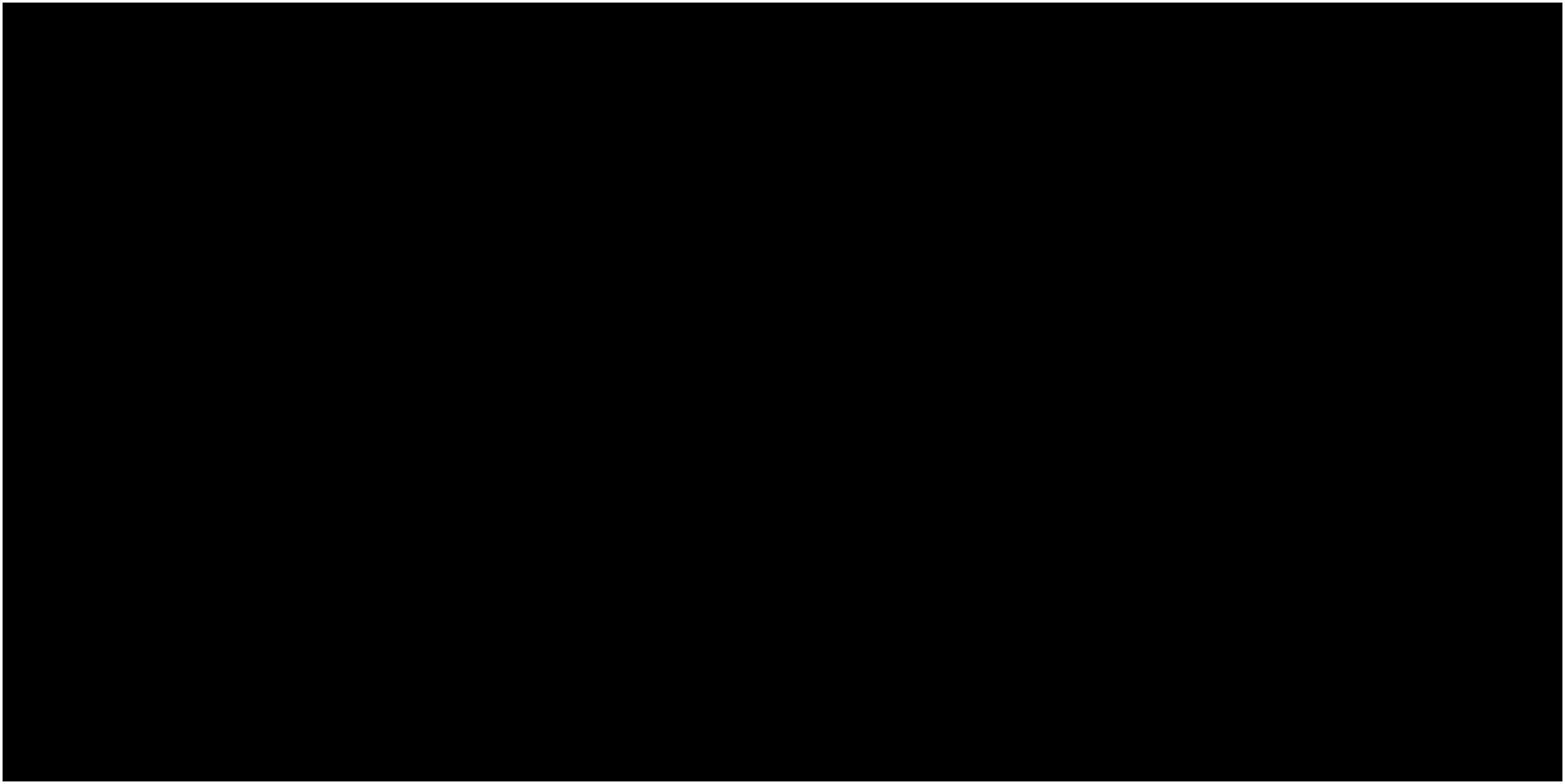


Lecture 2:

Image Classification pipeline



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Administrative

First assignment will come out tonight (or tomorrow at worst)

It is due **January 20** (i.e. in two weeks). Handed in through CourseWork It includes:

* Write/train/evaluate a kNN classifier
* Write/train/evaluate a Linear Classifier (SVM and Softmax)
* Write/train/evaluate a 2-layer Neural Network (backpropagation!)
* Requires writing numpy/Python code

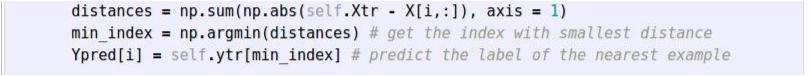
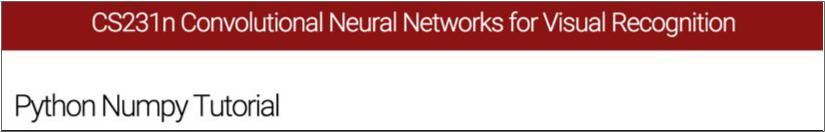
**Warning**: don’t work on assignments from last year!

Compute: Can use your own laptops, or Terminal.com

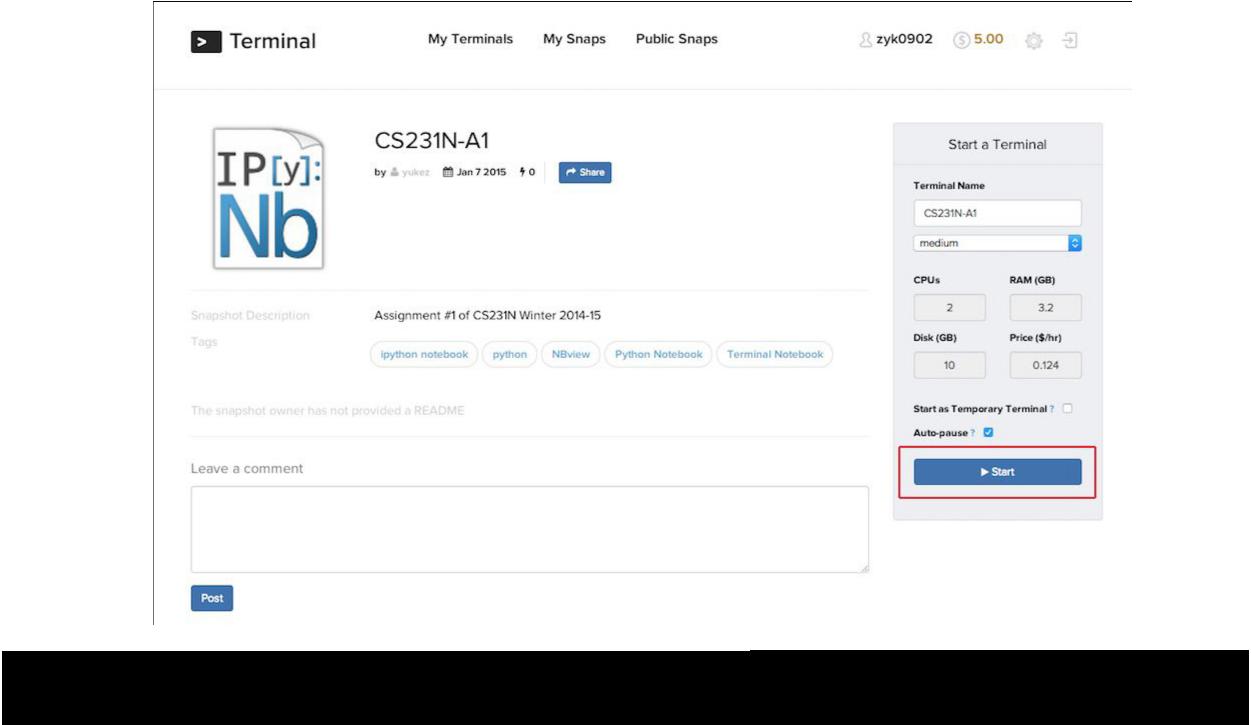


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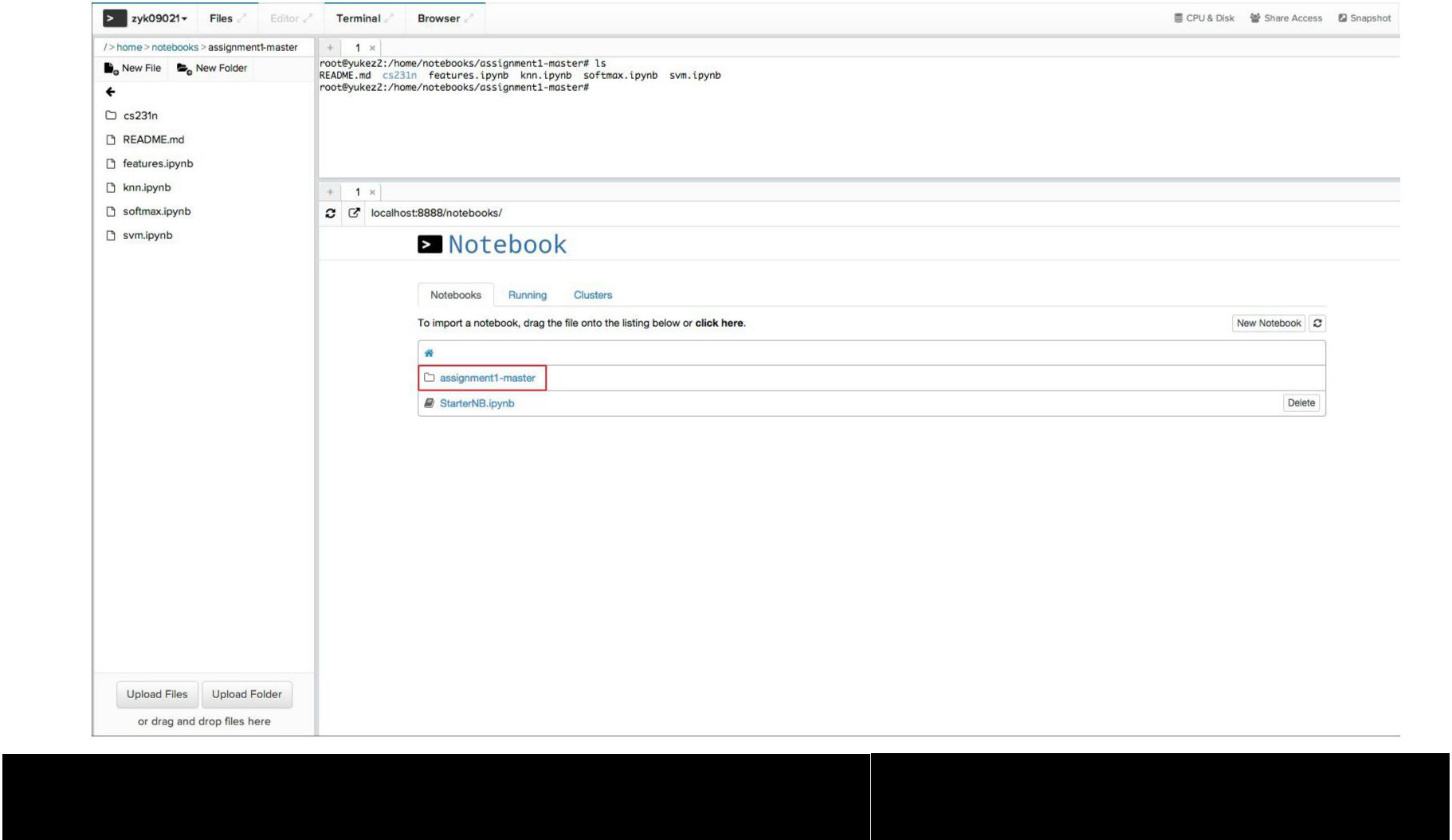
http://cs231n.github.io/python-numpy-tutorial/



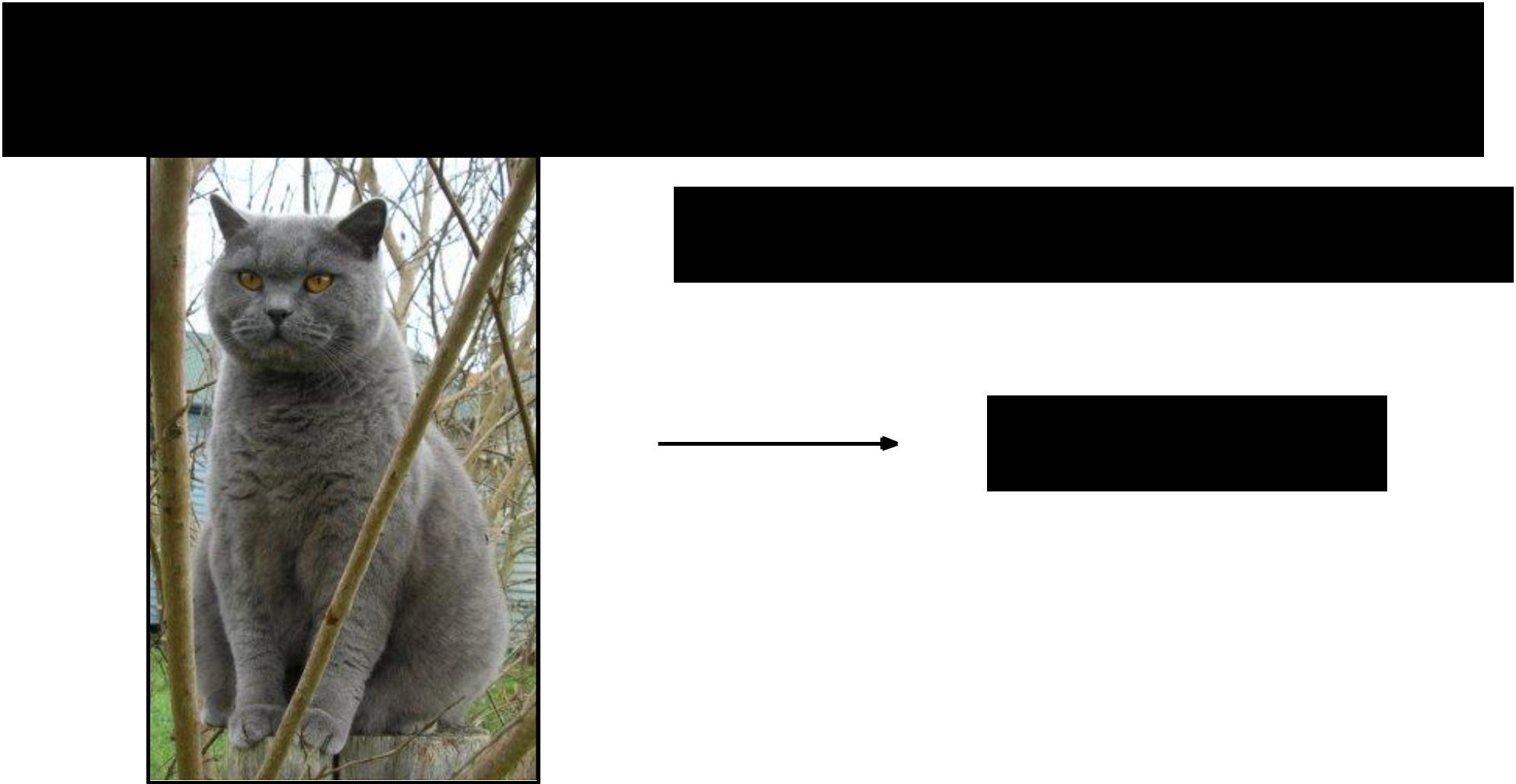
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|  |  |  |

**Image Classification**: a core task in Computer Vision

(assume given set of discrete labels)

{dog, cat, truck, plane, ...}

cat



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**The problem:**

*semantic gap*

Images are represented as 3D arrays of numbers, with integers between [0, 255].

E.g.

