

# Snapshots of Machine Learning

Speaker: John Burkardt  
jvburkardt@gmail.com

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Presentation to ???,  
Mathematics Department,  
University of Pittsburgh,  
?:00pm, ?? February 2026, ??? Thackeray

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Slides last modified on 15 February 2026.

# An “overnight” sensation after 75 years



In the early '50's, John McCarthy of Stanford announced the dawn of **Artificial Intelligence**...

75 years later, the newly named **Machine Learning** is taking off, collecting billions in investment, creating hundreds of AI companies, hiring employees by the thousands.

We introduce for beginners a few “snapshots” of the problems ML handles, briefly suggesting how the “magic tricks” can be done.

## Snapshot #1: Look! Up in the Sky!



What's that thing in the sky?

What angles describe it?

How far away is it?

Do we have enough data to determine its location? Or **too much**?

## Try for precision with more, inaccurate data



Using a theodolite, we can get two angles (elevation and azimuth) that define a 3D line passing near the object.

Two sightings by different observers give us two such lines.

Because of inaccuracy, those lines won't exactly intersect. What if we get 10 readings from scattered points?

## No exact answer; estimate location



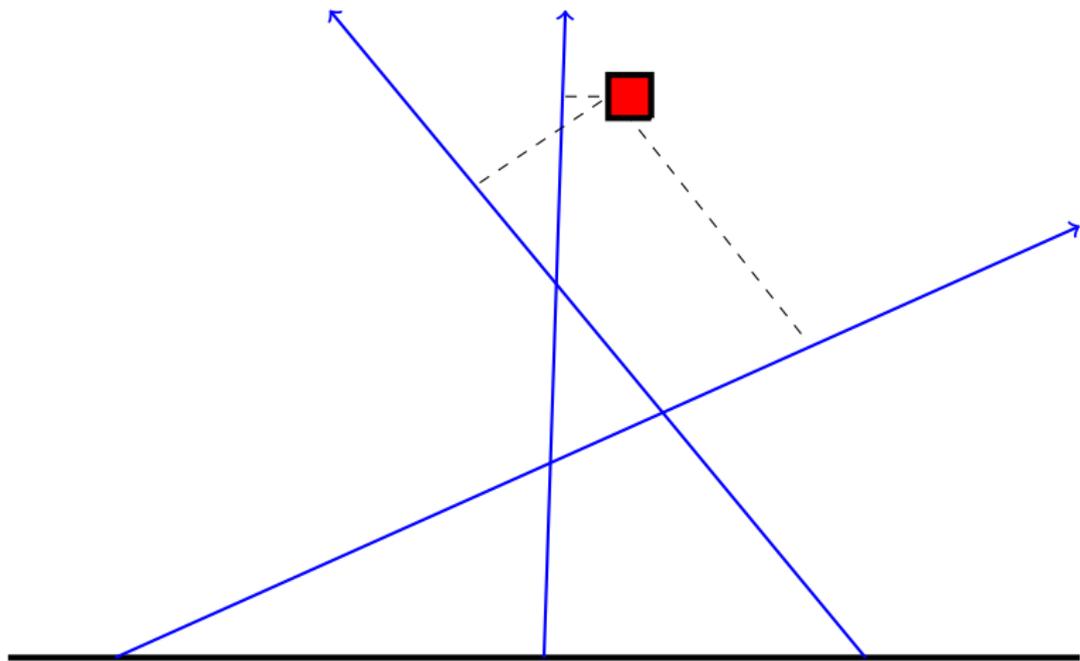
Suppose the exact location is  $x^*$ , and our estimate is  $x$ .

The error in our estimate can be measured by the square of the distance to each line, which we might store as a vector  $E^2(x)$ :

$$E^2(x) = (d_1(x)^2, d_2(x)^2, \dots, d_{10}(x)^2)$$

The value  $x$  that minimizes this error is our approximation for  $x^*$ .

## Minimize distance to sighting lines



Here, the red square is a bad estimate for the solution, given just 3 sighting lines.

# The Math Approach

A mathematical approach might consider the gradient of all the distances, compute the gradient direction, and repeatedly adjust the point  $x$  along the negative gradient direction, trying to reduce all the distances with each step.

This is a standard approach from least squares minimization, called **gradient descent**.

