ECE 884 Deep Learning

Lecture 2: Machine Learning Basics - 1

01/21/2021

Logistics

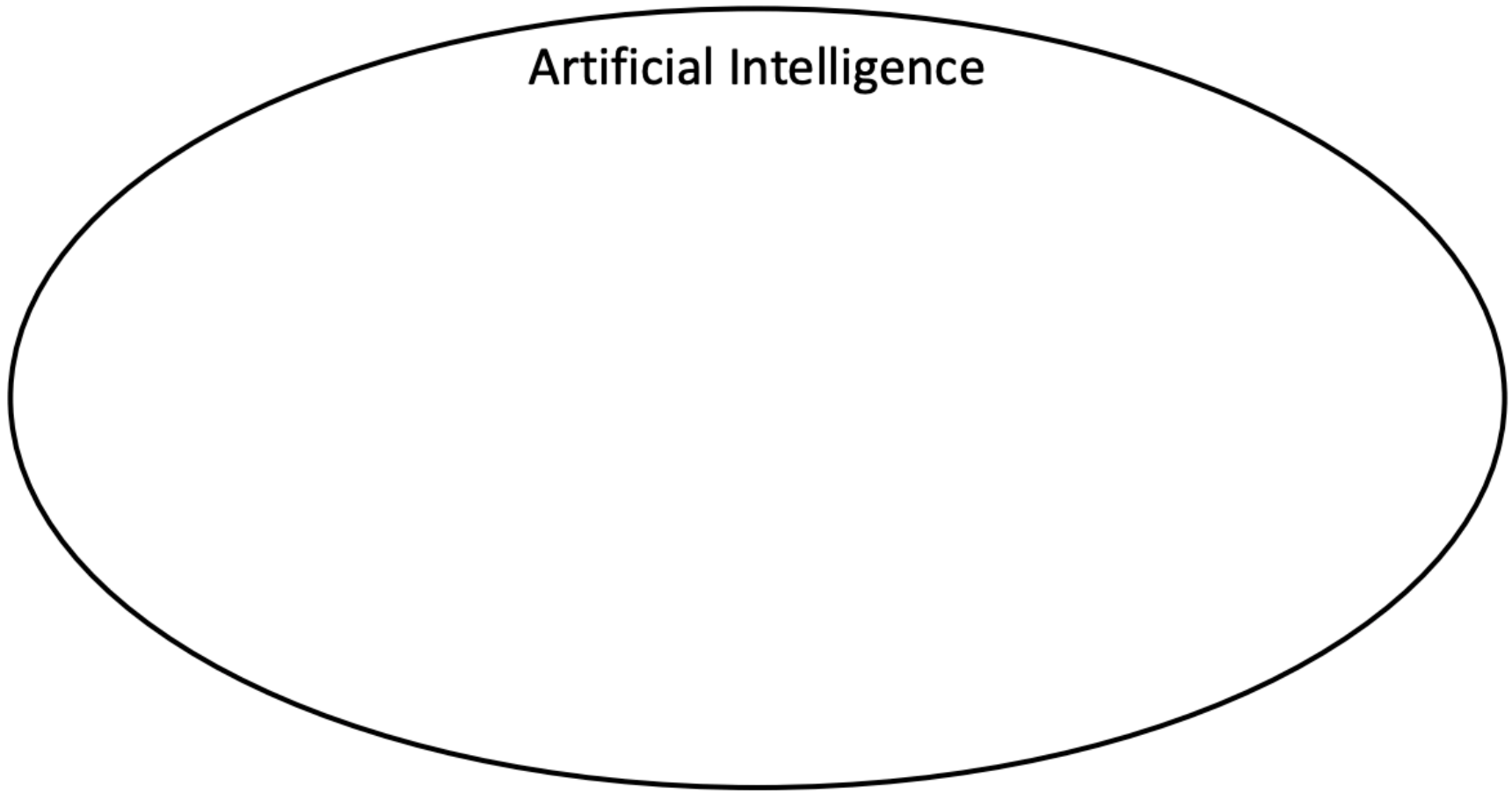
- Slack workspace
- Google sheet

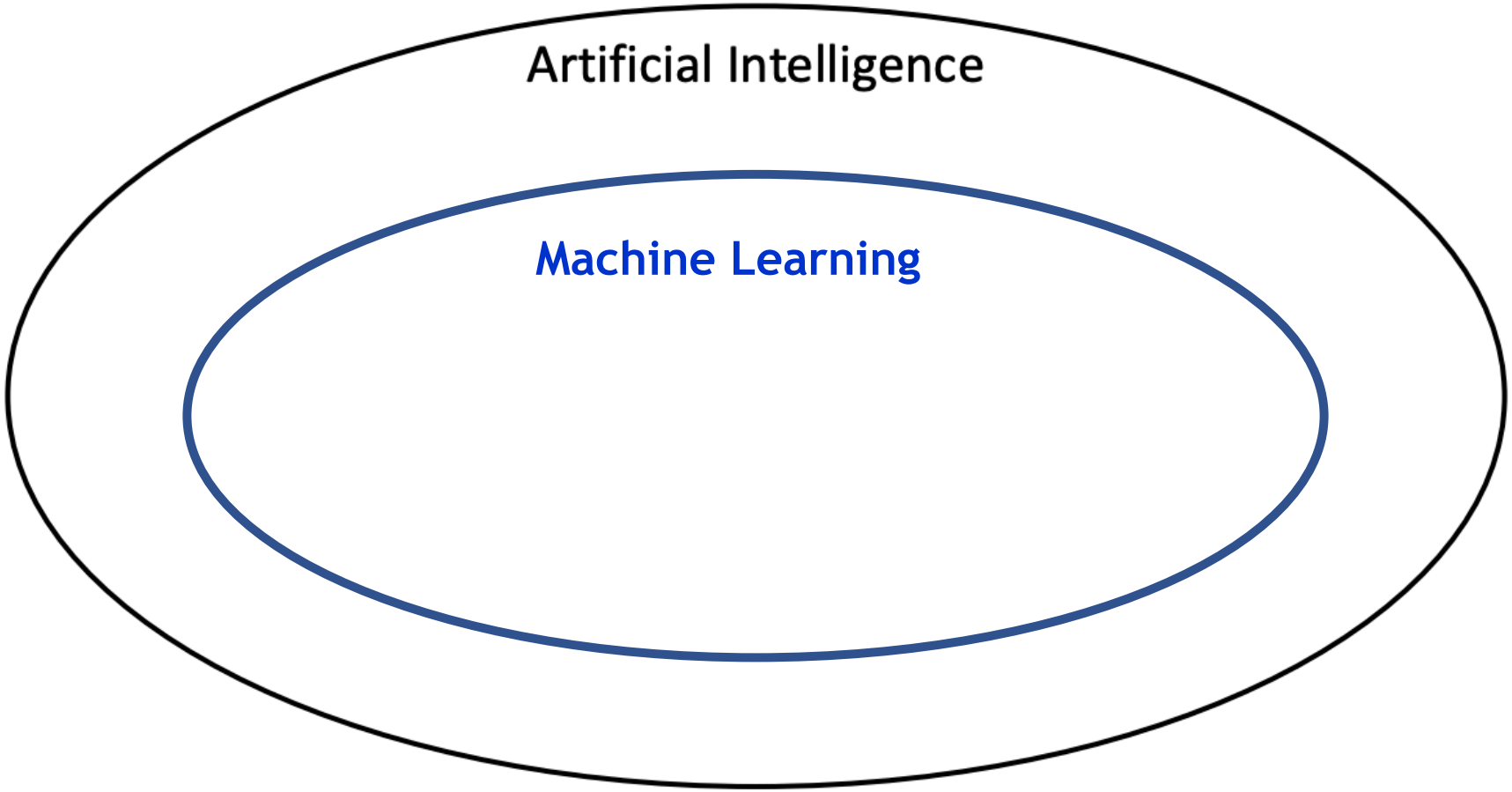
