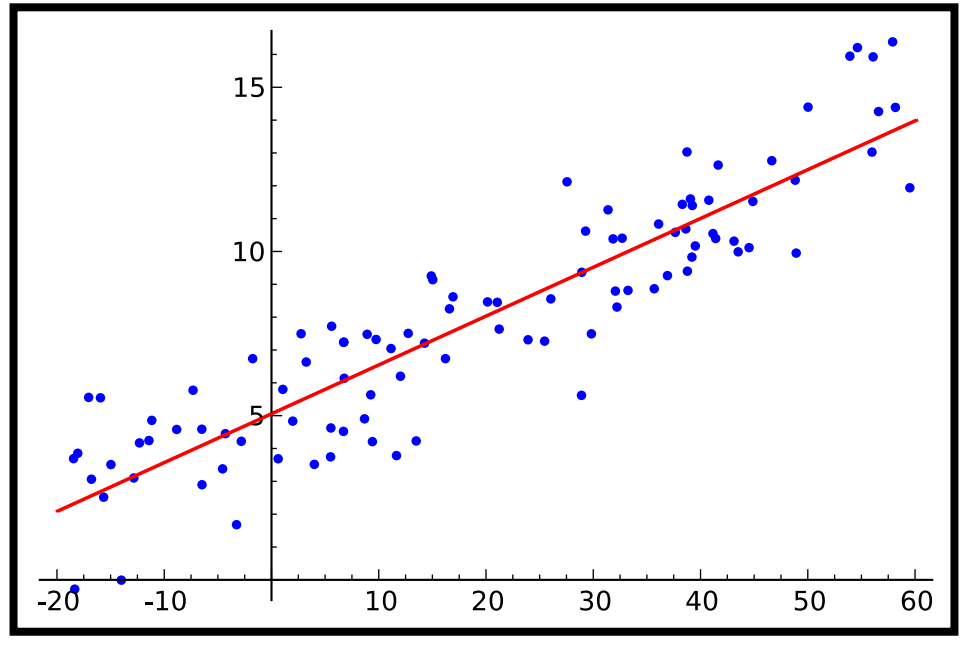
Linear Regression



$$y = \mathrm{b} + \mathrm{w} \cdot x$$

Linear Regression

$$y = \mathrm{b} + \mathrm{w} \cdot x$$

The problem is to find the "best" values for b and w given the data x, y.

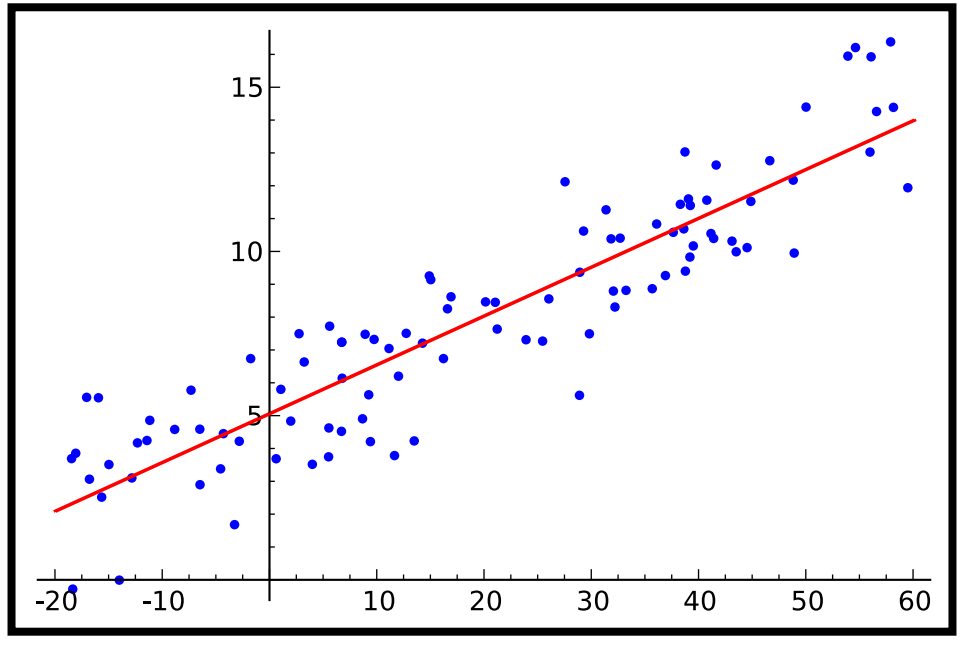
- Select loss function.
- Select minimization algorithm.
- Find values of b and w that minimize loss function.