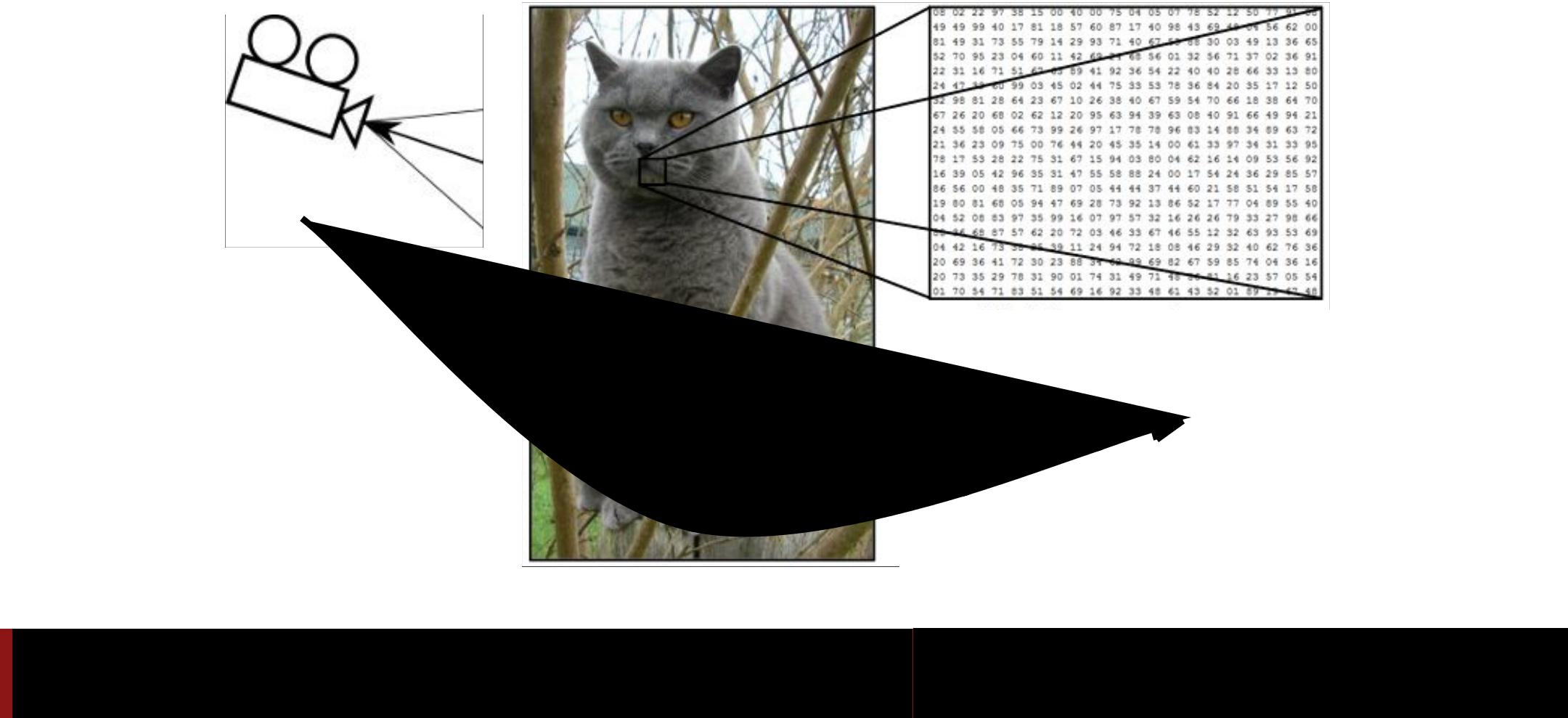
300 x 100 x 3

(3 for 3 color channels RGB)

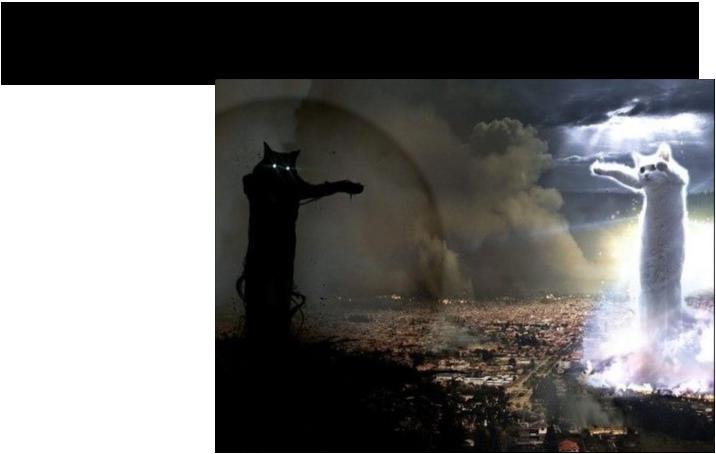


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Challenges: Viewpoint Variation



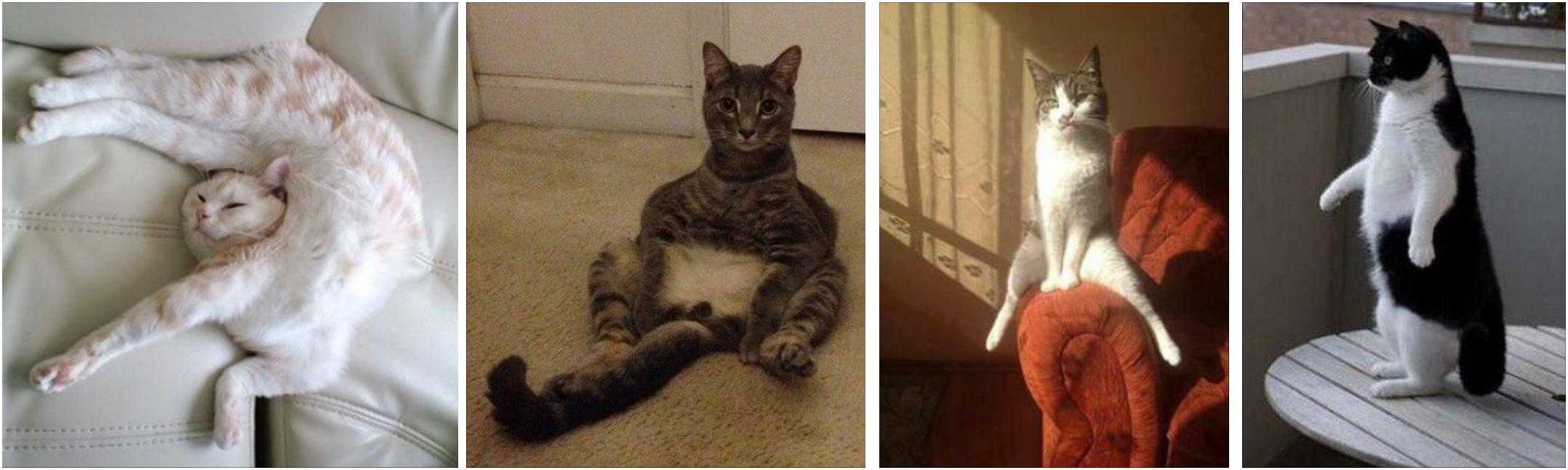
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Challenges: Illumination

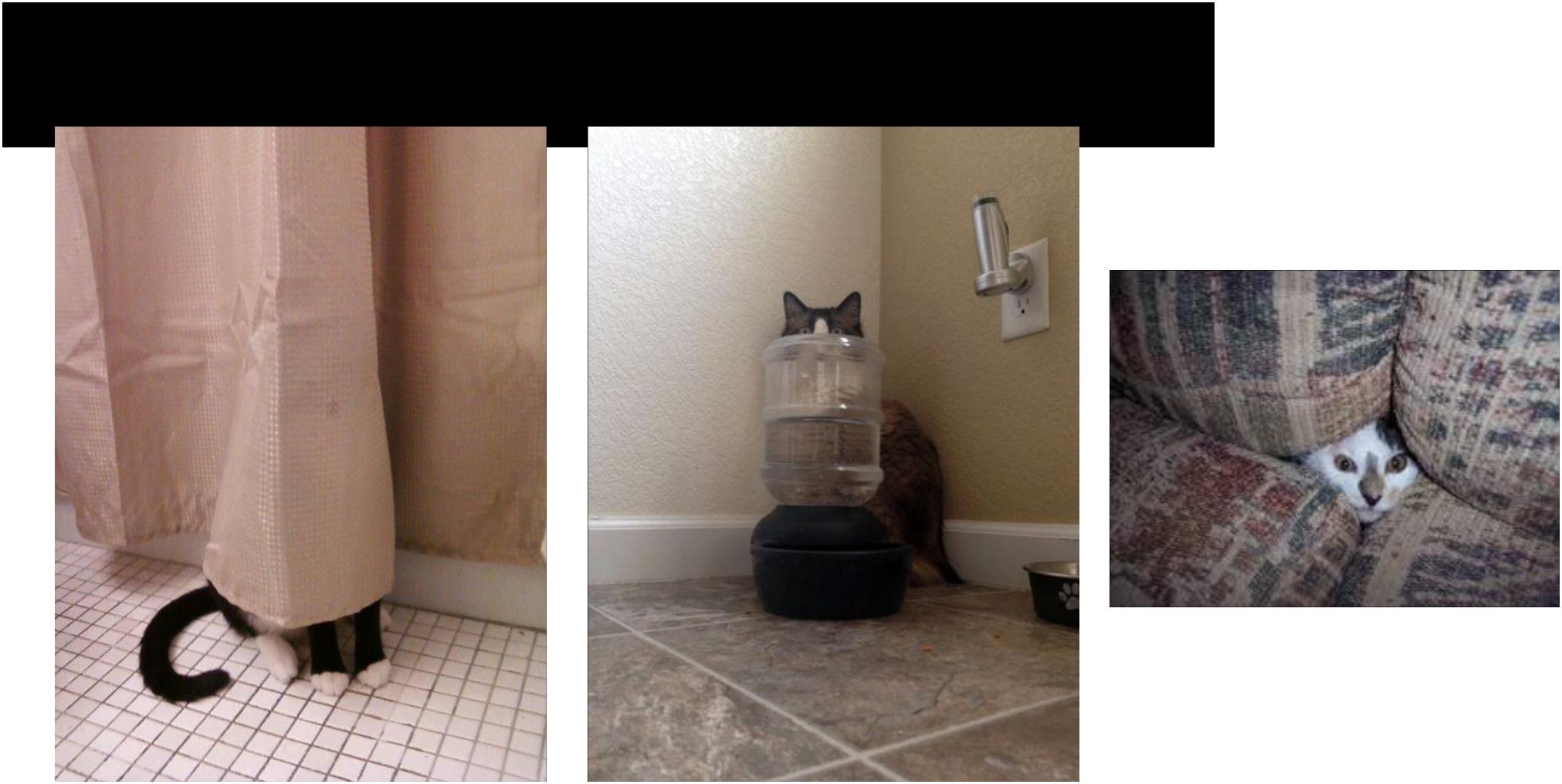


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Challenges: Deformation

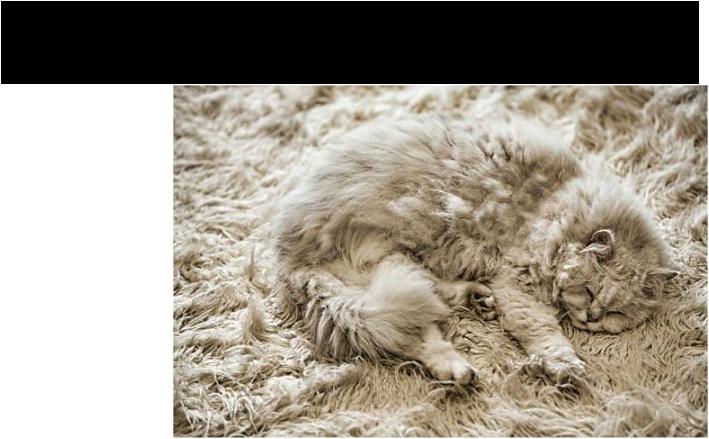


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Challenges: Occlusion



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Challenges: Background clutter



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Challenges: Intraclass variation



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**An image classifier**



Unlike e.g. sorting a list of numbers,

**no obvious way** to hard-code the algorithm forrecognizing a cat, or other classes.

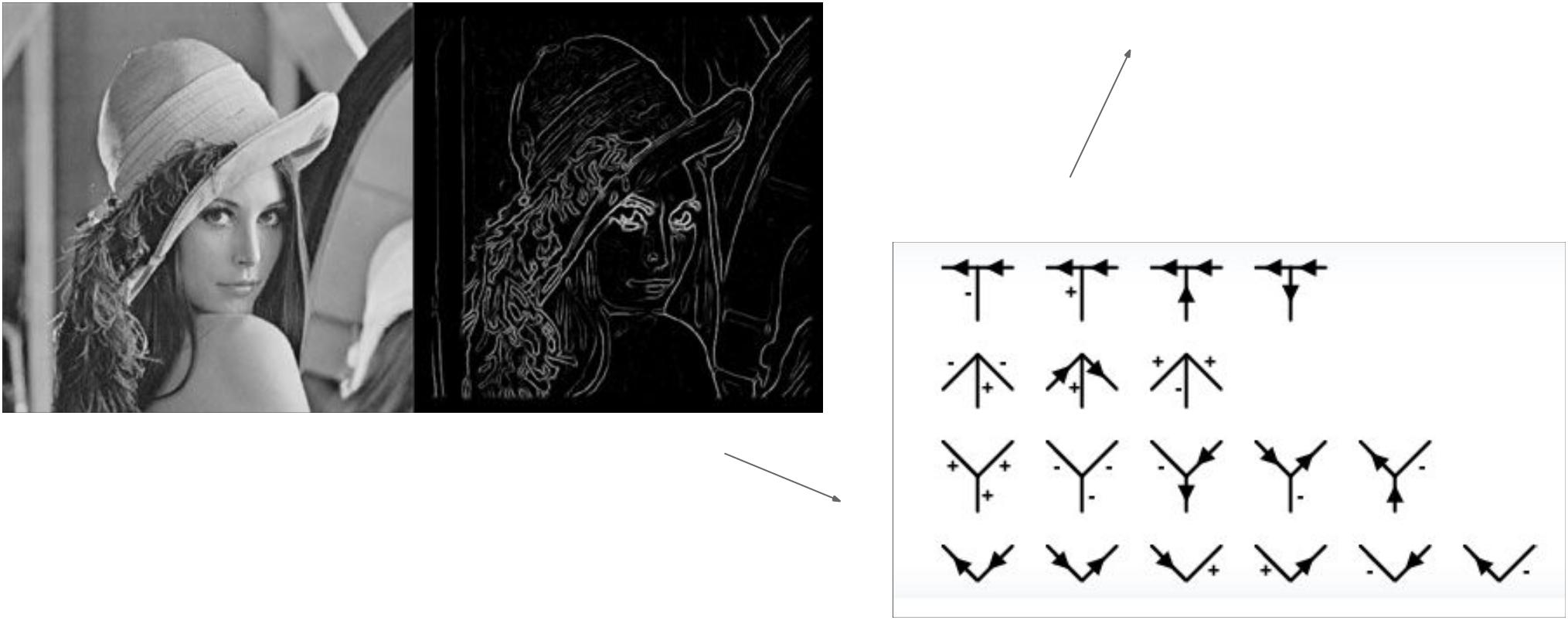


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Attempts have been made

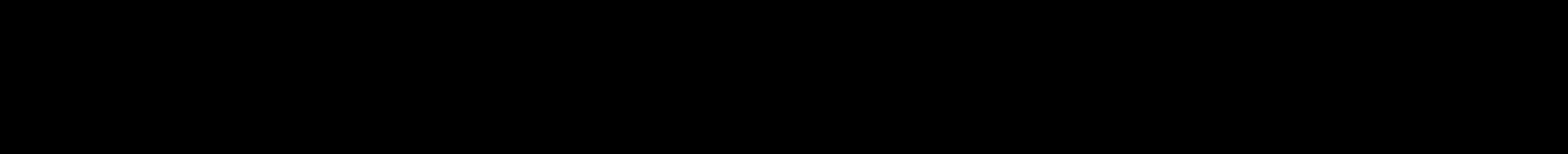


???