Today’s lecture

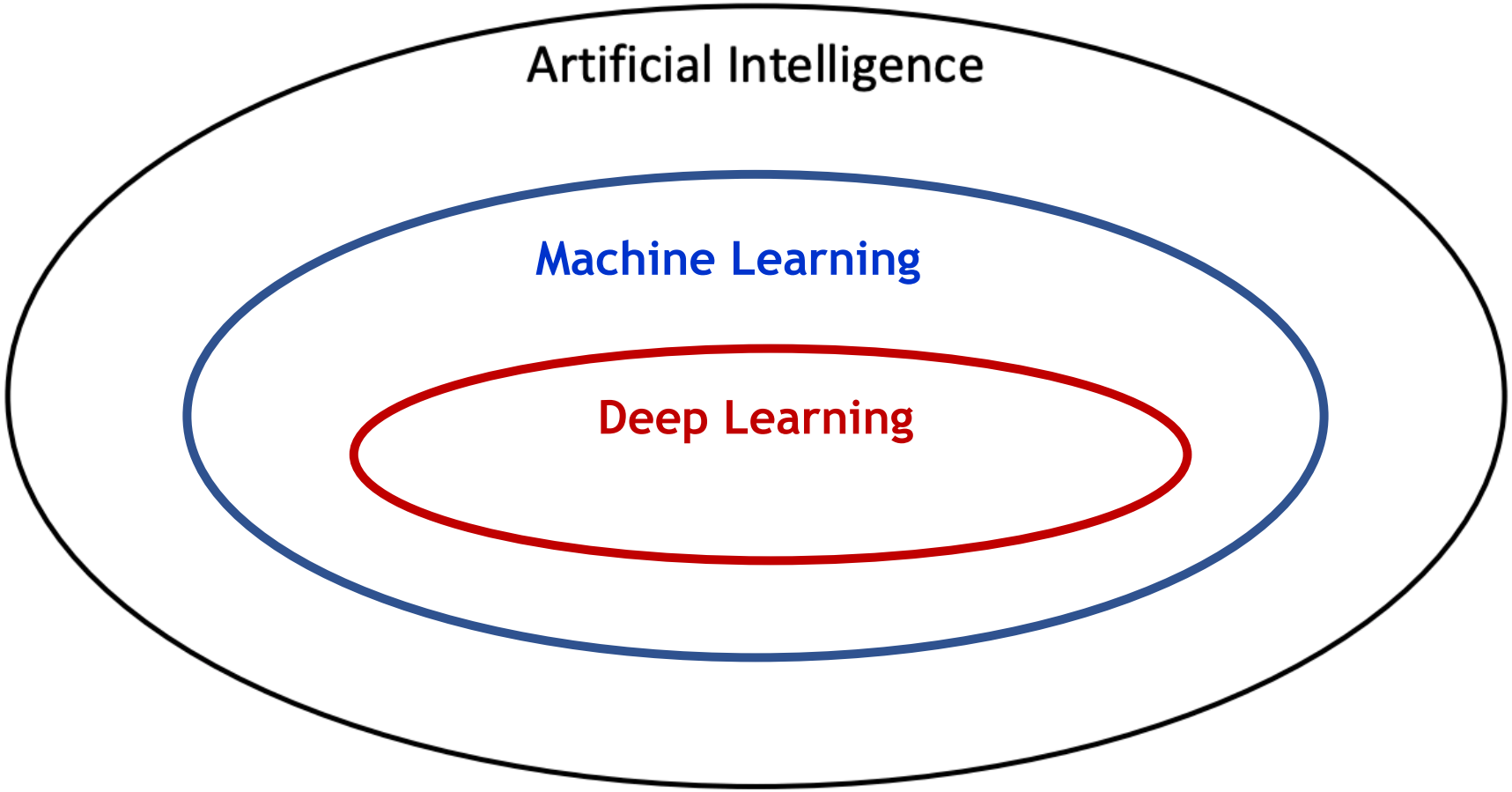
- What is Machine Learning?

- Supervised Learning Pipeline
  - Features
  - Hypothesis Space
  - Characteristics of Data Sets

What is machine learning?


Artificial Intelligence


Artificial Intelligence
Machine Learning


Artificial Intelligence
Machine Learning
Deep Learning

What is Machine Learning?

