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TYPES OF LEARNING

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HOW WAS THE QUIZ?

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Grades

What if	Then
x > 15	You're in good shape. Just remember to review the prerequisite material occasionally.
15 >= x > 10	Carefully review the prerequisite material to avoid potential difficulties in the class.
10 >= x	Please visit office hours so we can discuss your situation in more detail.

Prereq Quiz

1.

Learning *Types*

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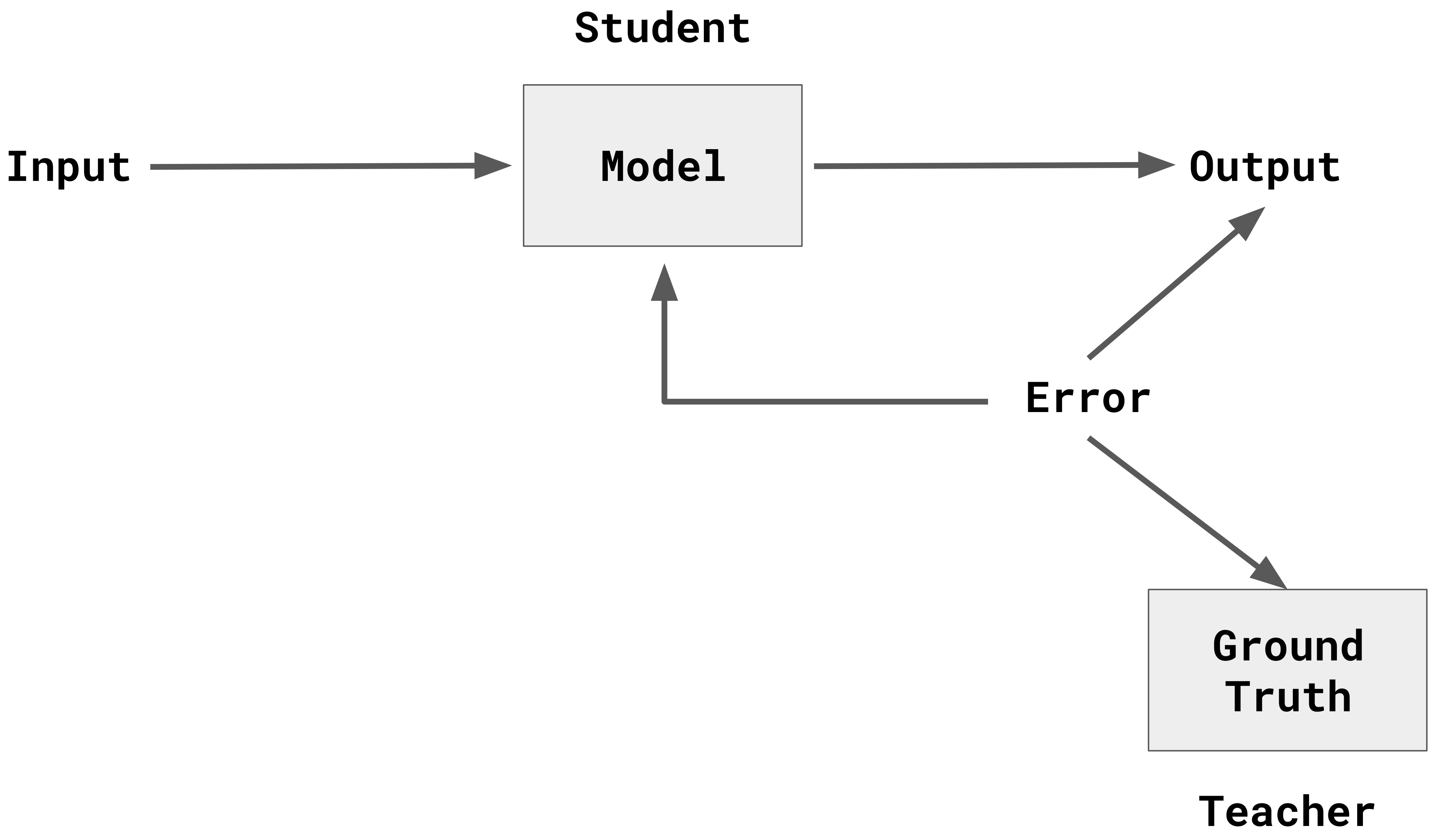
SUPERVISED LEARNING