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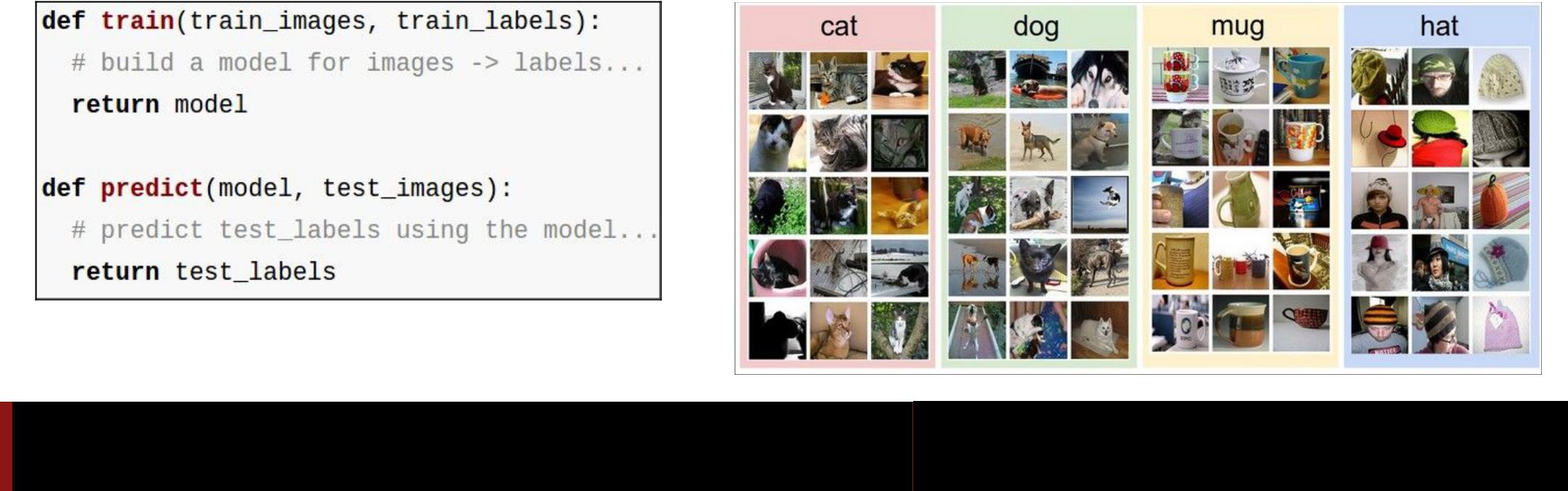
**Data-driven approach:**



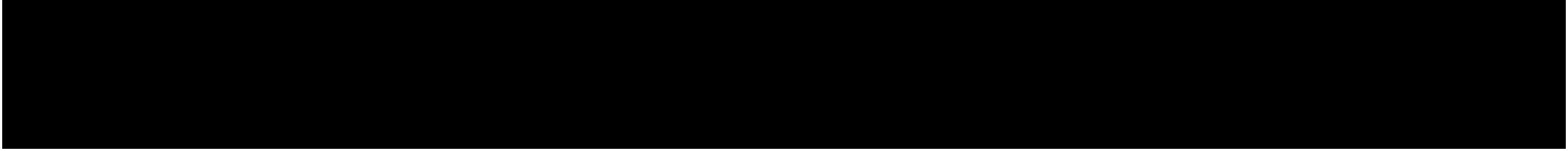
1. Collect a dataset of images and labels
2. Use Machine Learning to train an image classifier
3. Evaluate the classifier on a withheld set of test images



**Example training set**

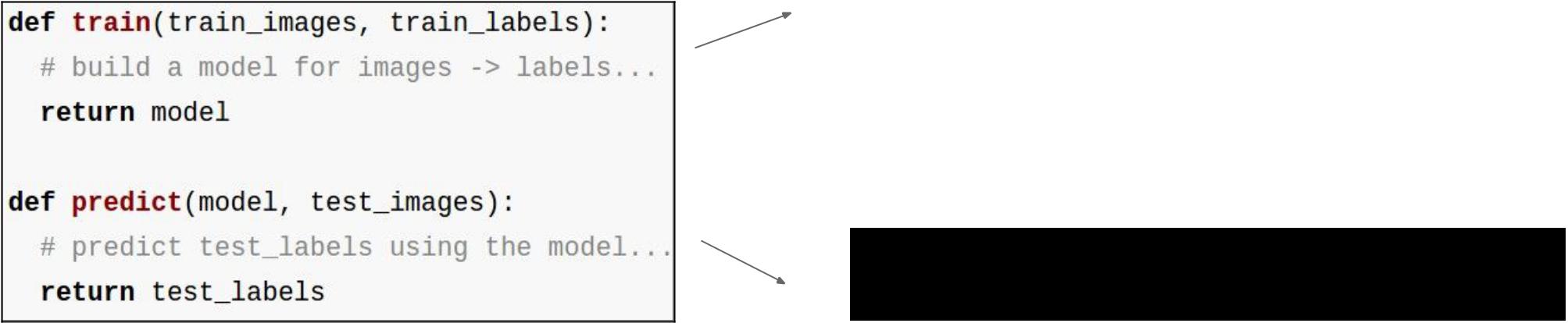


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First classifier: **Nearest Neighbor Classifier**



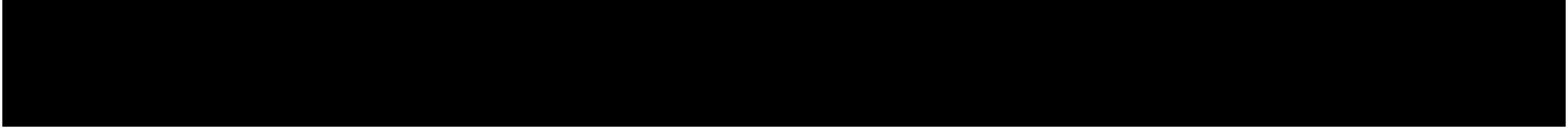
Remember all training images and their labels



Predict the label of the most similar training image



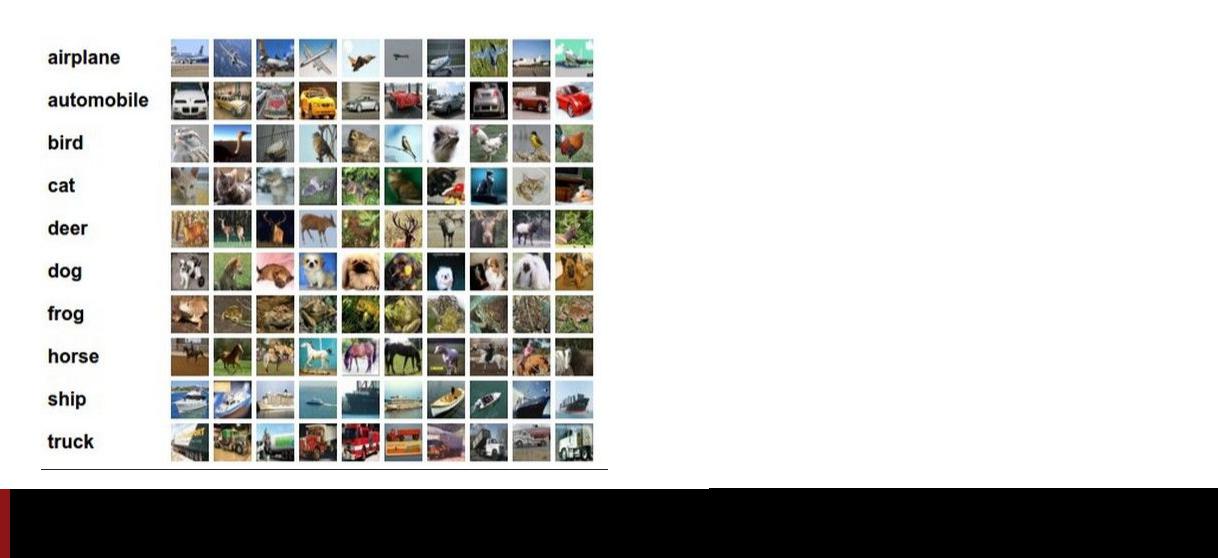
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Example dataset: **CIFAR-10**

1. labels

**50,000** training images, each image is tiny: 32x32

**10,000** test images.



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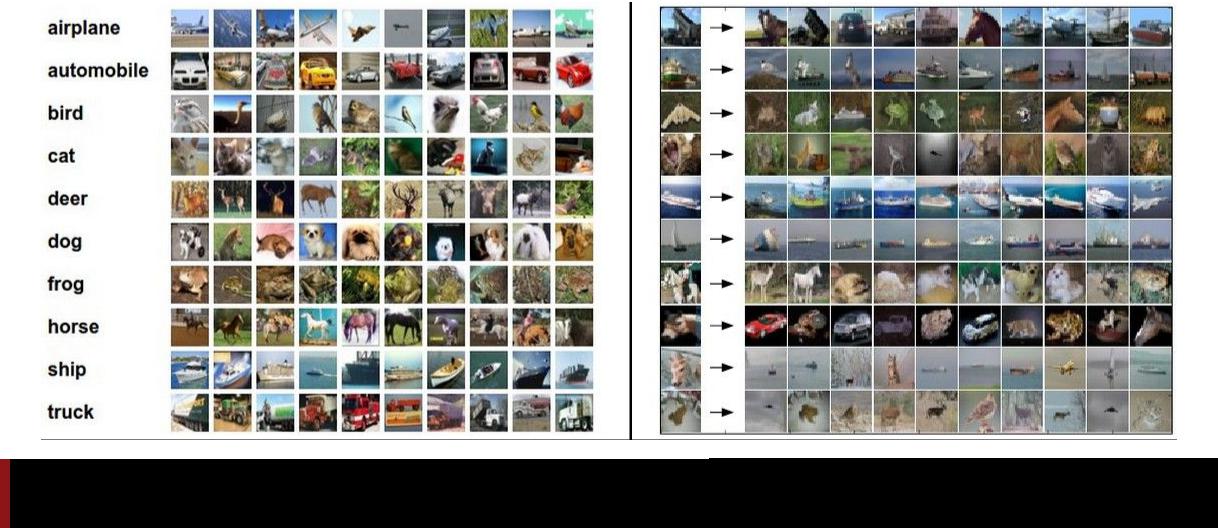
Example dataset: **CIFAR-10**

1. labels

**50,000** training images

examples of nearest neighbors in rows

**10,000** test images.

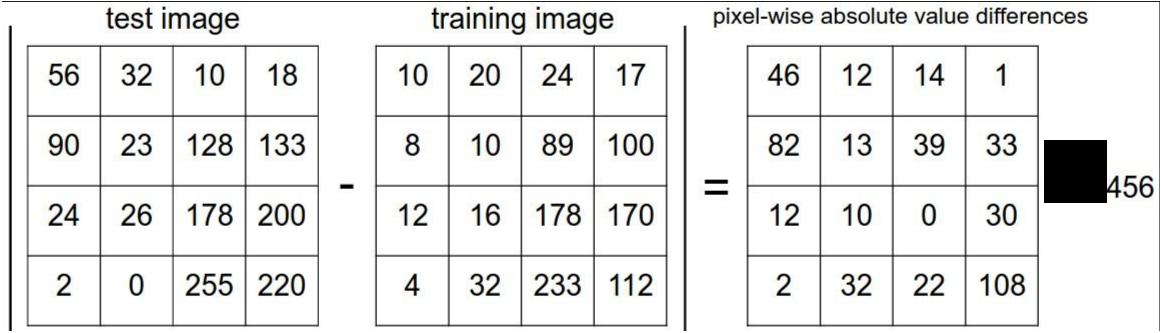


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How do we compare the images? What is the **distance metric**?



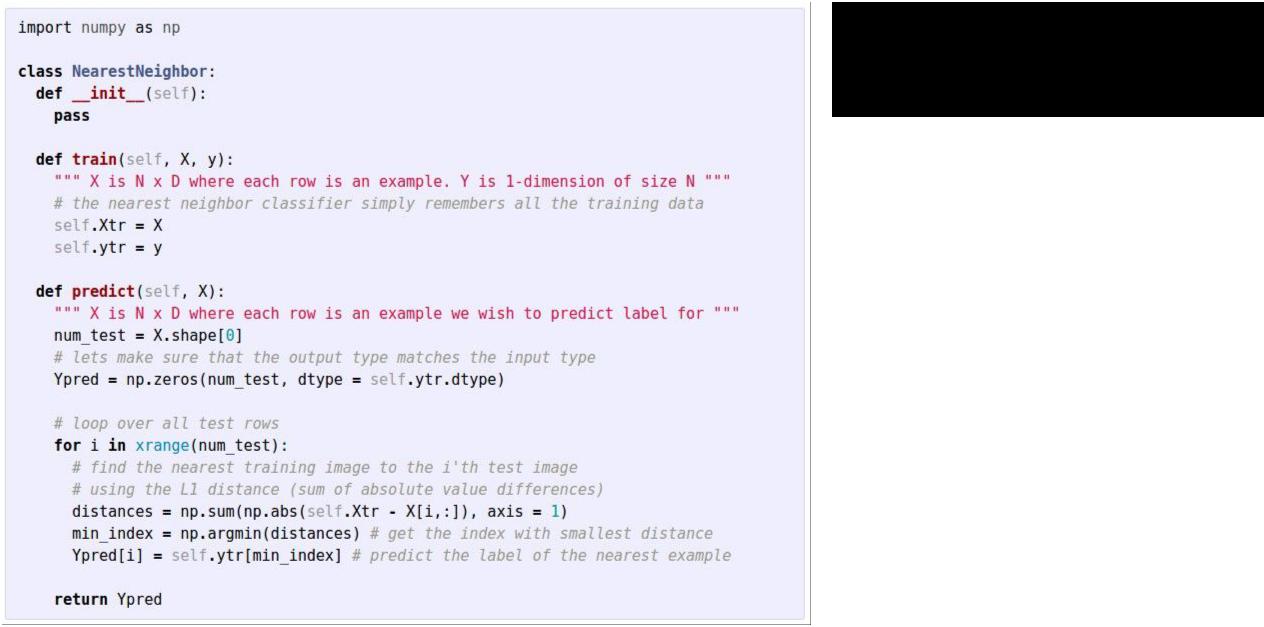
**L1 distance:**



add

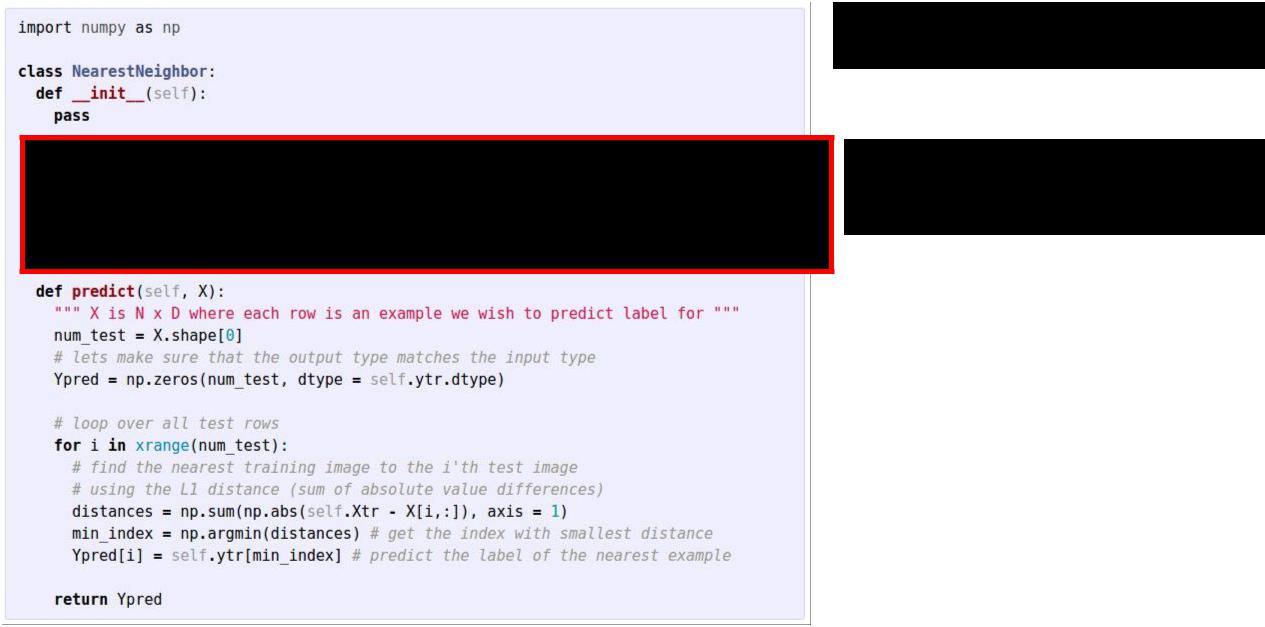


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Nearest Neighbor classifier



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Nearest Neighbor classifier

remember the training data



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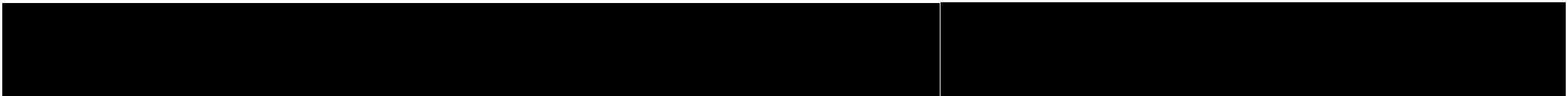