- It is very hard to write programs that solve problems like recognizing a three-dimensional object from a novel viewpoint in new lighting conditions in a cluttered scene.
  - We don't know what program to write because we don't know how its done in our brain.
  - Even if we had a good idea about how to do it, the program might be horrendously complicated.

- It is hard to write a program to compute the probability that a credit card transaction is fraudulent.
  - There may not be any rules that are both simple and reliable. We need to combine a very large number of weak rules.
  - Fraud is a moving target. The program needs to keep changing.

The Machine Learning Approach

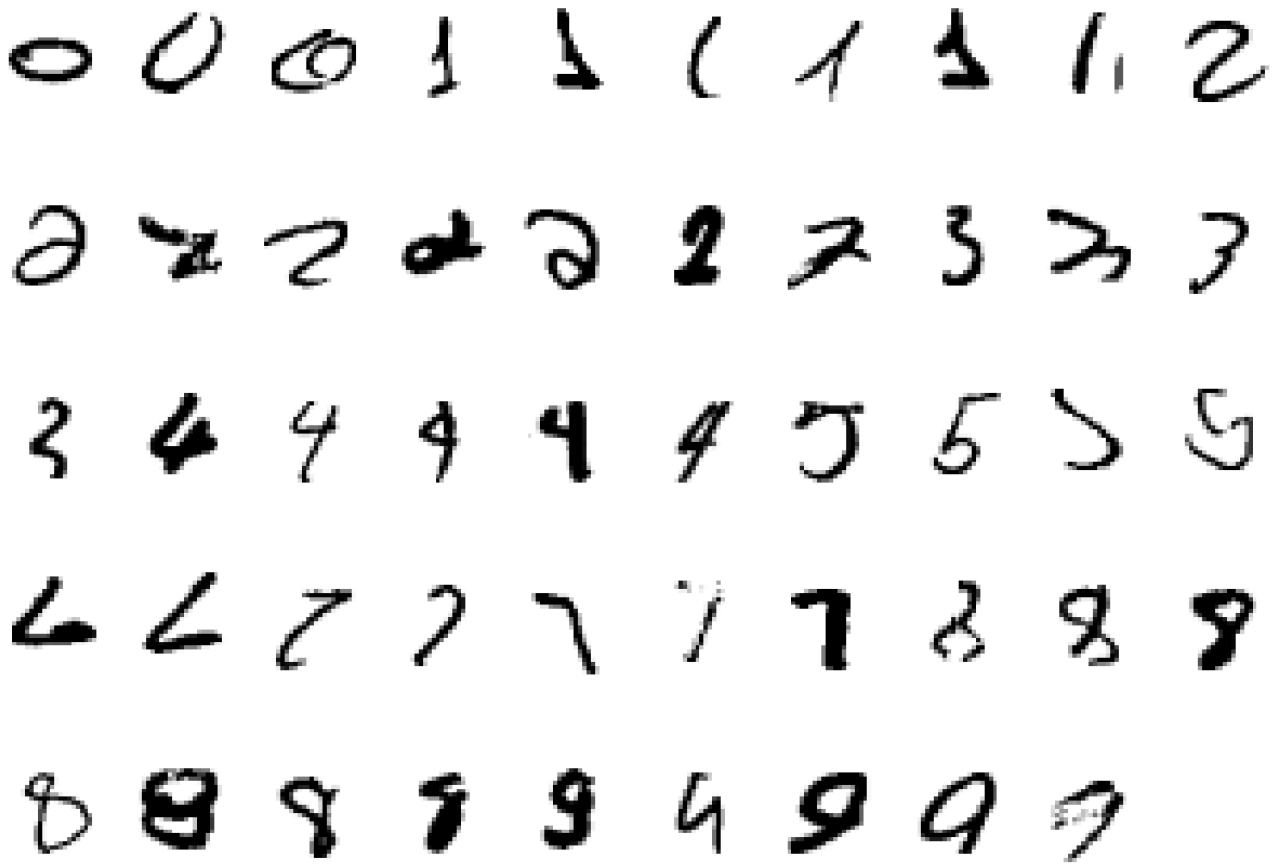
- Instead of writing a program by hand for each specific task, we collect lots of examples that specify the correct output for a given input.
- A machine learning algorithm then takes these examples and produces a program that does the job.
  - The program produced by the learning algorithm may look very different from a typical hand-written program. It may contain millions of numbers.
  - If we do it right, the program works for new cases as well as the ones we trained it on.
  - If the data changes the program can change too by training on the new data.
- Massive amounts of computation are now cheaper than paying someone to write a task-specific program.