In general, to make one improvement step, we have to recompute the derivative of each of the component errors. For our example, this might require 2, 3, or even 10 calculations per step, and perhaps 50, 100, or 200 steps.

# The ML approach

We have thought about a sighting problem involving 2, 3 or 10 sighting lines (our data). In machine learning, by contrast, there might be thousands or even millions of data items.

The cost of one step of gradient descent is suddenly a million times what it was for our small problem.

Instead, machine learning can aim for an approximation of the approximation, picking just one (or a few) lines at a time and moving the estimate closer to them. By repeatedly choosing a small random subset of the lines, ML can still get an excellent approximation.

In machine learning, this is the **stochastic gradient descent**.

Many ML problems involving enormous sets of data can be solved with limited time and memory using this trick.

## Snapshot #2: The Robot Realtor



We've fired our human realtor, and bought a robot - you!

Your job is to assign an asking price for houses.

We give you 404 sets of 14 data values to learn from. Good luck!

# The Data Dump

- **crim**, per capita crime rate by town.
- **zn**, proportion of land zoned for lots over 25,000 sq.ft.
- **indus**, proportion of non-retail business acres per town.
- **chas**, Charles River access (= 1 if on river; 0 otherwise).
- **nox**, nitrogen oxides concentration (parts per 10 million).
- **rm**, average number of rooms per dwelling.
- **age**, proportion of owner-occupied units built prior to 1940.
- **dis**, mean of distances to five Boston employment centers.
- **rad**, index of accessibility to radial highways.
- **tax**, full-value property-tax rate per \$10,000.
- **prratio**, pupil-teacher ratio by town.
- **mix**, a measure of racial mixture.
- **lstat**, lower status of the population (percent).
- **medv**, median value of owner-occupied homes in \$1000s.

## Your prediction won't be an algebraic formula

Along with the data, we have also given you **price**, the asking price of each of these houses, as determined by the human realtor we just fired.

Your job is to come up with prices for our next customers, based on the same kind of data we collected earlier.

Notice that the data is of many different types (real, strictly positive, percentages, integers, logical) and that some of the data values are probably much more important than others.

It is **extremely unlikely** that you can come up with a typical algebraic formula

$$\text{price} = f(\text{data})$$

that will reproduce the original prices and produce reasonable estimates of the prices for our next customers!

# Training and Testing

The ML approach is to create a model of the data, and then test it before applying it to new problems. So it divides the given data into **training** and testing sets.

For the training set, ML tries to predict the known price of each house based on the known data. Rather than using algebraic polynomials, ML is going to use something called a neural network, which we can think of as just a fancier and more powerful way of modeling data. After several modeling iterations, it arrives at a model that we can symbolize as

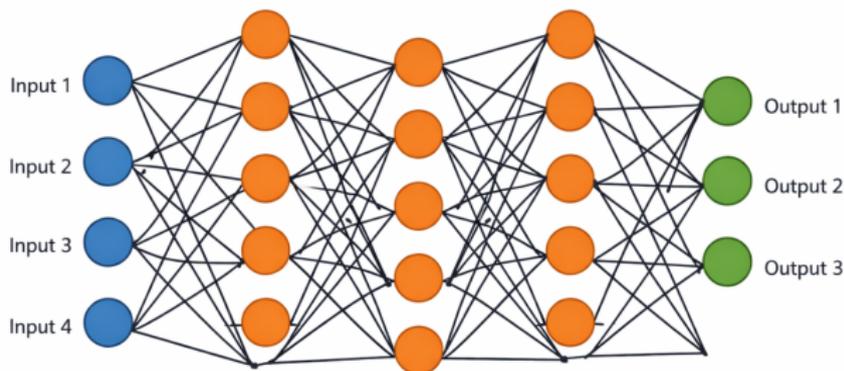
$$\text{price} \approx f(\text{data}) \text{ for data in training set}$$

Now the model is tested:

$$\text{price} \overset{?}{\approx} f(\text{data}) \text{ for data in testing set}$$

If this discrepancy is large, ML tries harder to adjust the model.

# The Model Architecture



The model that is created is called a neural network. Data enters at nodes on the input layer. Each node processes its data and passes it to the right. Results come out in the last layer.

We can try to improve a model by adding nodes or layers, or increasing the connectivity.