Linear Regression

For linear regression, our loss function is the sum of squared errors

$$L(\mathrm{b}, \mathrm{w}) = \sum_{i=1}^{N} e_i^2$$

Linear Regression



$$\hat{y}_i = \mathrm{b} + \mathrm{w} \cdot x_i$$

$$e_i = \hat{y}_i - y_i$$

Linear Regression

How to minimize the loss function?

Various algorithms - outside our scope for today

Linear Regression

The values of w and b that minimize the loss function are our estimates $\hat{b}$ and $\hat{w}$.

When we get a new value of x, we can predict y using

$$\hat{y}_{new} = \hat{b} + \hat{w} \cdot x_{new}$$

Linear Regression

For example, the `mtcars` dataset is included with R includes data on 32 automobiles from a 1974 issue of *Motor Trend* magazine.

```
                   mpg cyl  disp  hp drat    wt  qsec vs am gear carb
Mazda RX4         21.0   6 160.0 110 3.90 2.620 16.46  0  1    4    4
Mazda RX4 Wag     21.0   6 160.0 110 3.90 2.875 17.02  0  1    4    4
Datsun 710        22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1
Hornet 4 Drive    21.4   6 258.0 110 3.08 3.215 19.44  1  0    3    1
Hornet Sportabout 18.7   8 360.0 175 3.15 3.440 17.02  0  0    3    2
...
```

Linear Regression

We'll regress `mpg` on `wt`.

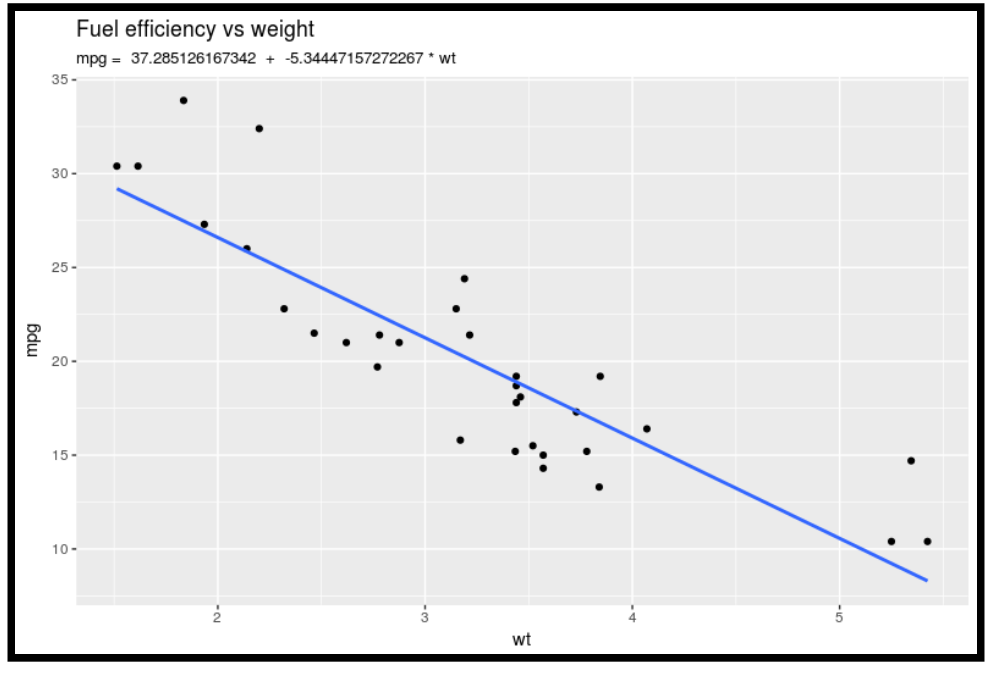
```
Call:
lm(formula = mpg ~ wt, data = mtcars)

Residuals:
    Min      1Q  Median      3Q     Max
-4.5432 -2.3647 -0.1252  1.4096  6.8727

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  37.2851     1.8776  19.858  < 2e-16 ***
wt           -5.3445     0.5591  -9.559 1.29e-10 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.046 on 30 degrees of freedom
Multiple R-squared:  0.7528,    Adjusted R-squared:  0.7446
F-statistic: 91.38 on 1 and 30 DF,  p-value: 1.294e-10
```