Some examples of tasks best solved by learning

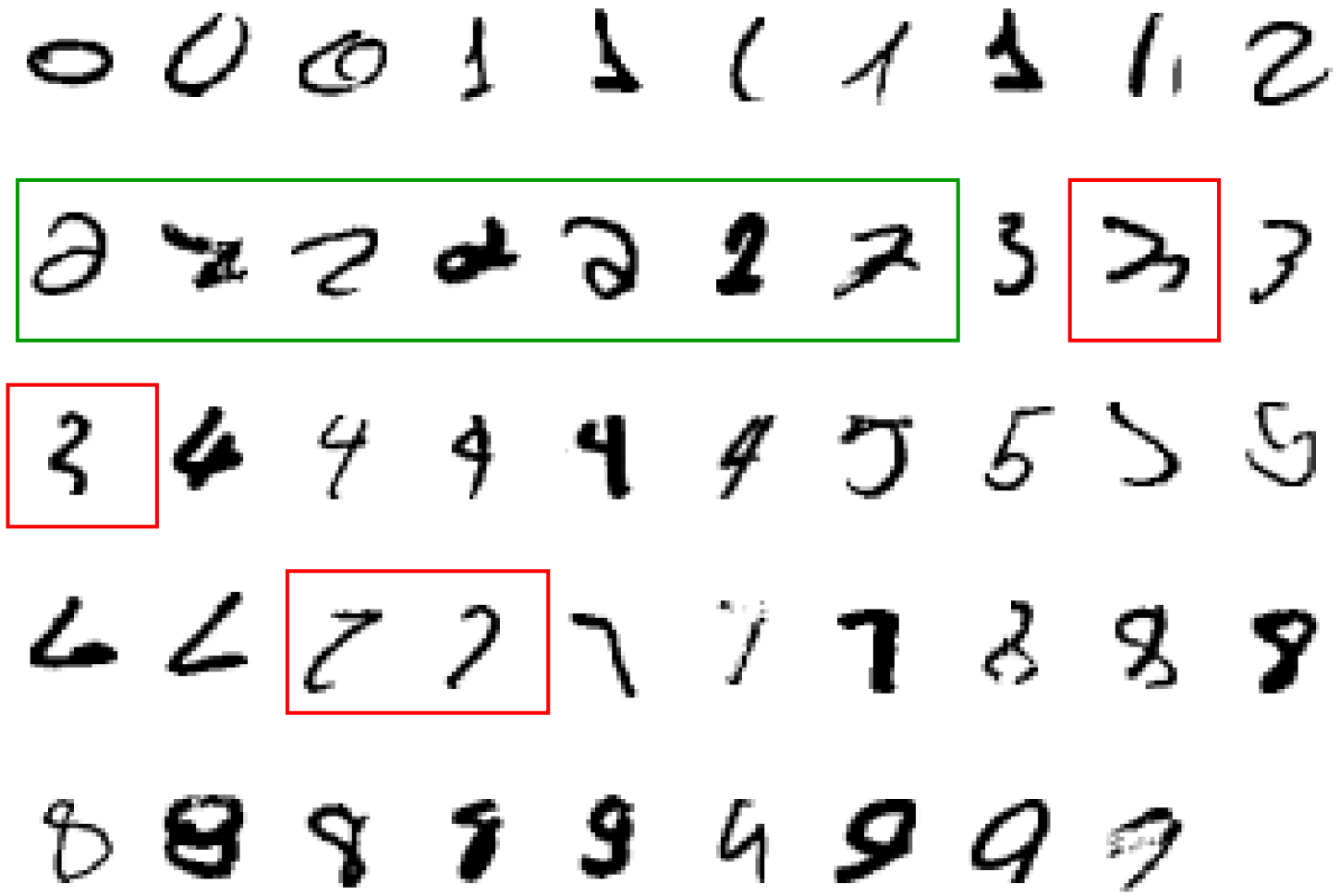
- Recognizing patterns:
  - Objects in real scenes
  - Facial identities or facial expressions
  - Spoken words
- Recognizing anomalies:
  - Unusual sequences of credit card transactions
  - Unusual patterns of sensor readings in a nuclear power plant
- Prediction:
  - Future stock prices or currency exchange rates
  - Which movies will a person like?