Nearest Neighbor classifier

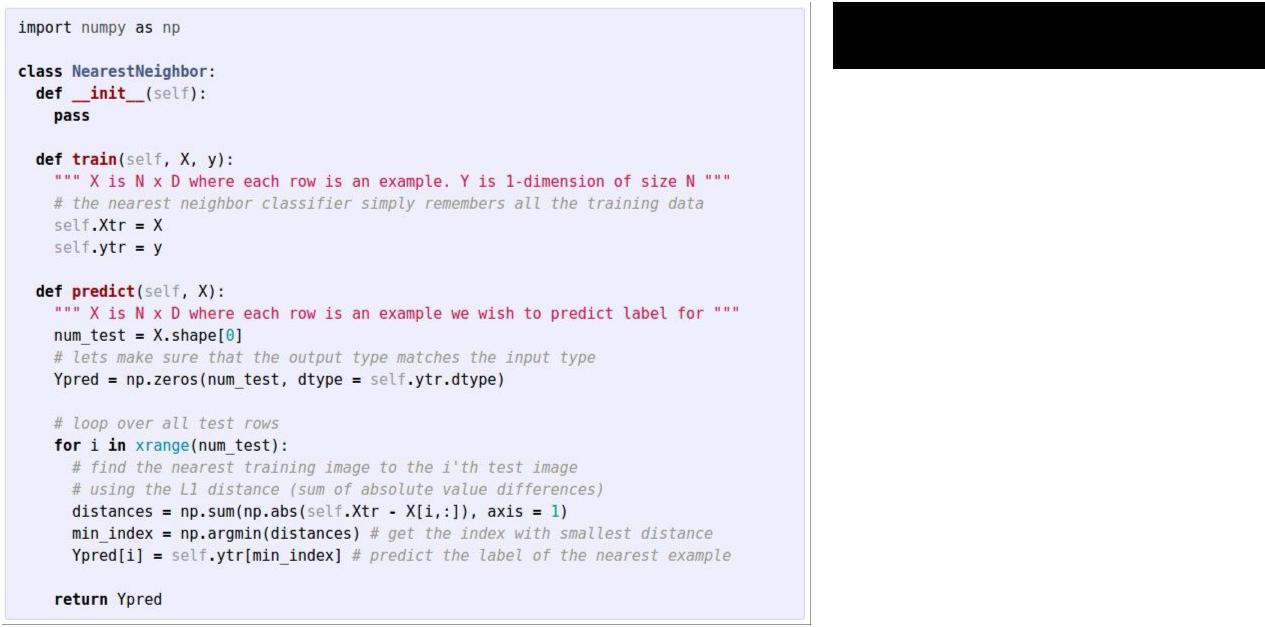
for every test image:

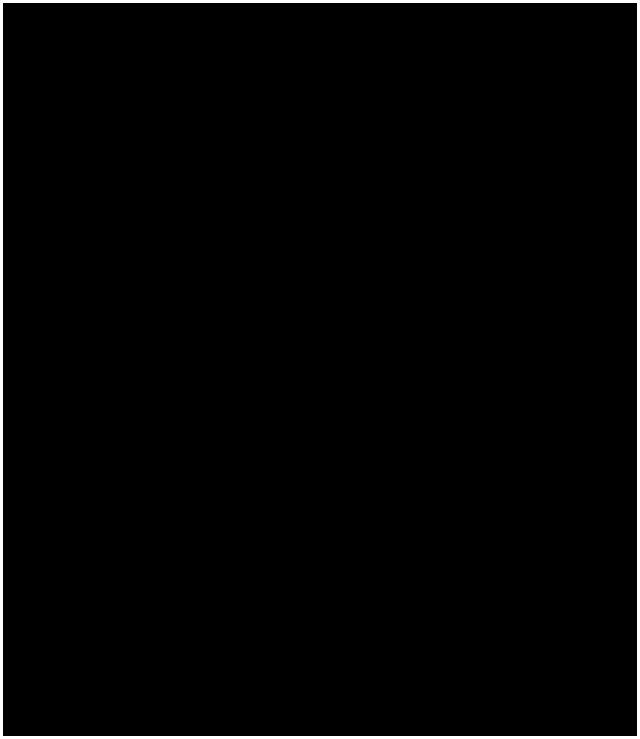
- find nearest train image with L1 distance

- predict the label of nearest training image



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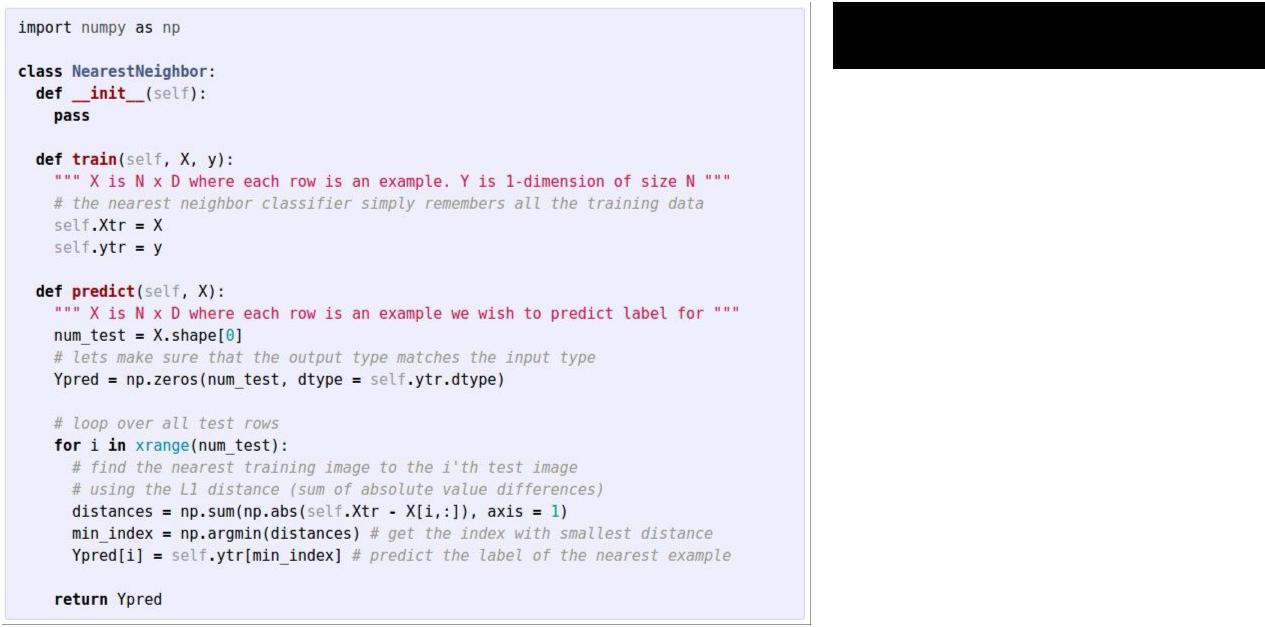
Nearest Neighbor classifier



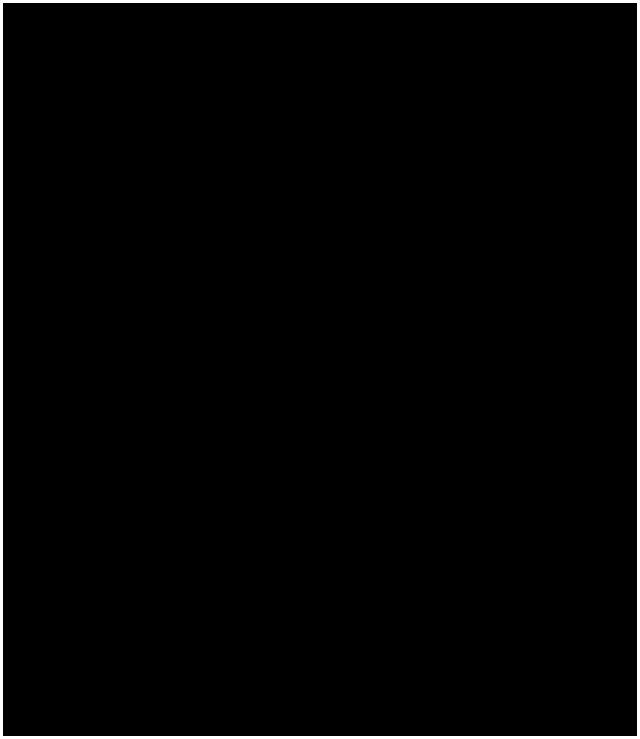
1. **how does the classification speed depend on the size of the training data?**



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Nearest Neighbor classifier

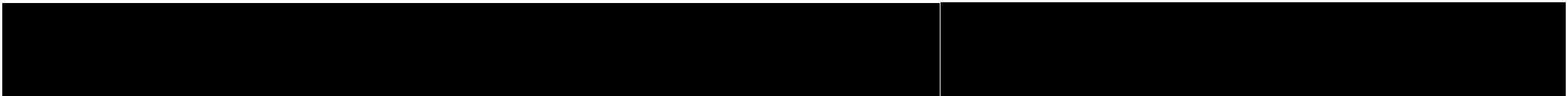


Q: how does the classification speed depend on the size of the training data? **linearly :(**

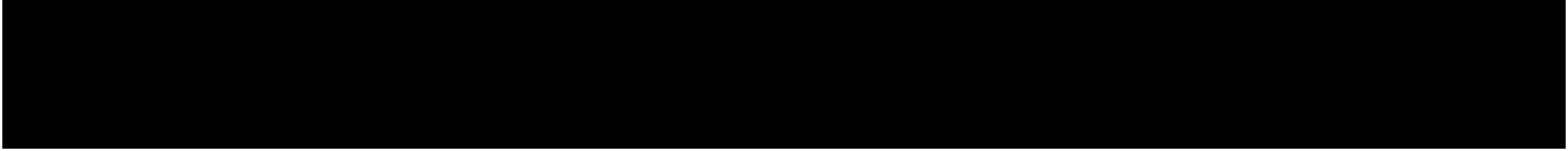
This is **backwards**:

- test time performance is usually much more important in practice.

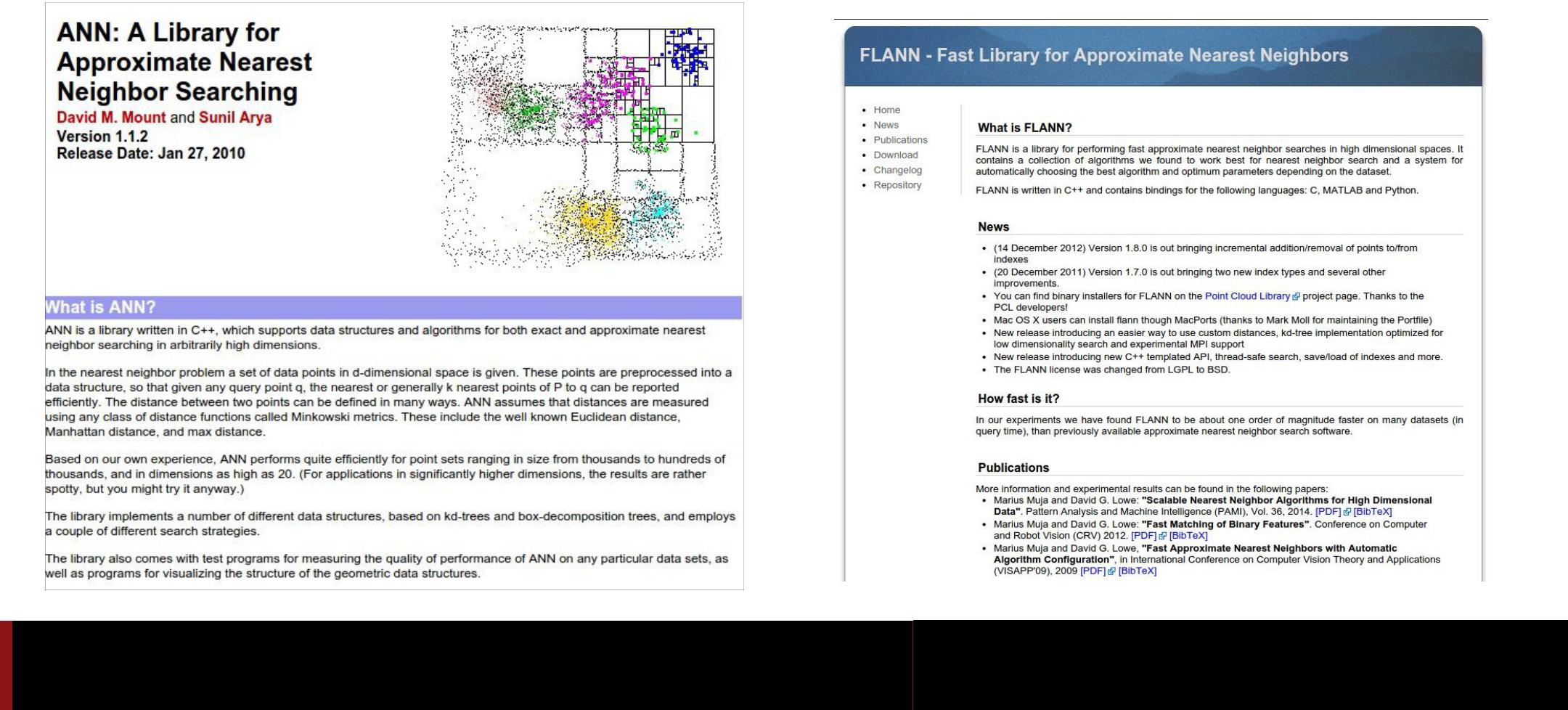
- CNNs flip this: expensive training, cheap test evaluation



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**Aside: Approximate Nearest Neighbor**

find approximate nearest neighbors quickly

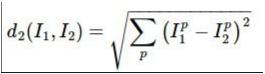


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The choice of distance is a **hyperparameter** common choices:



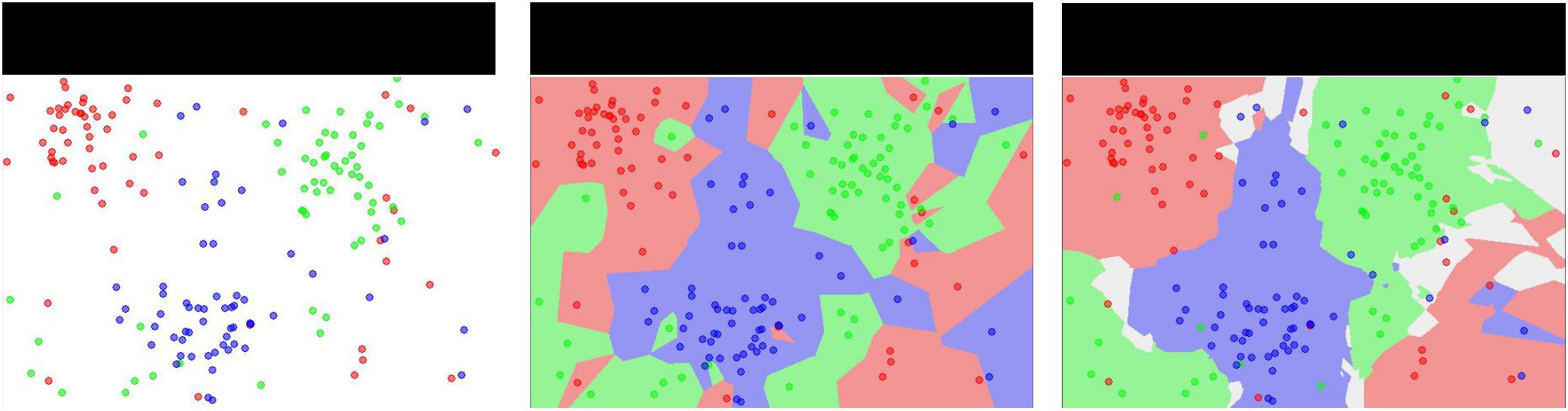
L1 (Manhattan) distance L2 (Euclidean) distance