UNSUPERVISED LEARNING

REINFORCEMENT LEARNING

Supervised Learning



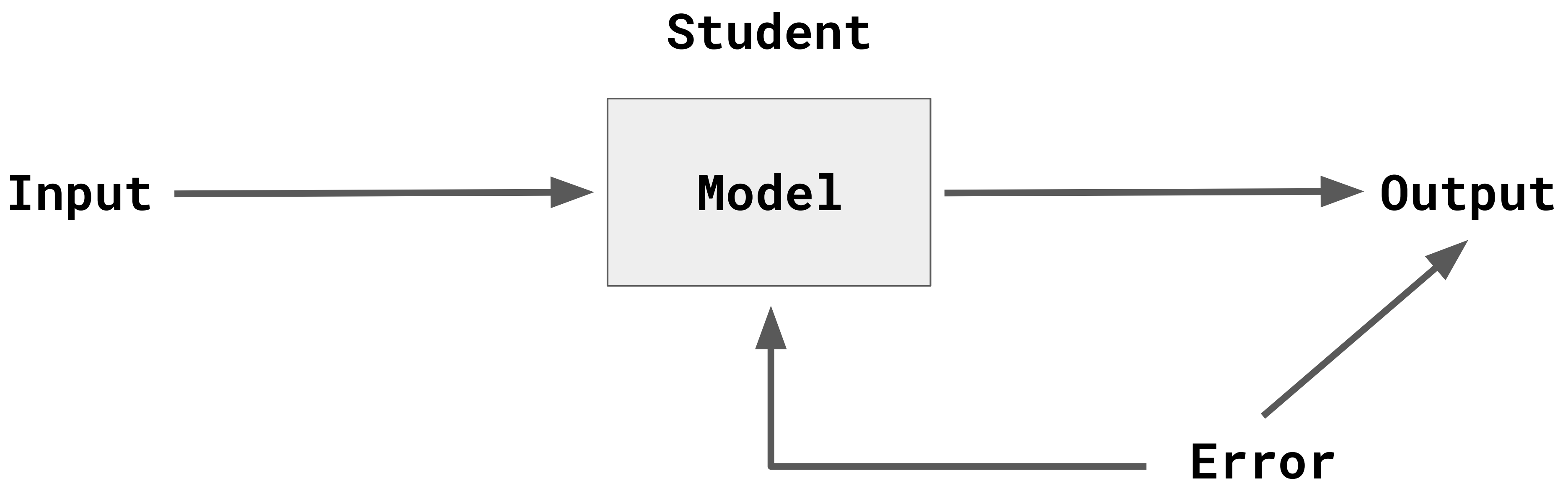
Supervised Learning

task, T	performance measure, P	experience, E

Supervised Learning

task, T	performance measure, P	experience, E
Predict a value (boolean, numerical, categorical) How is the expected output?	Error (MSE, MAE, Cross Entropy) How do we measure how close we are to the expected results?	(Input, GT) Input: Numerical, images, text, signals Output: Expected value What are we learning?