Linear Regression



$$mpg = \hat{\mathrm{b}} + \hat{\mathrm{w}} \cdot wt$$

$$\hat{\mathrm{b}} = 37.2851, \hat{\mathrm{w}} = -5.3445$$

Linear Regression

Typically we'll regress `mpg` on multiple variables.

```
Call:
lm(formula = mpg ~ ., data = mtcars)

Residuals:
    Min      1Q  Median      3Q     Max
-3.4506 -1.6044 -0.1196  1.2193  4.6271

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 12.30337   18.71788   0.657   0.5181
cyl         -0.11144    1.04502  -0.107   0.9161
disp         0.01334    0.01786   0.747   0.4635
hp          -0.02148    0.02177  -0.987   0.3350
drat         0.78711    1.63537   0.481   0.6353
wt          -3.71530    1.89441  -1.961   0.0633 .
qsec         0.82104    0.73084   1.123   0.2739
vs           0.31776    2.10451   0.151   0.8814
am           2.52023    2.05665   1.225   0.2340
gear         0.65541    1.49326   0.439   0.6652
carb        -0.19942    0.82875  -0.241   0.8122
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.65 on 21 degrees of freedom
Multiple R-squared:  0.869,    Adjusted R-squared:  0.8066
F-statistic: 13.93 on 10 and 21 DF,  p-value: 3.793e-07
```

Binary Classification

Let's consider the problem of classifying elements of a set into two groups based on a classification rule.

Examples

- Spam detection - is an email message spam?
- Medical diagnosis - does the patient have diabetes?
- Marketing - will the customer make a purchase?
- Quality control - is a manufactured item defective?

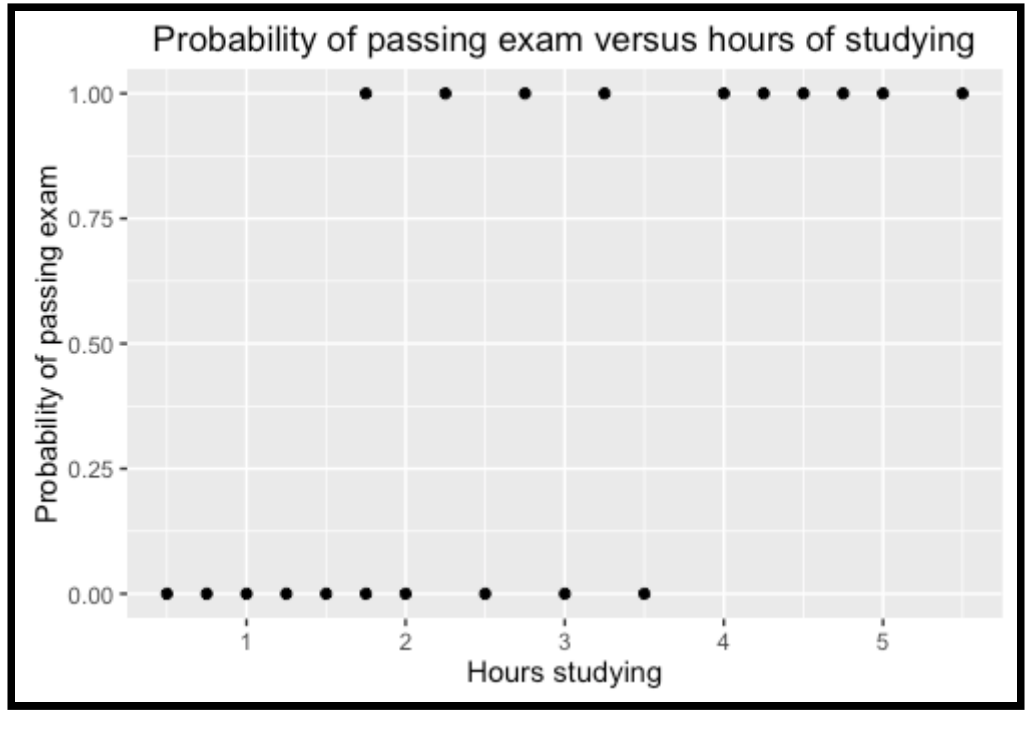
Binary Classification

Let's suppose we have a single explanatory variable x and

$$y = \begin{cases} 1 & \text{if the example is a member of the class} \\ 0 & \text{otherwise} \end{cases}$$