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k-Nearest Neighbor

find the k nearest images, have them vote on the label



the data NN classifier 5-NN classifier



http://en.wikipedia.org/wiki/K-nearest\_neighbors\_algorithm



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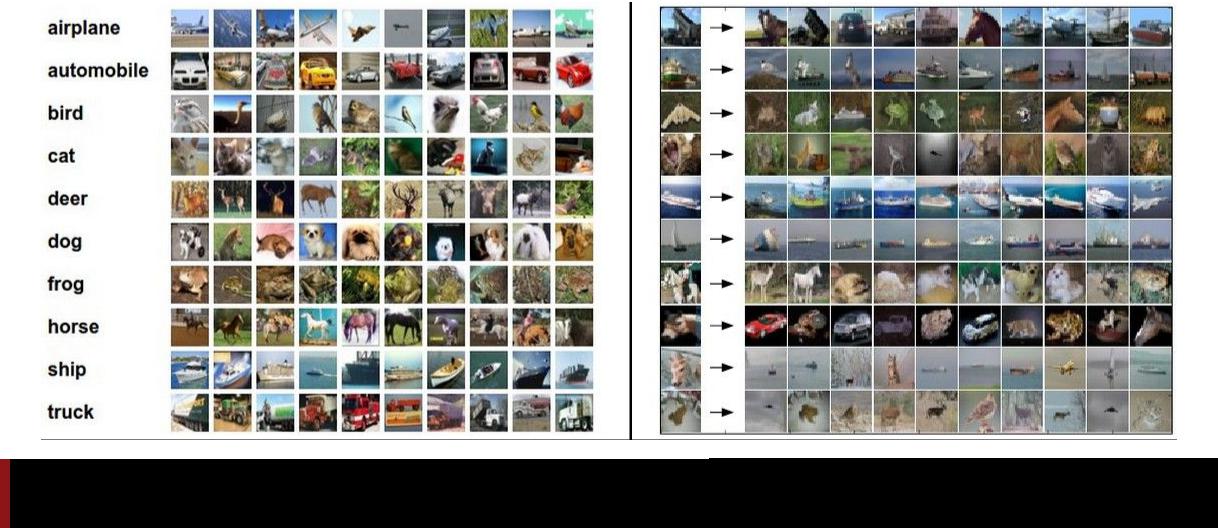
Example dataset: **CIFAR-10**

1. labels

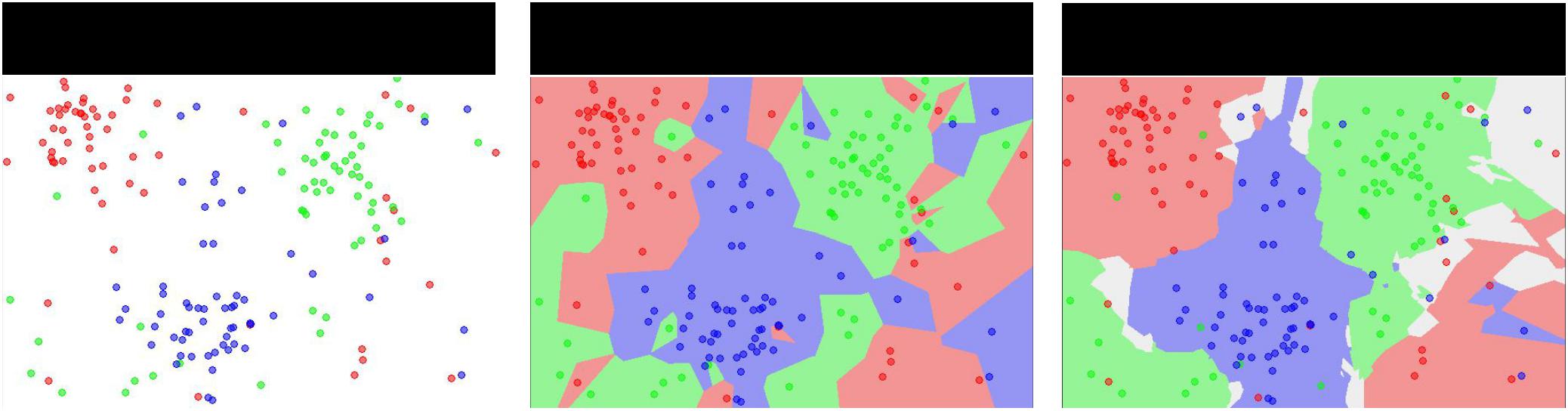
**50,000** training images

examples of nearest neighbors in rows

**10,000** test images.



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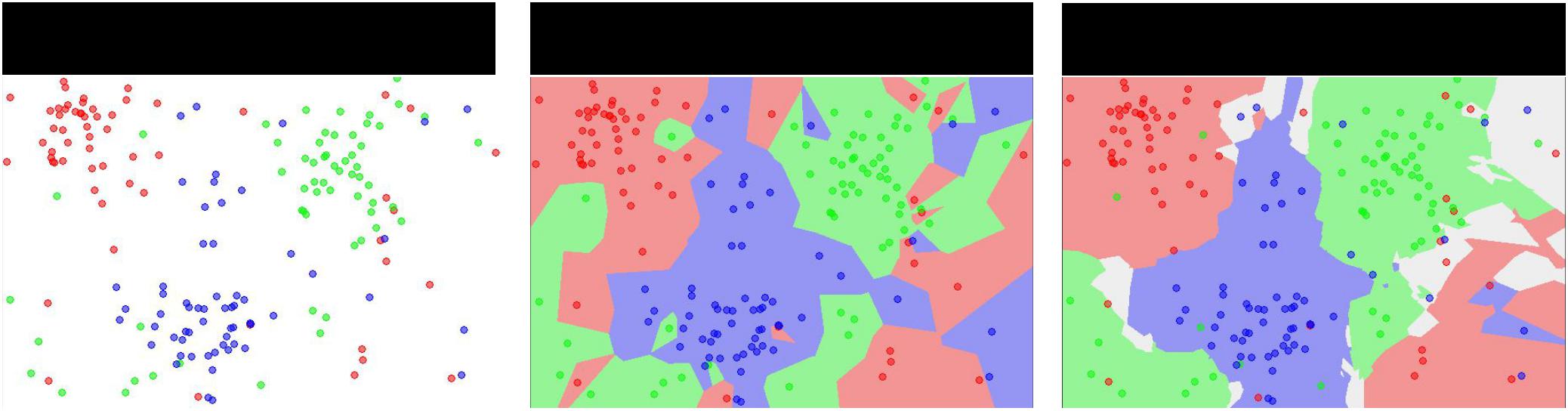
the data NN classifier 5-NN classifier



1. what is the accuracy of the nearest neighbor classifier on the training data, when using the Euclidean distance?



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the data NN classifier 5-NN classifier



Q2: what is the accuracy of the **k-**nearest neighbor classifier on the training data?



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What is the best **distance** to use?

What is the best value of **k** to use?

i.e. how do we set the **hyperparameters**?



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What is the best **distance** to use?

What is the best value of **k** to use?

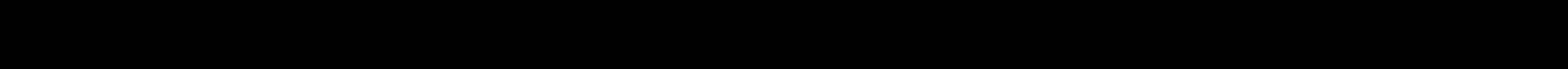
i.e. how do we set the **hyperparameters**?

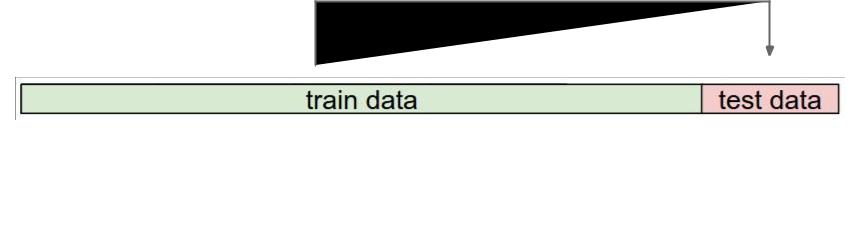
Very problem-dependent.

Must try them all out and see what works best.

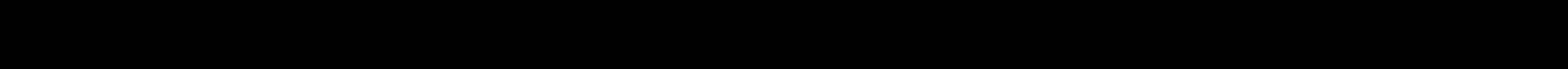


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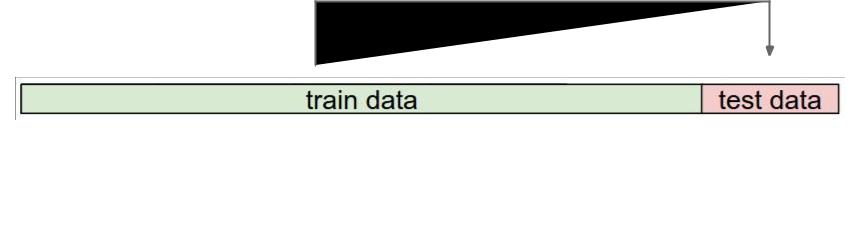
Try out what hyperparameters work best on test set.



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Trying out what hyperparameters work best on test set:

Very bad idea. The test set is a proxy for the generalization performance! Use only **VERY SPARINGLY,** at the end.



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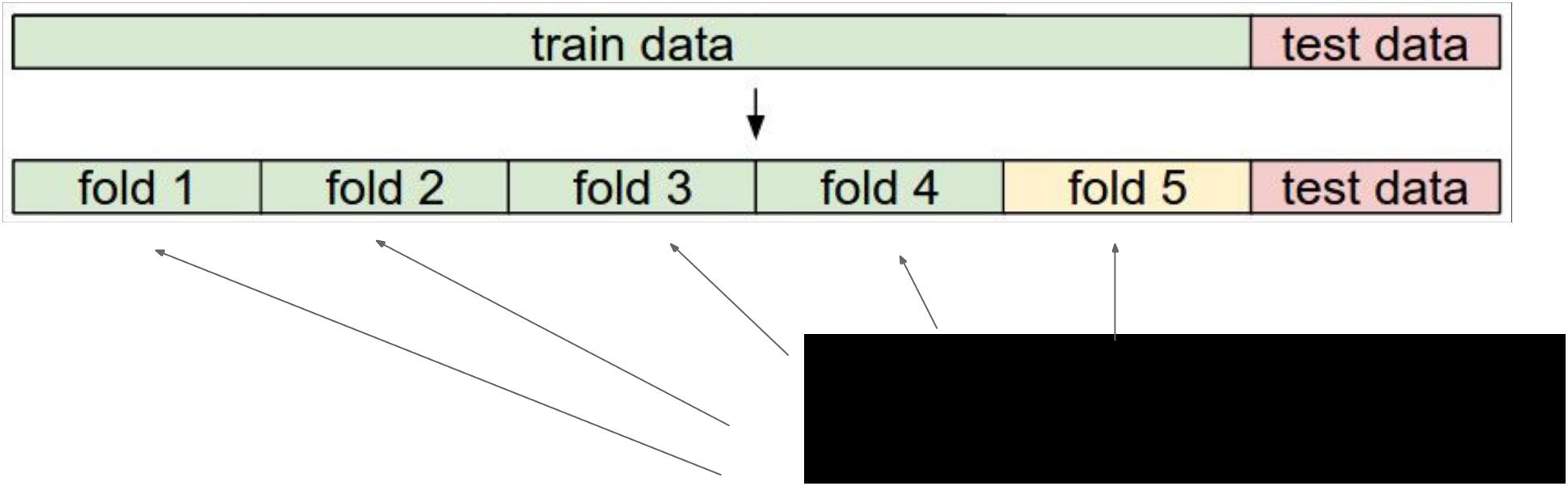


Validation data

use to tune hyperparameters



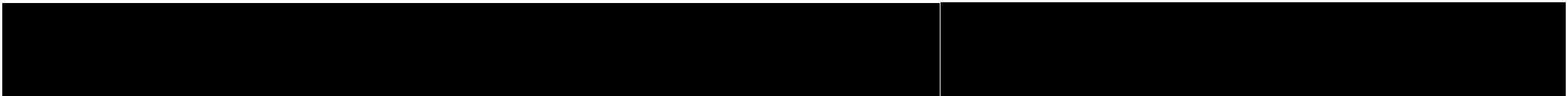
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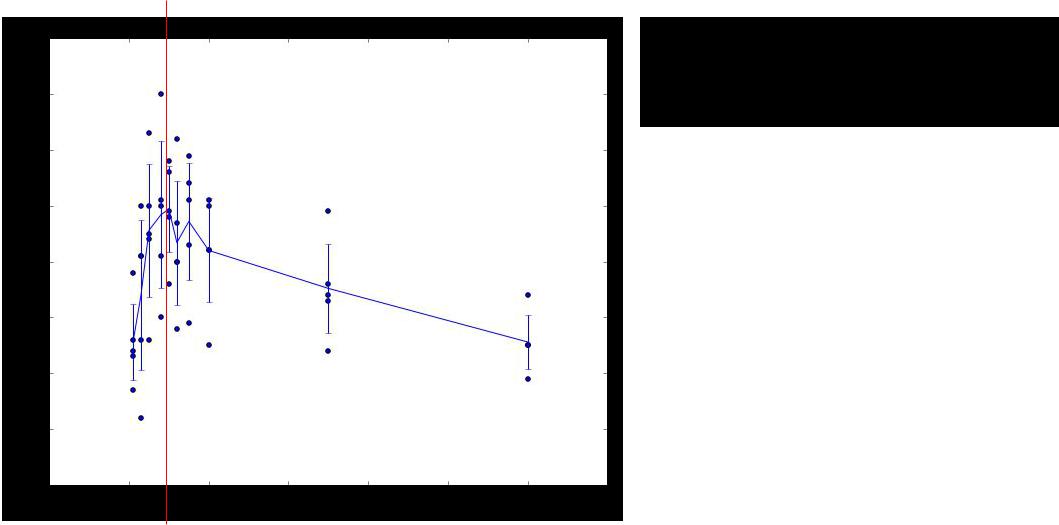
**Cross-validation**

cycle through the choice of which fold

is the validation fold, average results.



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Example of 5-fold cross-validation for the value of **k.**

Each point: single outcome.