For now, we can think of all this as **ML Voodoo!**

## Using the model

The model has been generated with the training data, tested with the testing data, and if necessary, regenerated for better approximation.

Now it can be tried out on data it has never seen. Of course, for our discussion, we happen to know these values!

Here we see what our ML model predicts for houses using data in has never seen before:

House	Predicted Price	Actual Price
1	\$ 9,381	\$ 7,200
2	\$18,657	\$18,800
3	\$21,714	\$19,000
4	\$32,730	\$27,000
5	\$25,009	\$22,200

These are not perfect results, but not at all embarrassing!

## Snapshot #3: Well Dog My Cats!



So far, our data has been numerical. But machine learning can also be applied to image data. Here, we will use it to try to separate pet images into separate piles for cats and dogs. Unlike the numerical examples, it is really not easy to see how to come up with a mathematical formula to handle this

## Snapshot #4: Alice In Moby Land



## A Tale Told by an Idiot

In one sense, it is amazing that, with the push of a button, we could generate a stream of words that seem like regular English text. So maybe is this enough to generate poems, plays, novels, articles?

- If a word is not in the data, it will never be in the output;
- Same thing for “short” strings;
- While the sequence of words may seem human, there is no logic behind them; no story to tell, no plot;
- It's like a conversation with a stroke victim; correct English but not expressing an underlying meaning.

# The uses of dummy text



## YOUR TITLE HERE

Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book.

It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including.

It is a long established fact that a reader will be distracted by the readable content of a page when looking at its layout. The point of using Lorem Ipsum is that it has a more-or-less normal distribution of letters, as opposed to using 'Content here, content here', making it look like readable English.

Many desktop publishing packages and web page editors now use Lorem Ipsum as their default model text, and a search for 'lorem ipsum' will uncover many web sites still in their infancy. Various versions have evolved over the years, sometimes by accident, sometimes on purpose.

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On the other hand, Markov text generation is a perfect way to create arbitrary amounts of “dummy text”, like the  **Lorem Ipsum**.

Snapshot #5: Nice to meet you, Professor Turing!

# Some logic questions

## Task 1: Single Supporting Fact

Mary went to the bathroom.  
John moved to the hallway.  
Mary travelled to the office.  
Where is Mary? A:office

## Task 2: Two Supporting Facts

John is in the playground.  
John picked up the football.  
Bob went to the kitchen.  
Where is the football? A:playground

## Task 3: Three Supporting Facts

John picked up the apple.  
John went to the office.  
John went to the kitchen.  
John dropped the apple.  
Where was the apple before the kitchen? A:office

## Task 4: Two Argument Relations

The office is north of the bedroom.  
The bedroom is north of the bathroom.  
The kitchen is west of the garden.  
What is north of the bedroom? A: office  
What is the bedroom north of? A: bathroom

## Task 5: Three Argument Relations

Mary gave the cake to Fred.  
Fred gave the cake to Bill.  
Jeff was given the milk by Bill.  
Who gave the cake to Fred? A: Mary  
Who did Fred give the cake to? A: Bill

## Task 6: Yes/No Questions

John moved to the playground.  
Daniel went to the bathroom.  
John went back to the hallway.  
Is John in the playground? A:no  
Is Daniel in the bathroom? A:yes

## Task 7: Counting

Daniel picked up the football.  
Daniel dropped the football.  
Daniel got the milk.  
Daniel took the apple.  
How many objects is Daniel holding? A: two

## Task 8: Lists/Sets

Daniel picks up the football.  
Daniel drops the newspaper.  
Daniel picks up the milk.  
John took the apple.  
What is Daniel holding? milk, football

## Task 9: Simple Negation

Sandra travelled to the office.  
Fred is no longer in the office.  
Is Fred in the office? A:no  
Is Sandra in the office? A:yes

## Task 10: Indefinite Knowledge

John is either in the classroom or the playground.  
Sandra is in the garden.  
Is John in the classroom? A:maybe  
Is John in the office? A:no

We have seen how machine learning

- adjusts a standard mathematical technique for large overdetermined sets of data;
- takes data of widely varying types, and produces a prediction;
- processes a set of images and classifies them as cats or dogs;
- "reads" a large text and produces a new "story";
- fools Alan Turing and wins the Imitation Game.