Binary Classification Example

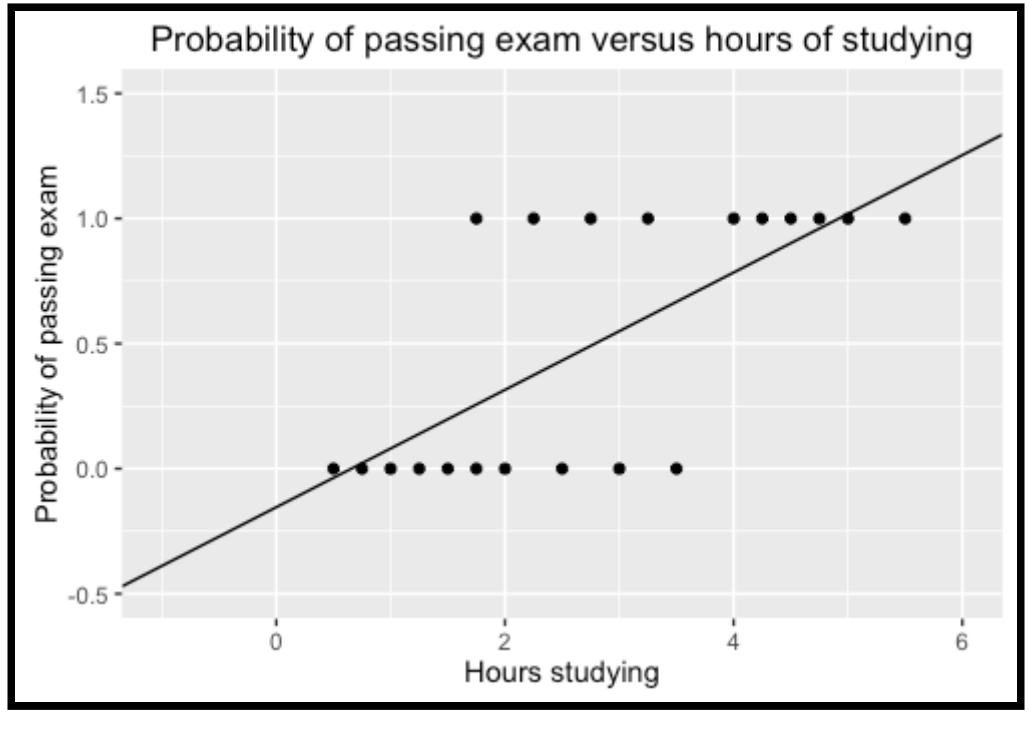
Suppose x is the number of hours a student studies for an exam, and y is whether the student passes the exam.



Binary Classification

We want $0 \leq Probability\ pass\ exam \leq 1$.

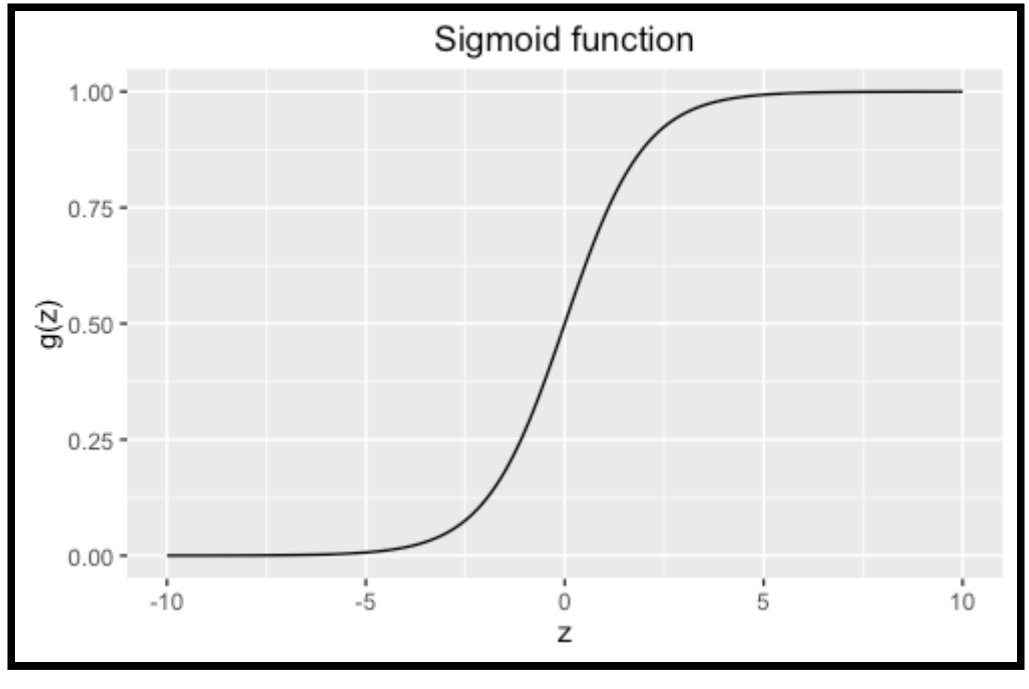
That means ordinary linear regression won't work.