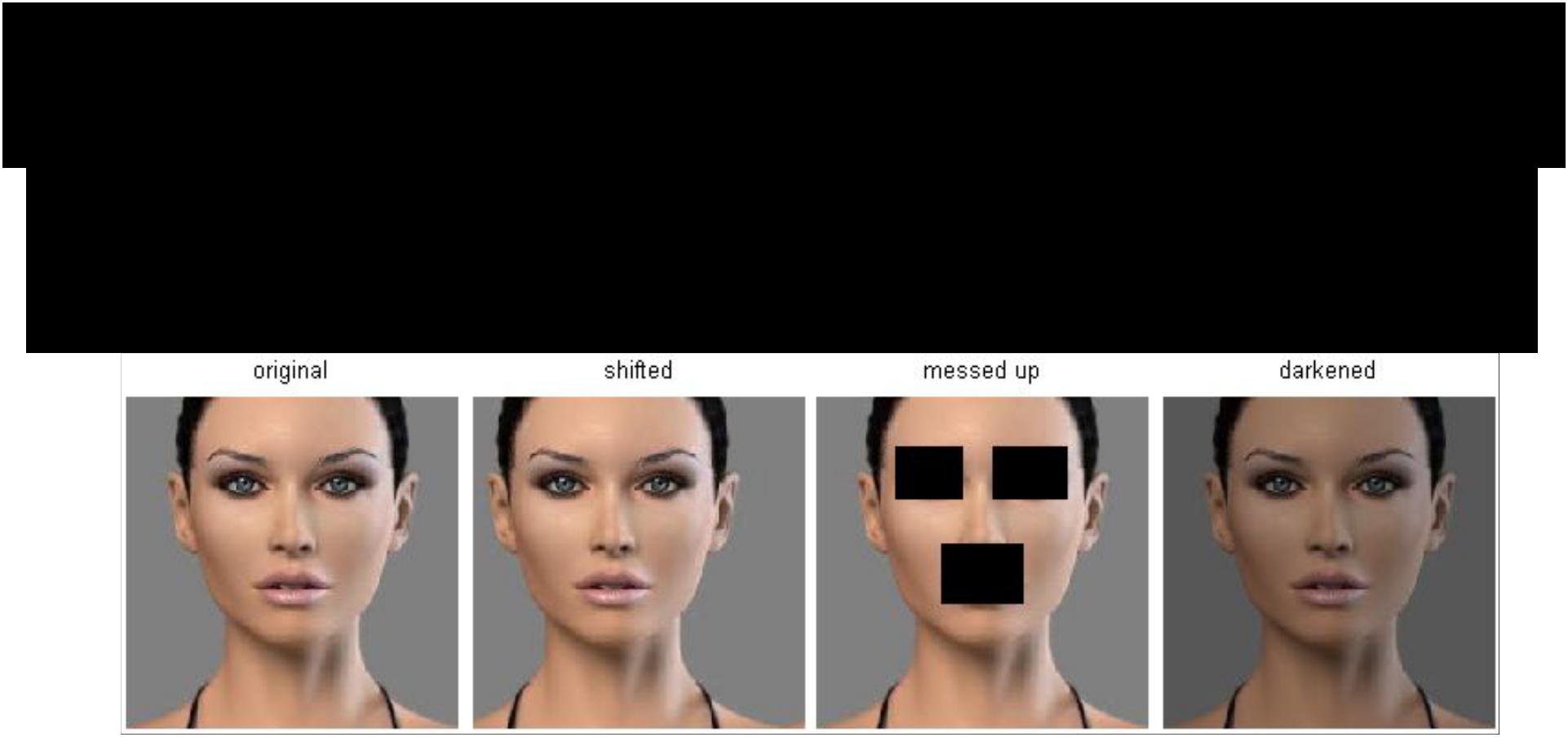
The line goes

through the mean, bars indicated standard deviation

(Seems that k ~= 7 works best for this data)



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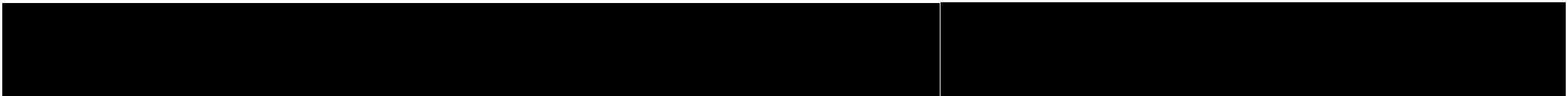


k-Nearest Neighbor on images **never used.**

* terrible performance at test time
* distance metrics on level of whole images can be very unintuitive

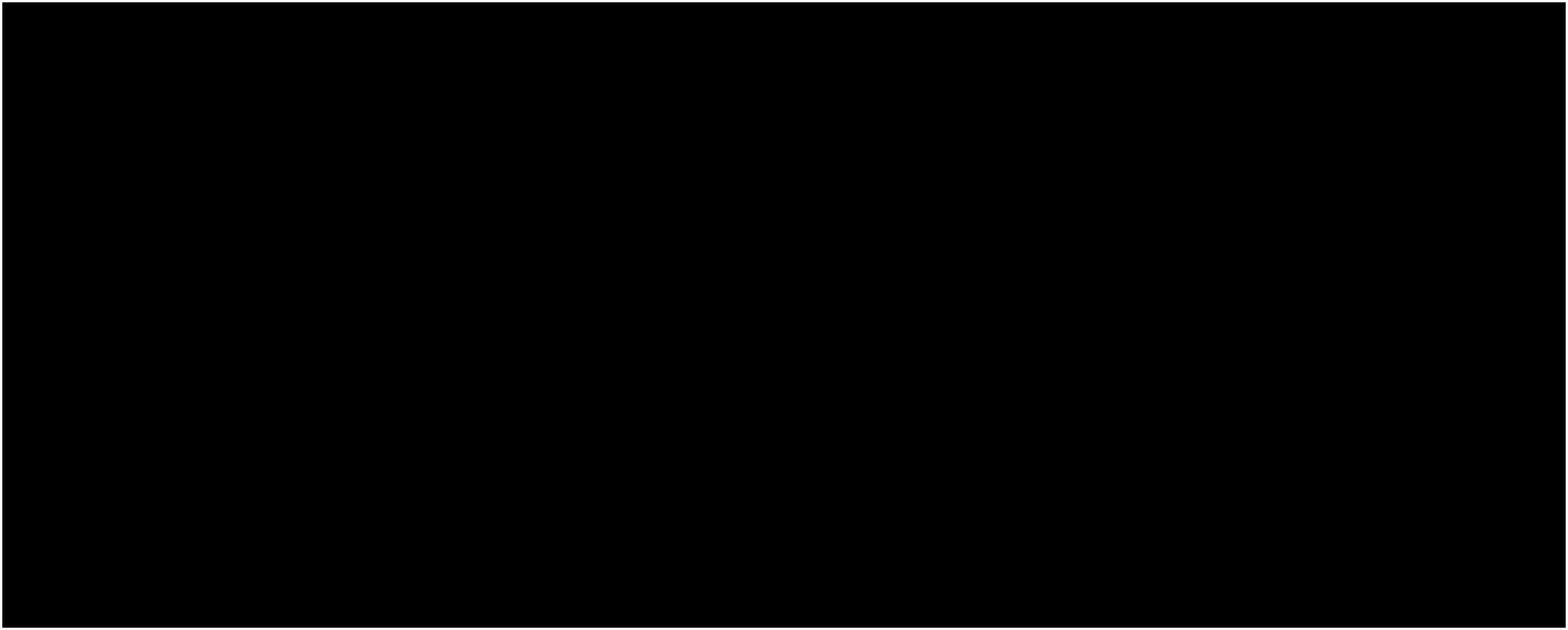


(all 3 images have same L2 distance to the one on the left)



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Summary



* **Image Classification:** We are given a **Training Set** of labeled images, askedto predict labels on **Test Set**. Common to report the **Accuracy** of predictions (fraction of correctly predicted images)
* We introduced the **k-Nearest Neighbor Classifier**, which predicts the labels based on nearest images in the training set
* We saw that the choice of distance and the value of k are **hyperparameters** that are tuned using a **validation set**, or through **cross-validation** if the size of the data is small.
* Once the best set of hyperparameters is chosen, the classifier is evaluated once on the test set, and reported as the performance of kNN on that data.



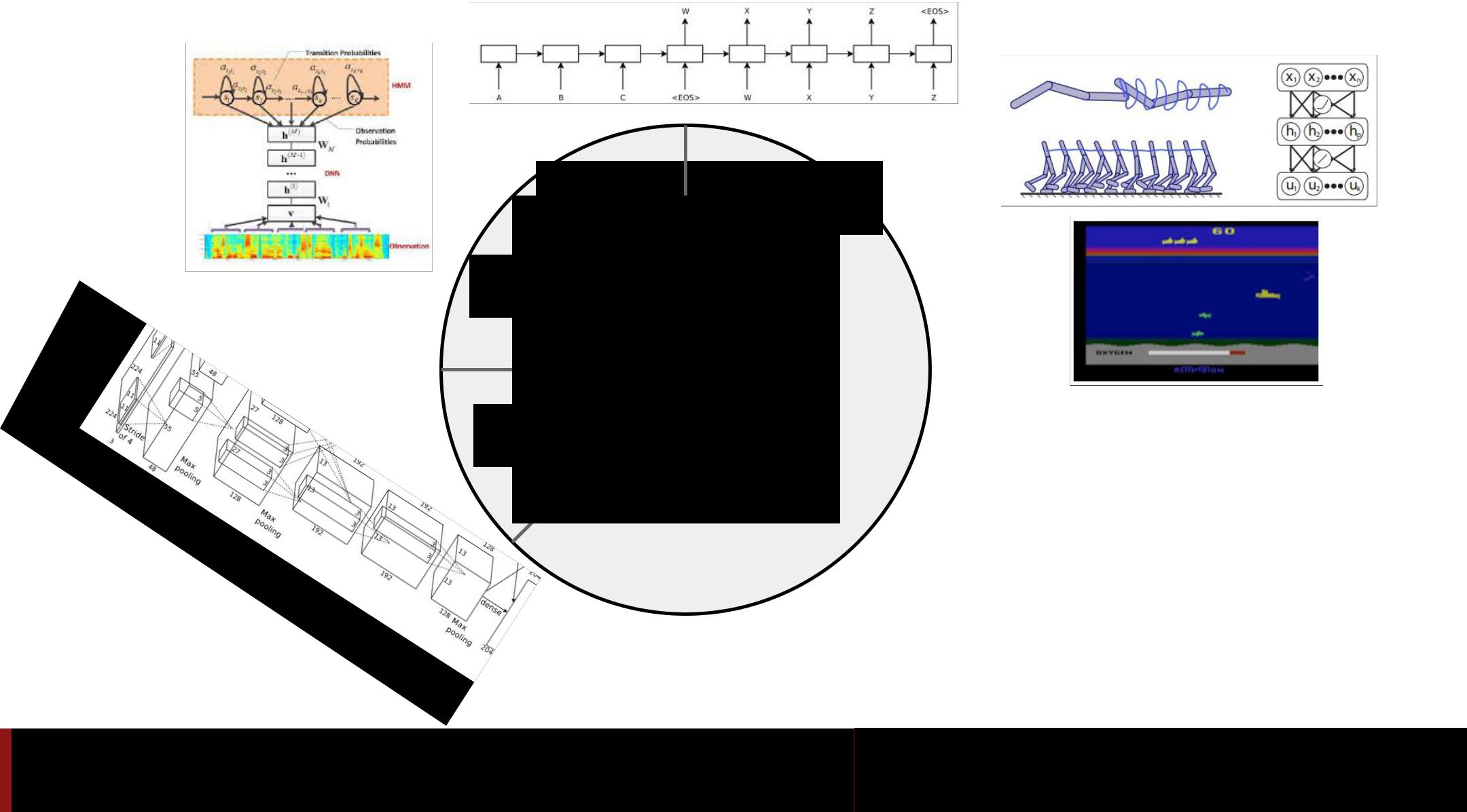
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Linear Classification



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language control



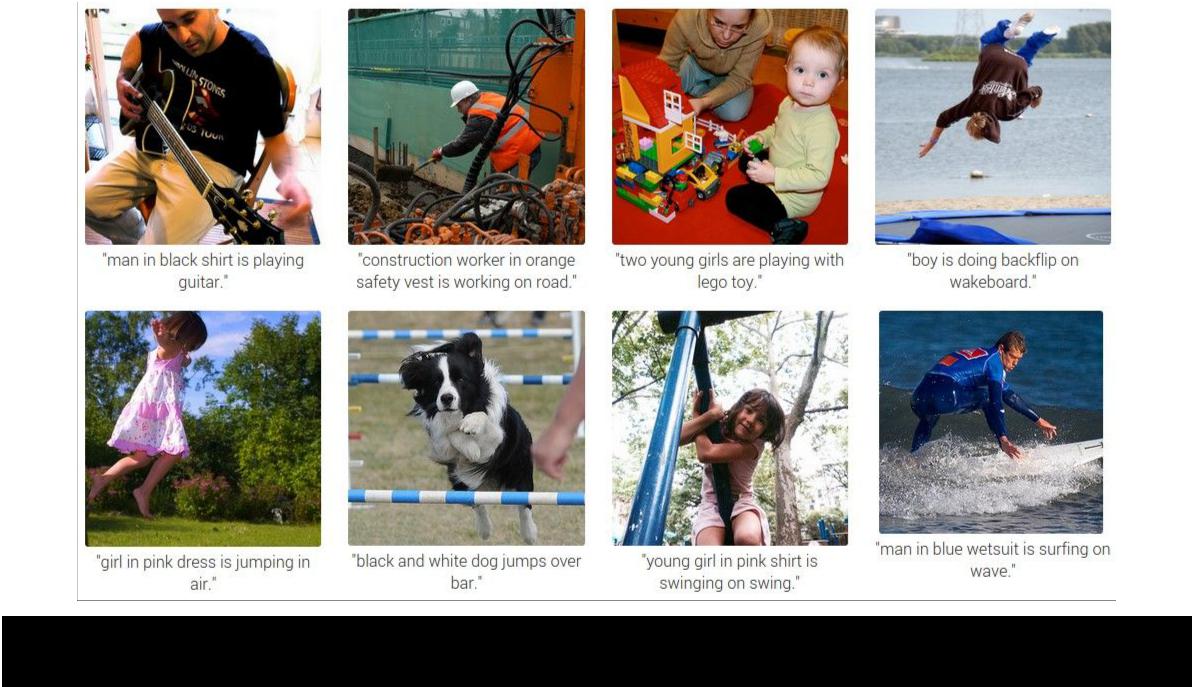
see

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Neural Networks practitioner



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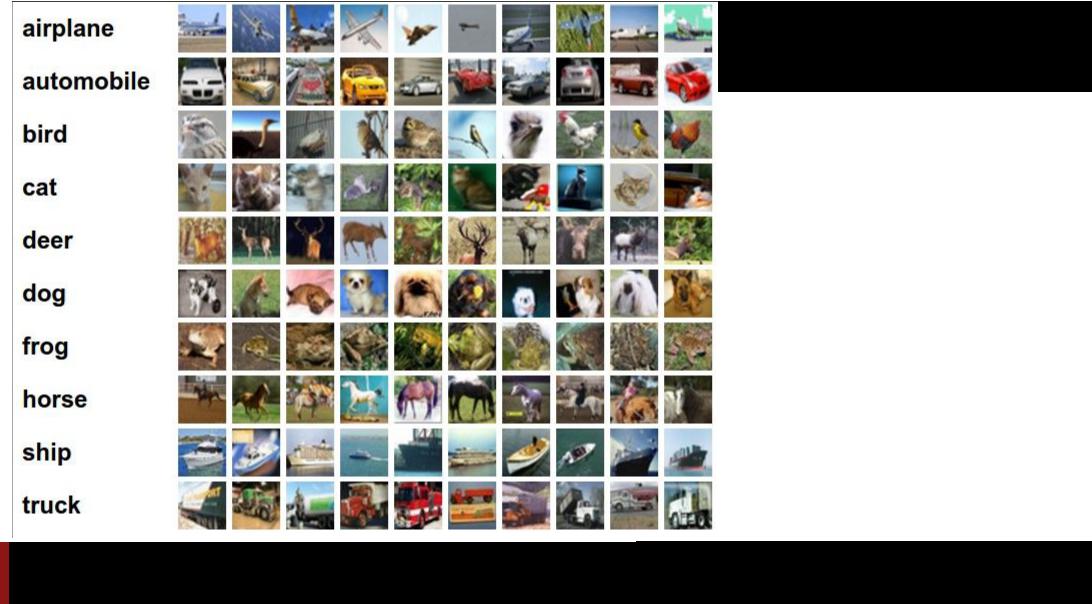
|  |  |  |
| --- | --- | --- |
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|  |  |  |

**RNN**

**CNN**



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Example dataset: **CIFAR-10**

1. labels

**50,000** training imageseach image is **32x32x3**

**10,000** test images.

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Parametric approach



|  |  |
| --- | --- |
| image parameters |  |
| f(**x**,**W**) | **10** numbers, |
|  | indicating class |
|  | scores |