A standard example of machine learning

- The MNIST database of hand-written digits.



It is very hard to say what makes a 2



There are many different flavors of machine learning

Supervised Learning

- Given inputs (data-label pairs), learn a model to predict output

Example: Image Classification

apple

pear

tomato

cow

dog

horse

input

desired output

apple

pear

tomato

cow

dog

horse

Example: Lazebnik, Images: ETH-80 dataset

Example: Image Classification

apple

pear

tomato

cow

dog

horse

```
[[105 112 108 111 104  99 106  99  96 103 112 119 104  97  93  87]
 [ 91  98 102 106 104  79  98 103  99 105 123 136 110 105  94  85]
 [ 76  85  90 105 128 105  87  96  95  99 115 112 106 103  99  85]
 [ 99  81  81  93 120 131 127 100  95  98 102  99  96  93 101  94]
 [106  91  61  64  69  91  88  85 101 107 109  98  75  84  96  95]
 [114 108  85  55  55  69  64  54  64  87 112 129  98  74  84  91]
 [133 137 147 103  65  81  80  65  52  54  74  84 102  93  85  82]
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 [115 114 109 123 150 148 131 118 113 109 100  92  74  65  72  78]
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 [ 62  65  82  89  78  71  80 101 124 126 119 101 107 114 131 119]
 [ 63  65  75  88  89  71  62  81 120 138 135 105  81  98 110 118]
 [ 87  65  71  87 106  95  69  45  76 130 126 107  92  94 105 112]
 [118  97  82  86 117 123 116  66  41  51  95  93  89  95 102 107]
 [164 146 112  80  82 120 124 104  76  48  45  66  88 101 102 109]
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 [130 128 134 161 139 100 109 118 121 134 114  87  65  53  69  86]
 [128 112  96 117 150 144 120 115 104 107 102  93  87  81  72  79]
 [123 107  96  86  83 112 153 149 122 109 104  75  80 107 112  99]
 [122 121 102  80  82  86  94 117 145 148 153 102  58  78  92 107]
 [122 164 148 103  71  56  78  83  93 103 119 139 102  61  69  84]]
```

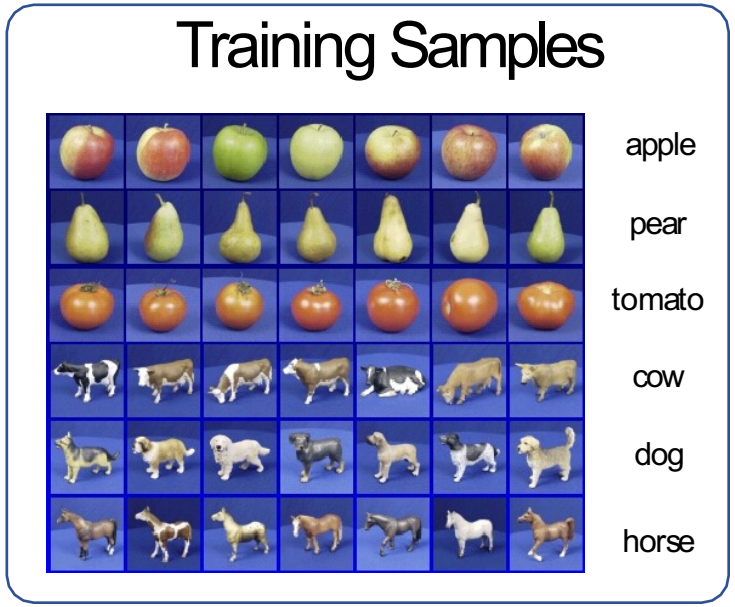
What the computer sees

An image is just a big grid of numbers between [0, 255]:

Example: Lazebnik, Images: ETH-80 dataset

Supervised Learning Pipeline

Training time



Features

Training Labels

Training

Learned model

Testing time

Test Sample

Features

Learned Model

Prediction

Credit: Lazebnik

Image Classification Datasets: MNIST

10 classes: Digits 0 to 9
28x28 grayscale images
50k training images
10k test images

Image Classification Datasets: CIFAR10

10 classes

50k training images (5k per class)

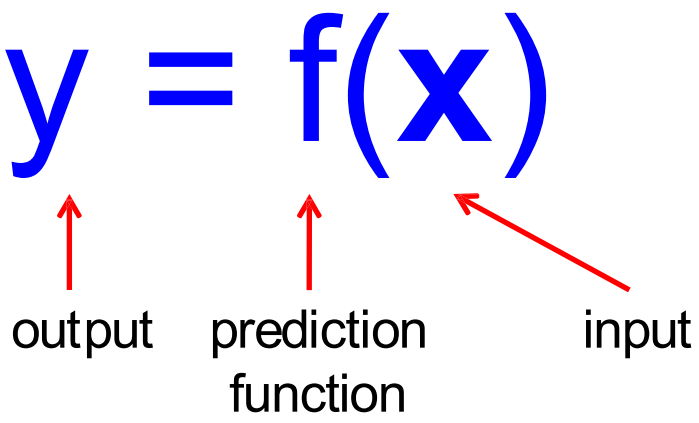
10k testing images (1k per class)

32x32 RGB images

Image Classification Datasets: ImageNet

- **1000** classes
- **~1.3M** training images (~1.3K per class) **50K** validation images (50 per class) **100K** test images (100 per class)

Supervised Learning Formulation



- Training (or learning): given a *training set* of labeled examples $\{(\mathbf{x}_1, y_1), \ldots, (\mathbf{x}_N, y_N)\}$, instantiate a predictor f
- Testing (or inference): apply f to a new *test example* $\mathbf{x}$ and output the predicted value $y = f(\mathbf{x})$

Credit: Lazebnik

Supervised Learning Formulation

$$y = f(\mathbf{x})$$

output — prediction function — input

Formulation:

- Given training data: $\{(\mathbf{x}_1, y_1), \ldots, (\mathbf{x}_N, y_N)\}$,
- Find $y = f(\mathbf{x})$ using training data
- such that f is correct on test data

Credit: Lazebnik, Liang

Supervised Learning Formulation

$$y = f(\mathbf{x})$$

output — prediction function — input

Formulation:

- Given training data: $\{(\mathbf{x}_1, y_1), \ldots, (\mathbf{x}_N, y_N)\}$,
- Find $y = f(\mathbf{x})$ ~~using training data~~
- such that f is correct on test data

What kind of functions are allowed?

Credit: Lazebnik, Liang

Supervised Learning Formulation

$$y = f(\mathbf{x})$$

output — prediction function — input

Formulation:

- Given training data: $\{(\mathbf{x}_1, y_1), \ldots, (\mathbf{x}_N, y_N)\}$,
- Find $y = f(\mathbf{x}) \in$ " using training data
- such that f is correct on test data

Hypothesis space of f

Credit: Lazebnik, Liang

Supervised Learning Formulation

$$y = f(\mathbf{x})$$

output — prediction function — input

Formulation:

- Given training data: $\{(\mathbf{x}_1, y_1), \ldots, (\mathbf{x}_N, y_N)\}$,
- Find $y = f(\mathbf{x}) \in$ " using training data
- such that f is correct on test data

Is there any connection between training and test data?

Credit: Lazebnik, Liang

Supervised Learning Formulation

$$y = f(\mathbf{x})$$

output — prediction function — input

Formulation:

- Given training data: $\{(\mathbf{x}_1, y_1), \ldots, (\mathbf{x}_N, y_N)\}$,
- Find $y = f(\mathbf{x}) \in$ " using training data
- such that f is correct on test data

i.i.d. samples from the same distribution D

Credit: Lazebnik, Liang

Any Question ?