Binary Classification

$$g(z) = \frac{1}{1 + e^{-z}}$$

is known as the **sigmoid** or **logistic** function.



Binary Classification

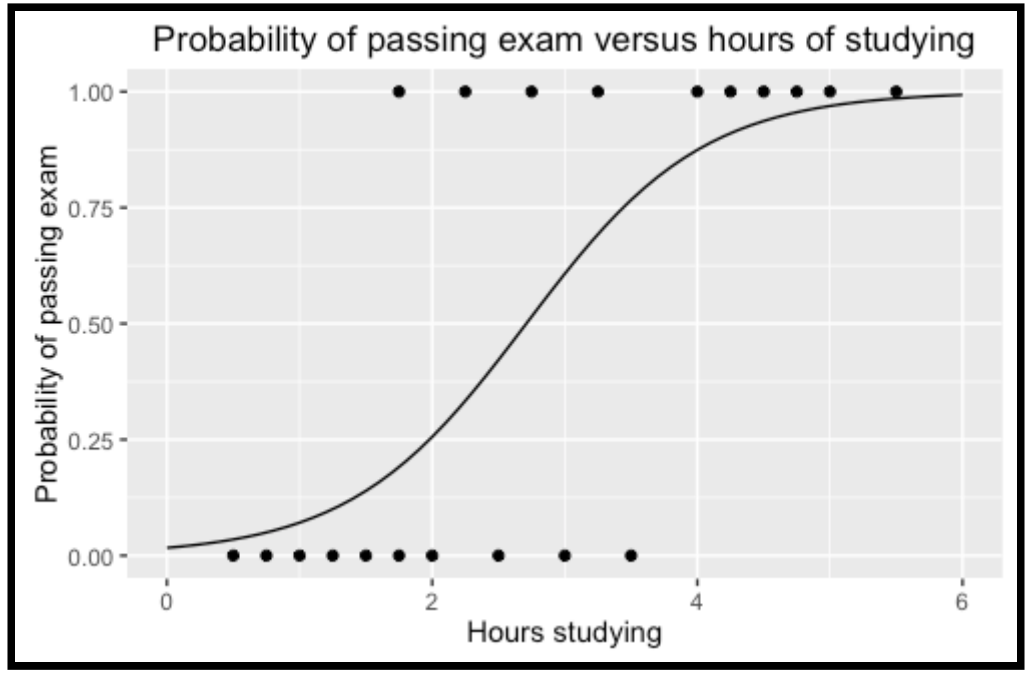
Suppose we use the following model.

$$z = \mathrm{b} + \mathbf{w} \cdot Hours$$

$$Probability\ pass\ exam = \frac{1}{1 + e^{-z}}$$

Binary Classification

If we estimate b and w using logistic regression, we get $\hat{\mathrm{b}} = -4.0777$ and $\hat{\mathrm{w}} = 1.5046$.



Binary Classification

For example, we might have a database of email messages labeled as "spam" or "email" with variables representing the relative frequencies of 50 common words and punctuation marks.

We could perform a logistic regression where

$$y = \begin{cases} 1 & \text{if the message is spam} \\ 0 & \text{otherwise} \end{cases}$$