**[32x32x3]**

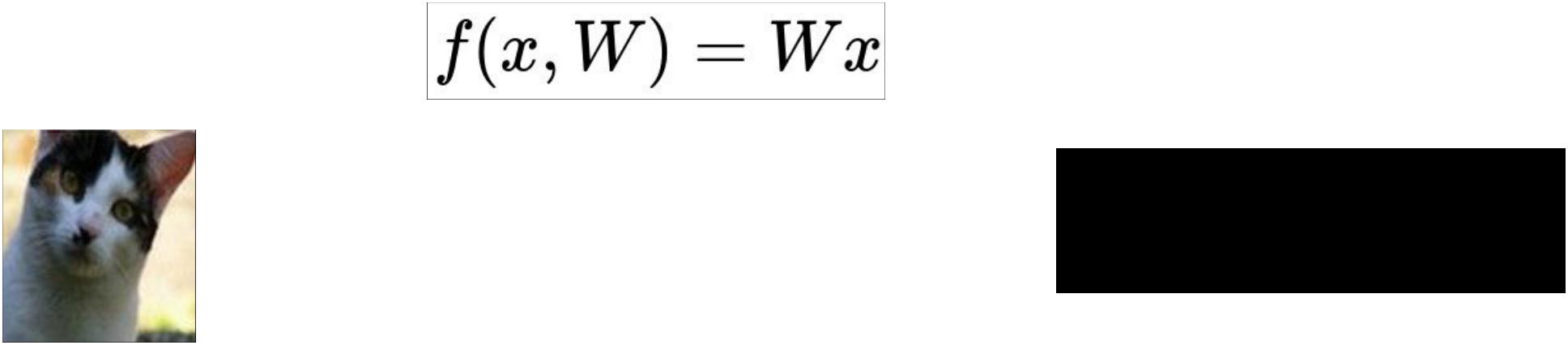
array of numbers 0...1

(3072 numbers total)



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Parametric approach: **Linear classifier**



**10** numbers,



indicating class

scores



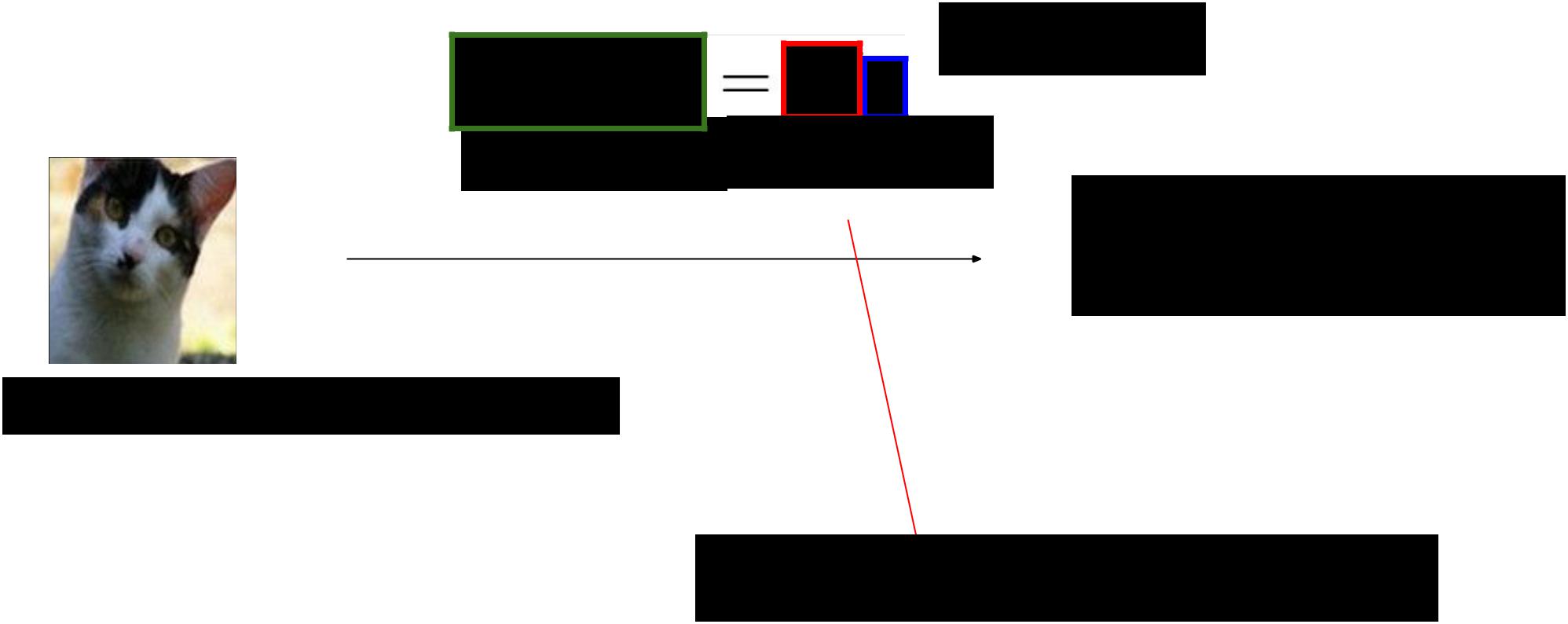
**[32x32x3]**

array of numbers 0...1



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Parametric approach: **Linear classifier**



**3072x1**

**10x1** **10x3072**

**10** numbers,



indicating class

scores

**[32x32x3]**

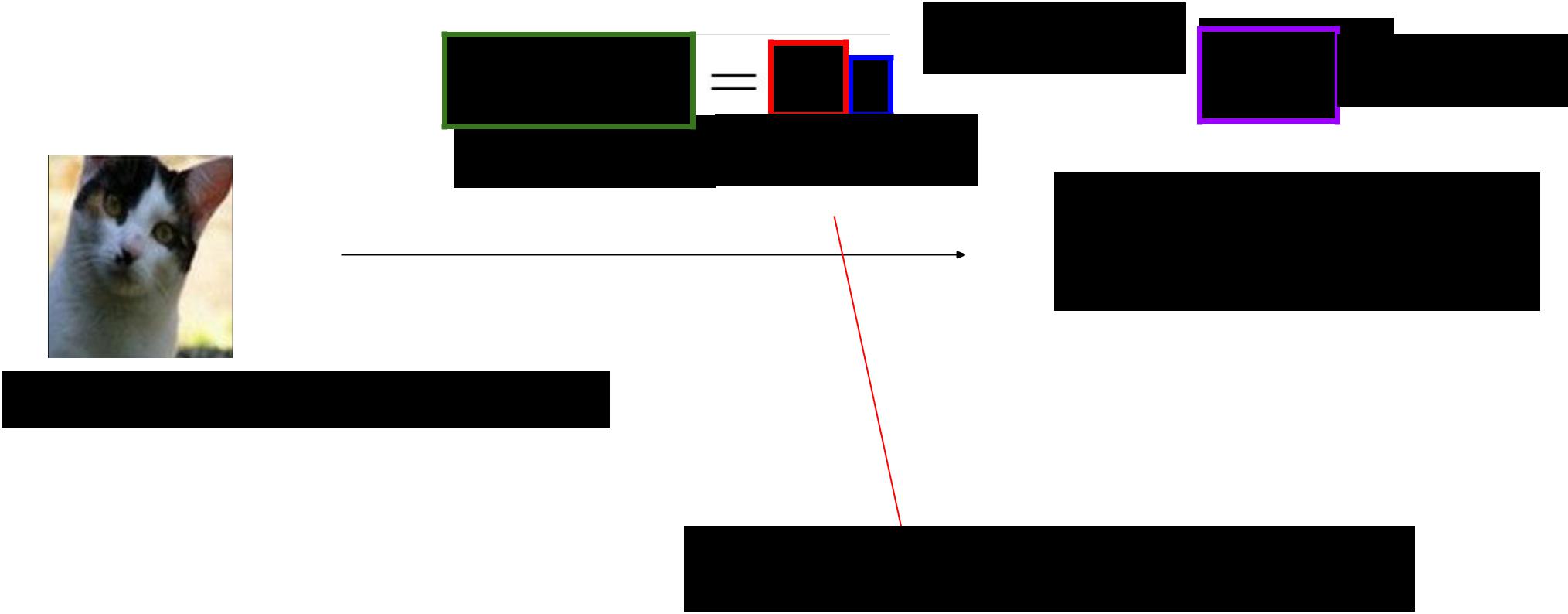
array of numbers 0...1

parameters, or “weights”



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Parametric approach: **Linear classifier**



**3072x1**

**10x1**

**10x1** **10x3072**

**10** numbers,



indicating class

scores

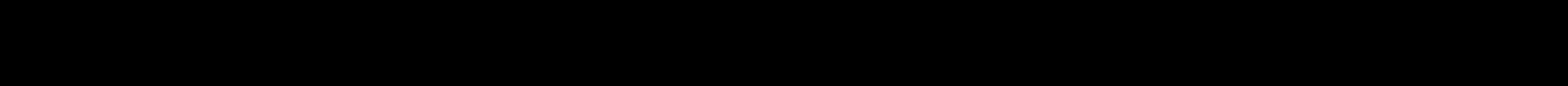
**[32x32x3]**

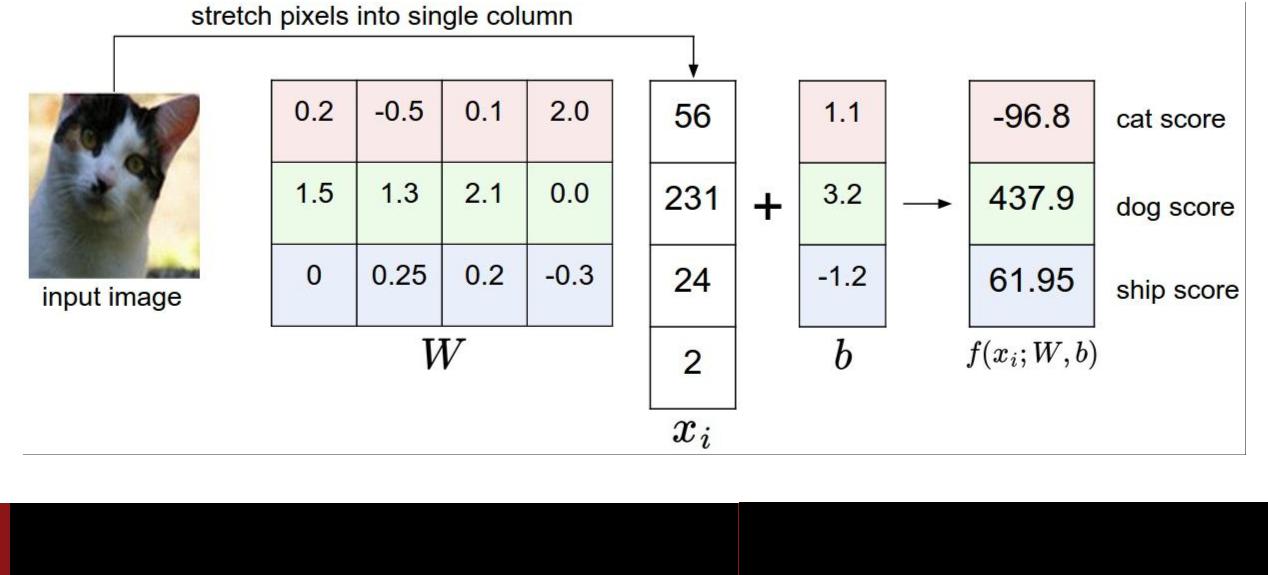
array of numbers 0...1

parameters, or “weights”

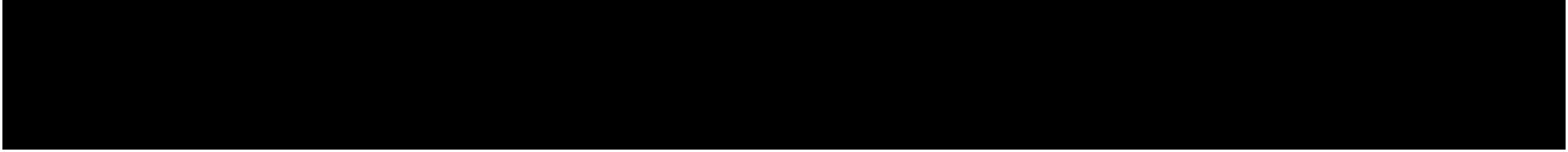


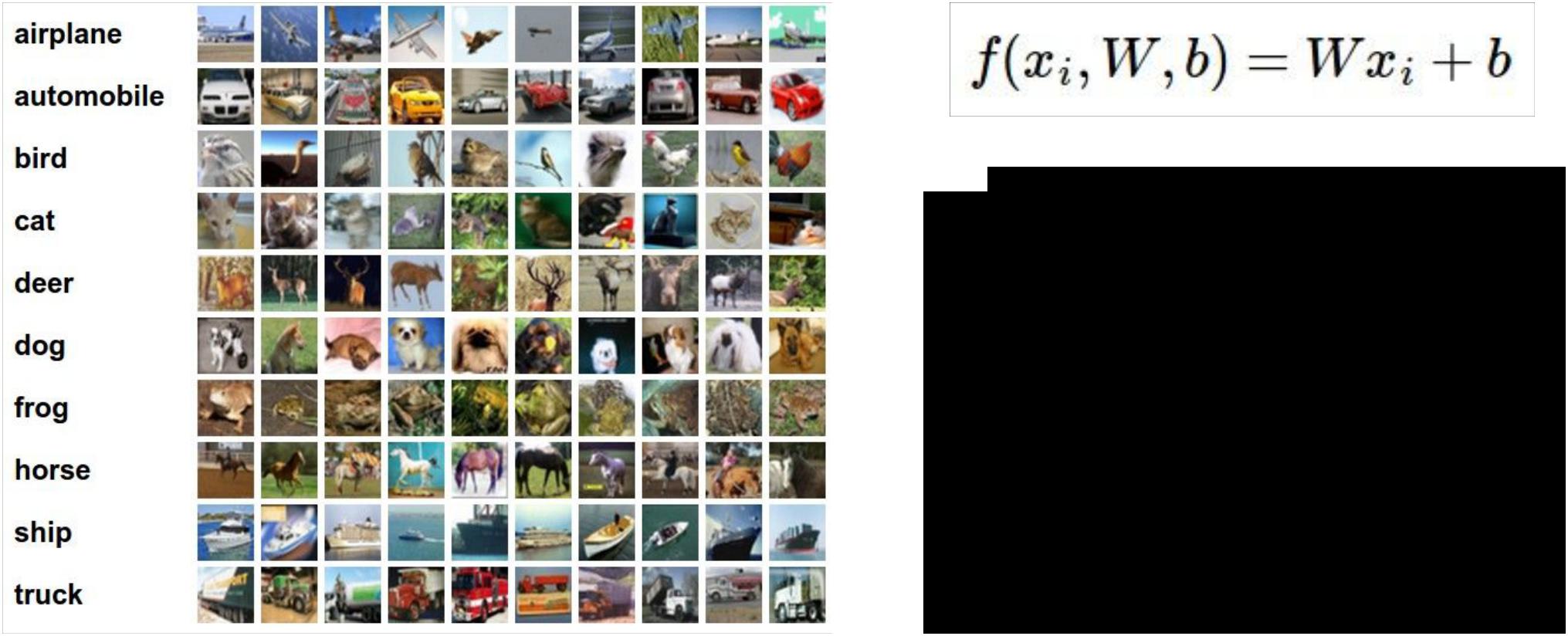
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Example with an image with 4 pixels, and 3 classes (cat/dog/ship)



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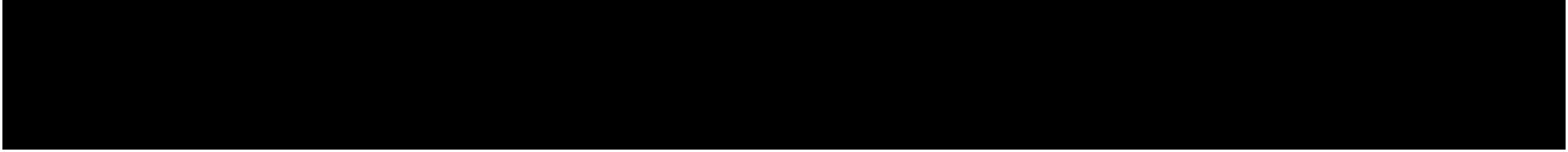
**Interpreting a Linear Classifier**