Binary Classification

Confusion matrix

		predicted: F	predicted: T
actual	F	TN 264	FP 14
	T	FN 22	TP 158

TN = true negatives

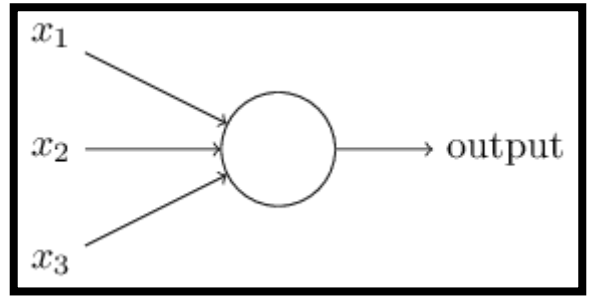
FN = false negatives

TP = true positives

FP = false positives

Neural Networks

Perceptron

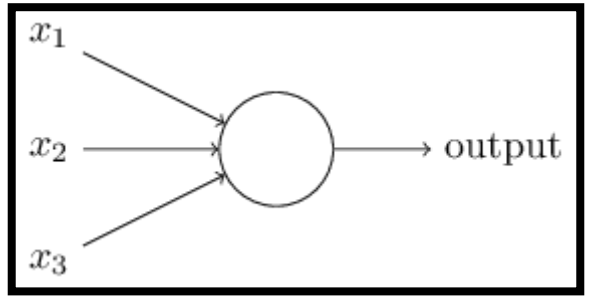


Output is binary.

Weights for each input

$$output = \begin{cases} 0 & \text{if} \sum_j w_j x_j \leq \text{ threshold} \\ 1 & \text{if} \sum_j w_j x_j > \text{ threshold} \end{cases}$$

Perceptron



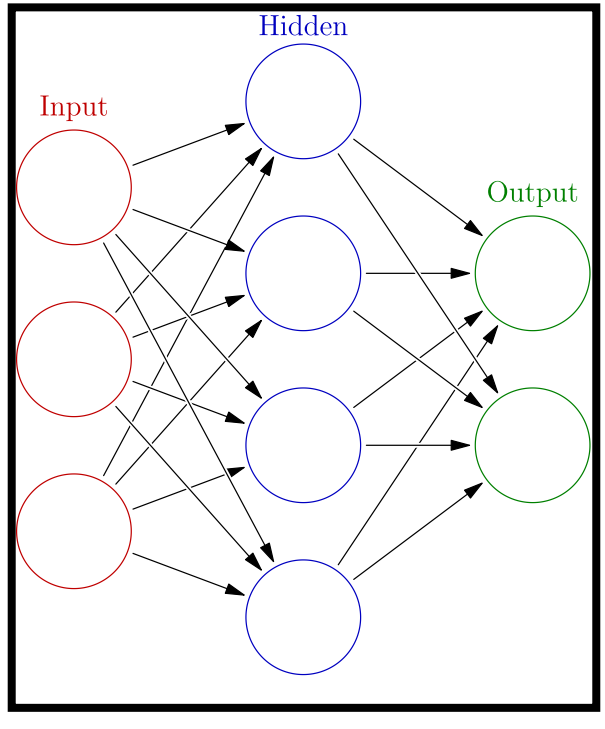
Equivalently, we can use **biases** instead of thresholds

$$output = \begin{cases} 0 & \text{if} \sum_j w_j x_j + b \leq 0 \\ 1 & \text{if} \sum_j w_j x_j + b > 0 \end{cases}$$

The weights (w_j) and biases (b) are the parameters that we will estimate or "learn."

Neural Networks

We can combine perceptrons together in layers to make an artificial neural network.



Neural Networks

It turns out that perceptrons don't work very well in a multi-layer network.

Why?

Because a small change in the weights or bias can cause a neuron to flip from 0 to 1 or vice versa.

Solution?

Use neurons with sigmoid activation functions.

Neural Networks

A neuron with a sigmoid activation function works like this:

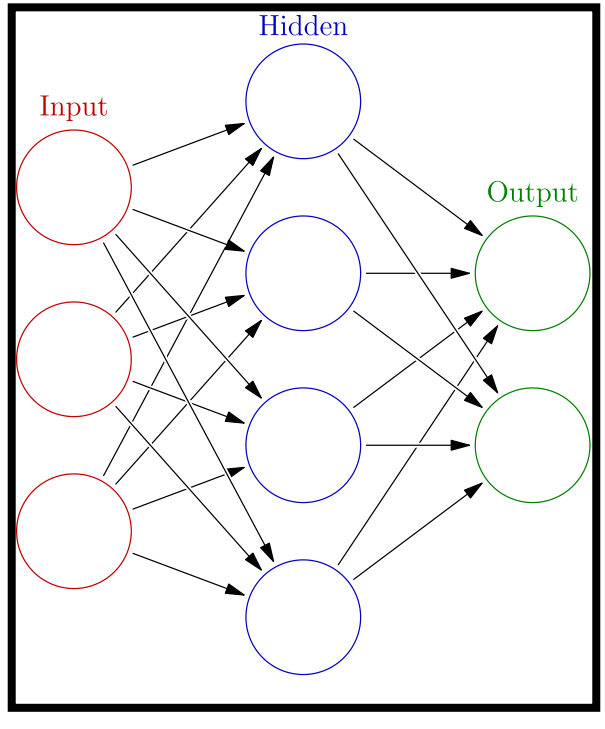
$$z = b + \sum_{i=1}^{M} w_i x_i$$

$$output = \frac{1}{1 + e^{-z}}$$

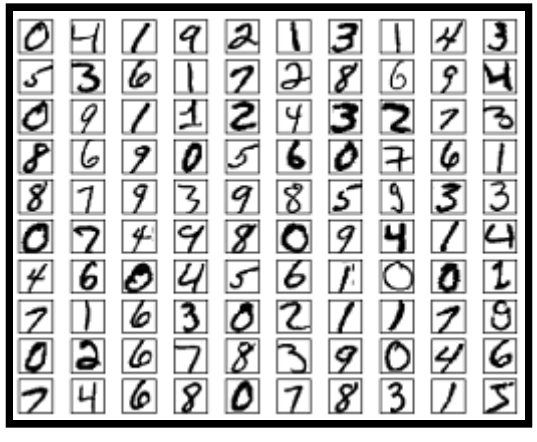
where the x_i's are the inputs, the w_i's are the weights, and b is the bias.

Neural Networks

Our hidden units will use sigmoid activation functions.



MNIST example



Data: http://yann.lecun.com/exdb/mnist/

MNIST example

Training data consists of 70,000 examples of handwritten digits.

For each example, we have

- 28 x 28 grey-level pixel image
- label indicating which digit it is (0-9)

MNIST example

In other words, our data consists of 70,000 rows with the following columns

- y = digit label (0-9)
- x_1 = value of pixel 1
- x_2 = value of pixel 2
- ...
- x_{784} = value of pixel 784

The pixel values are floating point numbers bewteen 0.0 and 1.0.

MNIST example

Given values for $x_1, x_2, \ldots x_{784}$,
we want to predict the digit or y.

One way we could do this is by running
a logistic regression for each digit.