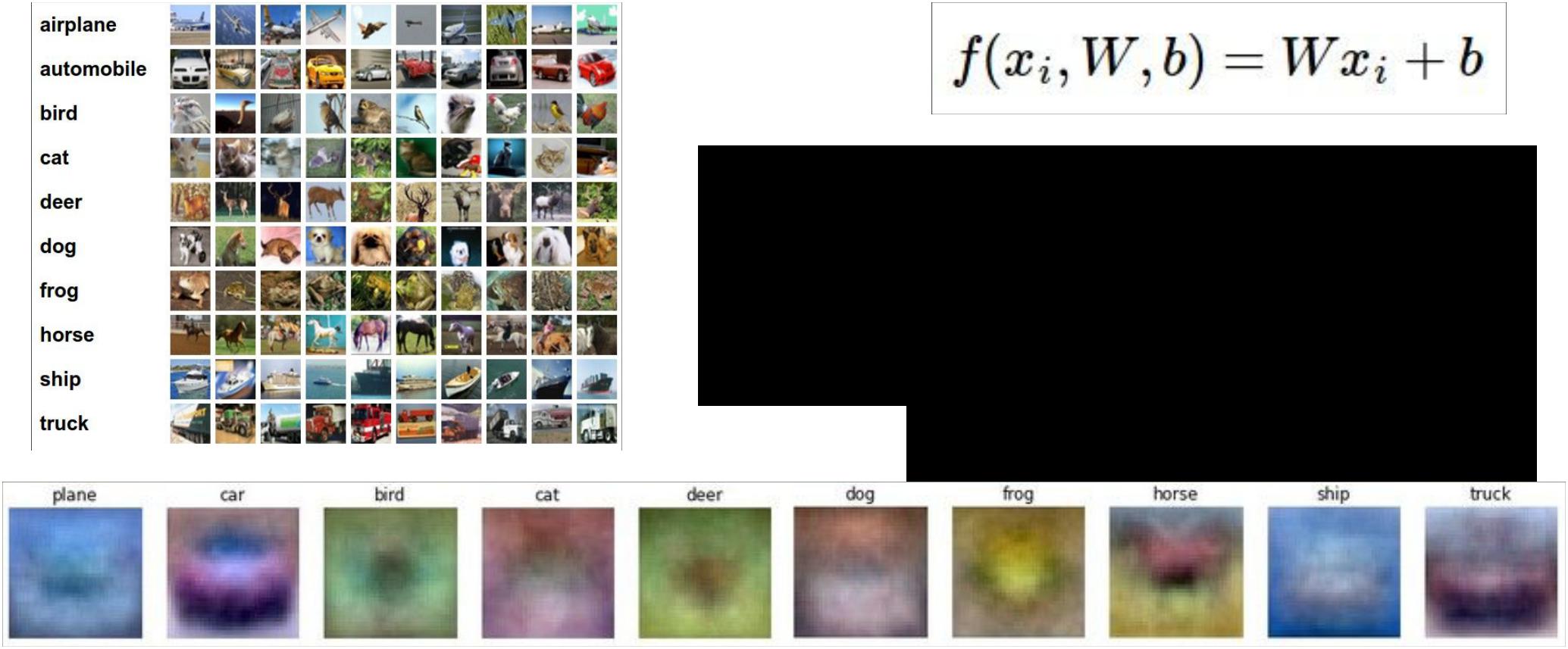


Q: what does the linear classifier do, in English?



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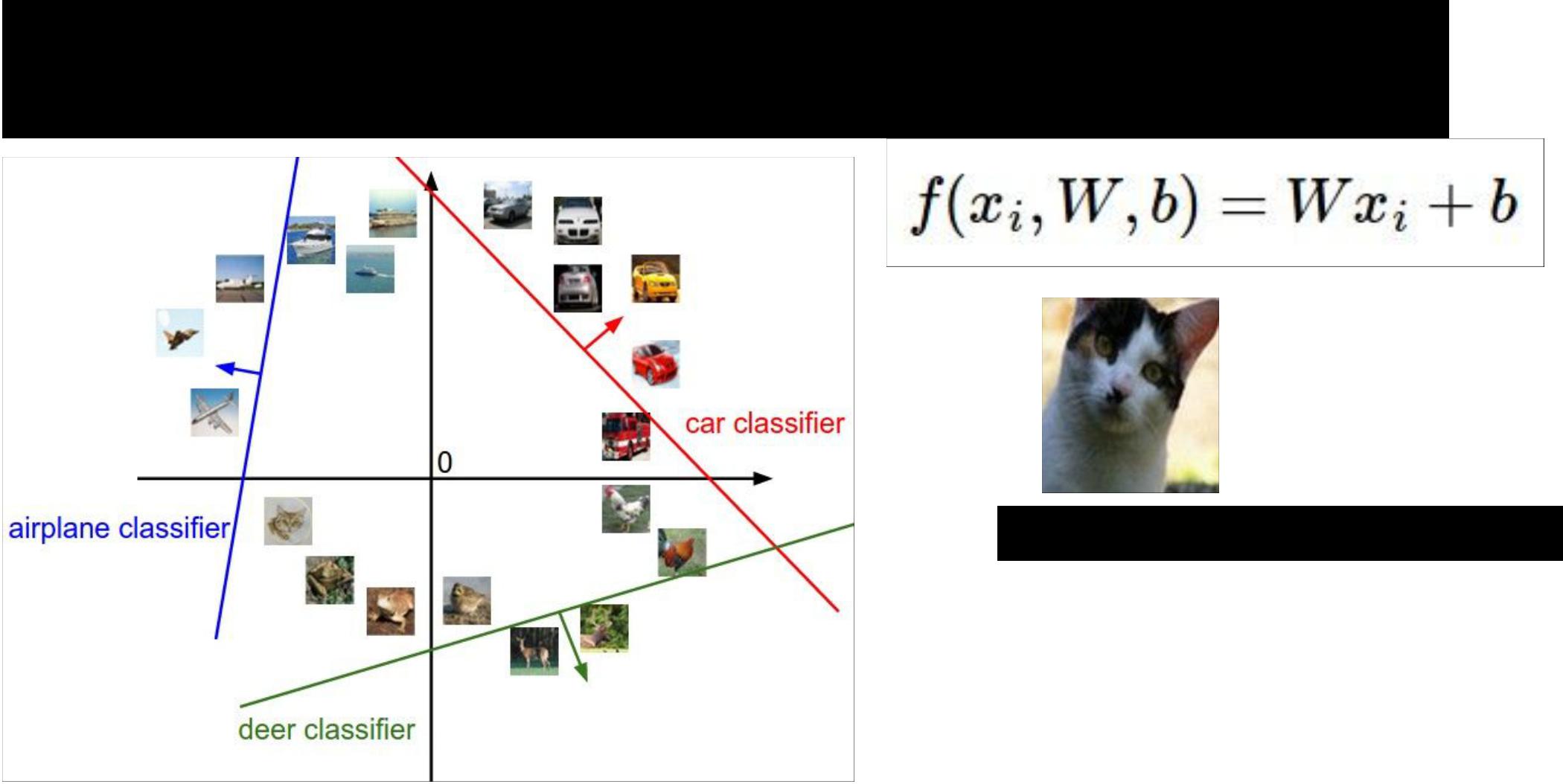
**Interpreting a Linear Classifier**



Example trained weights of a linear classifier trained on CIFAR-10:



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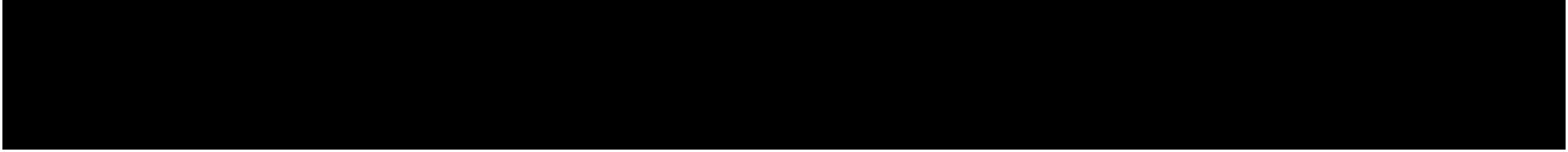
**Interpreting a Linear Classifier**

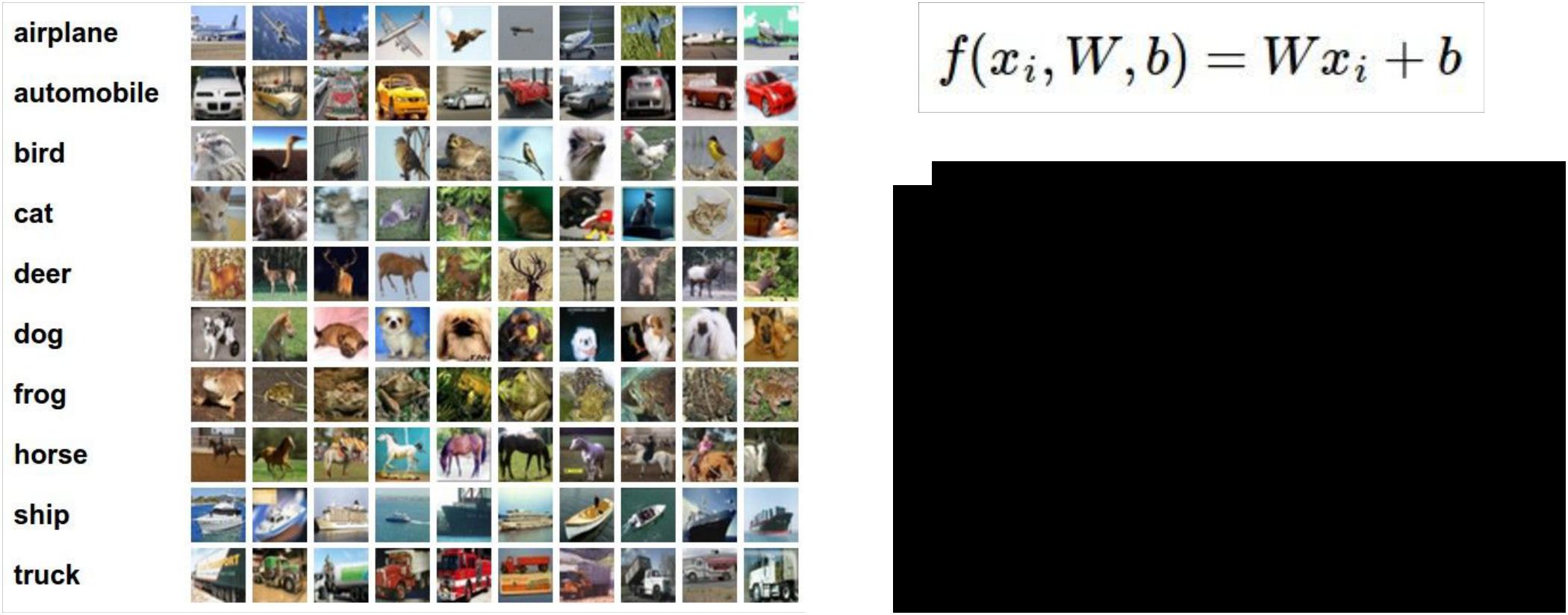
**[32x32x3]**

array of numbers 0...1 (3072 numbers total)



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**Interpreting a Linear Classifier**



Q2: what would be a very hard set of classes for a linear classifier to distinguish?



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**So far:** We defined a (linear) **score function:**



Example class scores for 3 images, with a random W:

-3.45 -0.51 3.42

-8.87 **6.04** 4.64

0.09 5.31 2.65

**2.9** -4.22 5.1

4.48 -4.19 2.64

8.02 3.58 5.55

3.78 4.49 **-4.34**

1.06 -4.37 -1.5

-0.36 -2.09 -4.79

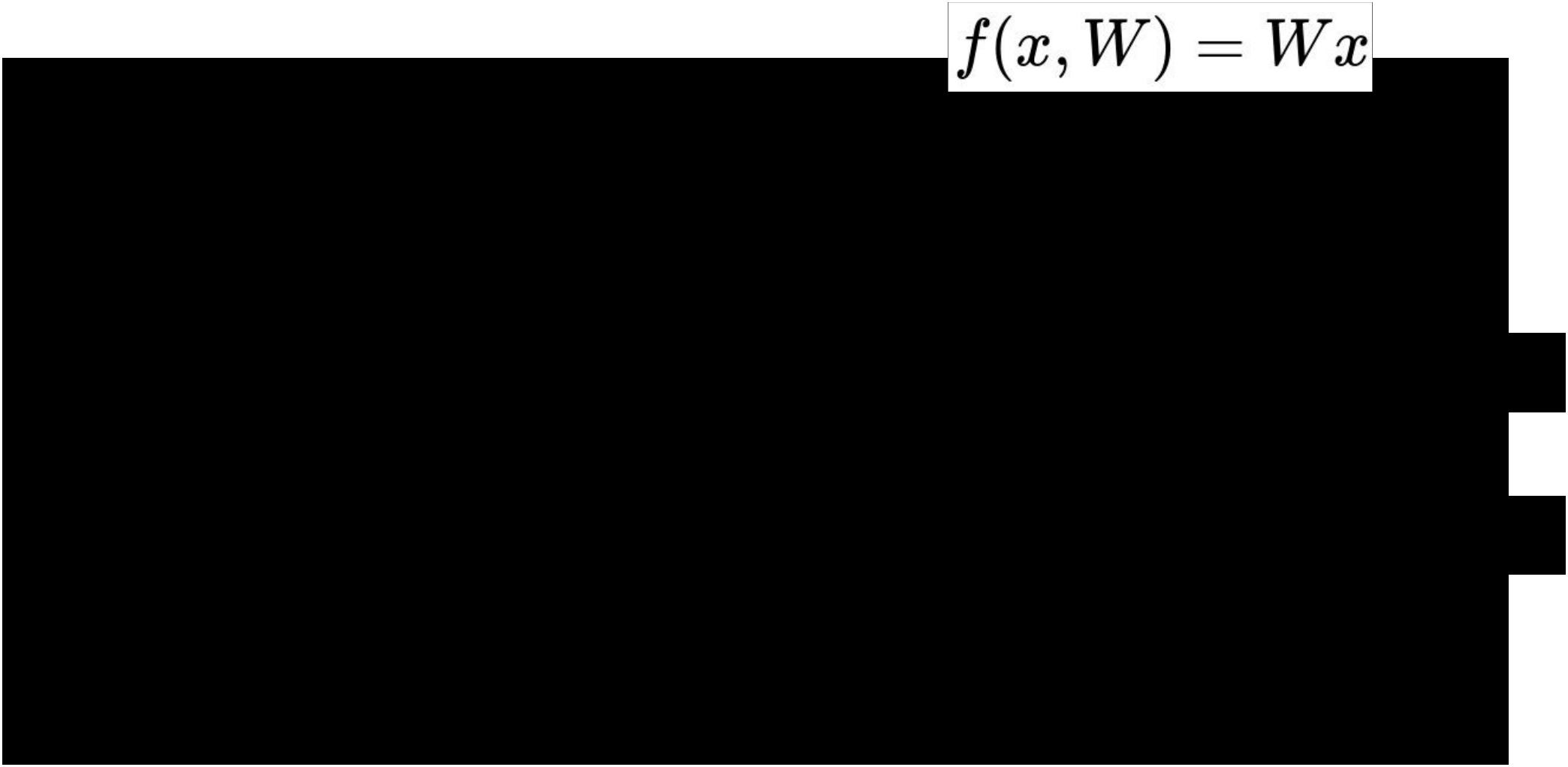
-0.72 -2.93 6.14

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Coming up:

* Loss function
* Optimization
* ConvNets!

(quantifying what it means to have a “good” W)



(start with random W and find a W that minimizes the loss)

(tweak the functional form of f)



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