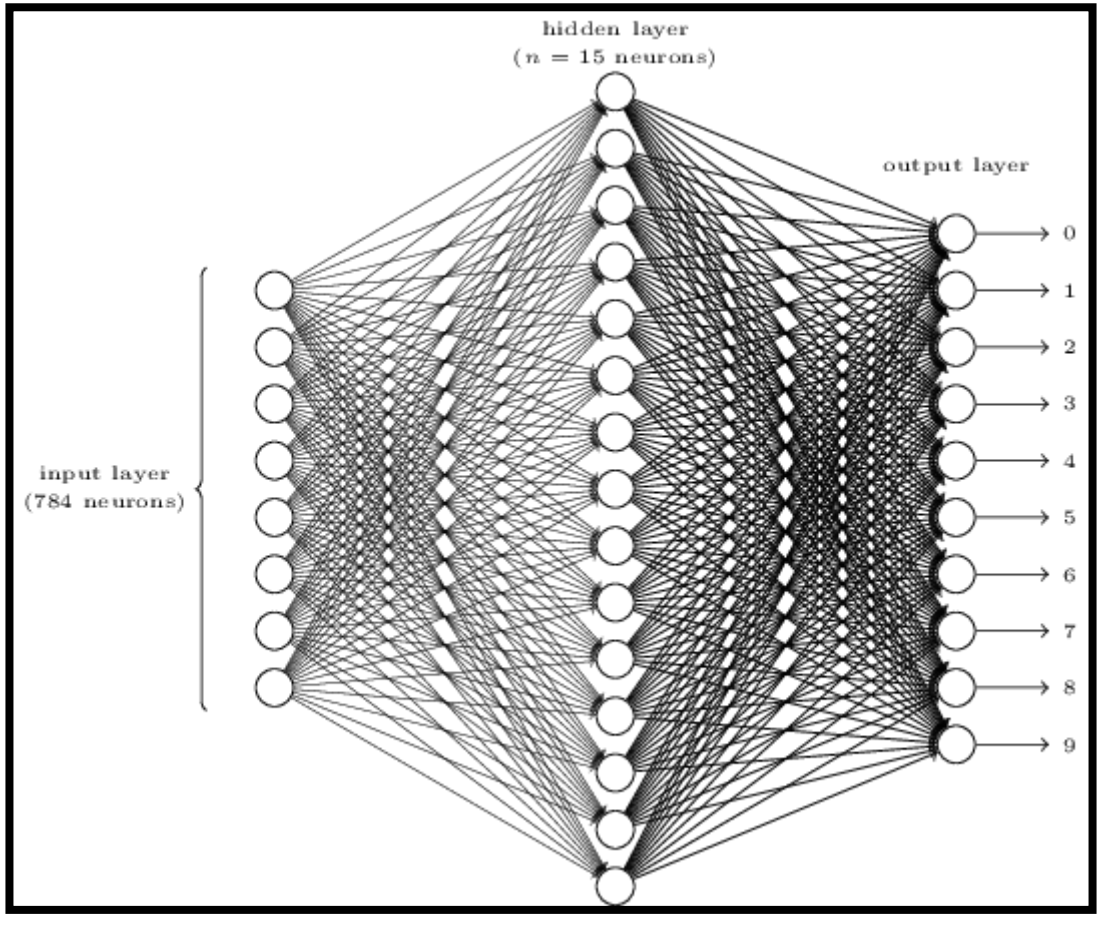
The first logistic regression would use

$$y = \begin{cases} 1 & \text{if the digit is zero} \\ 0 & \text{otherwise} \end{cases}$$

This is called **one versus rest** or **one against all**
classification.

MNIST example

We can get better results by using a neural network.



MNIST example

TensorFlow / Keras code demo

What did we leave out?

A lot!

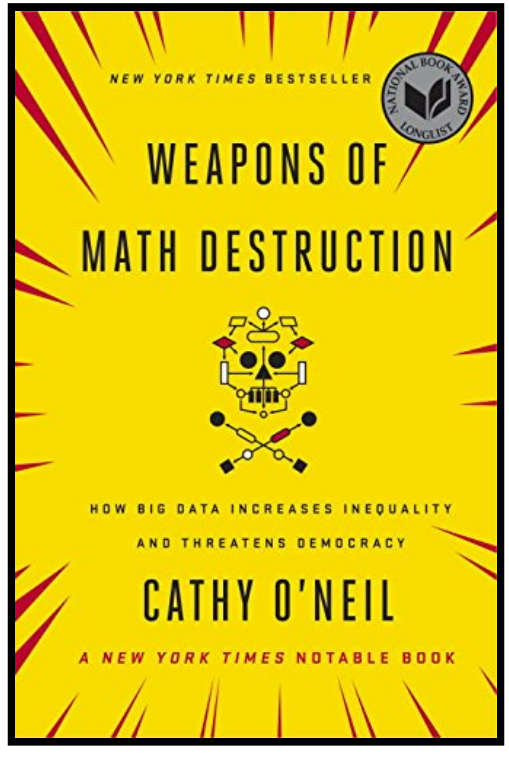
- Overfitting / regularization
- Convolutional neural networks
- Recurrent neural networks
- Much, much more

Keep in mind

- ML is susceptible to bias
- ML is hard to interpret
- ML is hard to explain
- ML is used in ways that affect people's lives

This makes ML potentially dangerous!

Recommended reading for everyone



WMD = algorithm that

- Is opaque
- Operates at scale
- Can damage people's lives

If you really want to learn ML

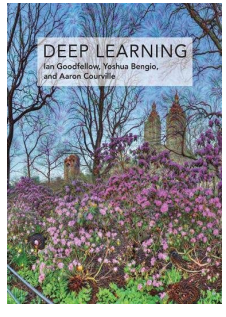
- Calculus
- Linear algebra
- Probability & statistics
- Information theory

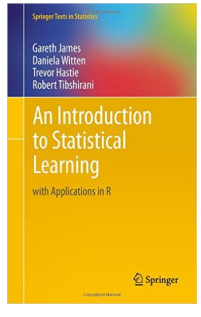
You can learn these as you go.

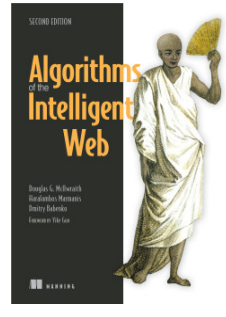
No one knows everything.

Resources

Books







- neuralnetworksanddeeplearning.com
- Fast.ai
- Coursera
- Wikipedia

Questions?

THE END

Thank you

 @david_body