Unsupervised Learning



Similar != Different

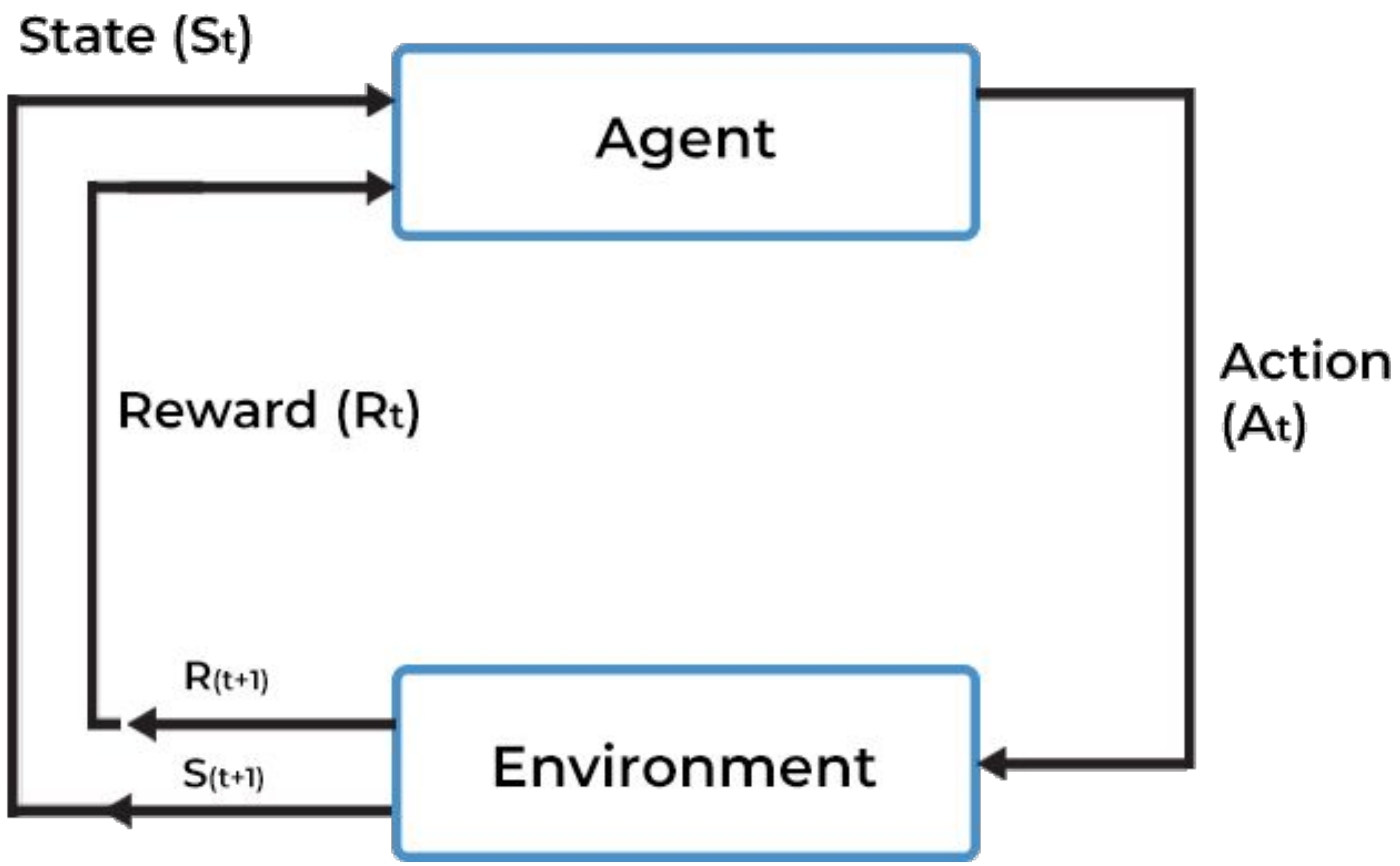
Unsupervised Learning

task, T	performance measure, P	experience, E

Unsupervised Learning

task, T	performance measure, P	experience, E
Predict a representation (multidimensional vector) How is the expected output?	Error (Intrinsic measures, similar != different) How do we measure how close we are to the expected results?	Input Input: Numerical, images, text, signals What are we learning?

Reinforcement Learning



Reinforcement Learning

task, T	performance measure, P	experience, E

Reinforcement Learning

task, T	performance measure, P	experience, E
Predict a step (multidimensional vector) How is the expected output?	Error (Regret of best reward) How do we measure how close we are from the maximum reward?	(Input, GT) Input: Description of the environment Output: Action What are we learning?

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2.

Example
Our First ML Task

task, T	performance measure, P	experience, E

Medical Diagnosis Dataset

Doctor diagnoses the patient as sick or not **y ∈ {+, -}**

based on attributes of the patient **x_1, x_2, ..., x_M**

	y	x_1	x_2	x_3	x_4
i	**allergic?**	**hives?**	**sneezing?**	**red eye?**	**has cat?**
1	-	Y	N	N	N

Medical Diagnosis Dataset

Doctor diagnoses the patient as sick or not $y \in \{+, -\}$

based on attributes of the patient $x\_1, x\_2, \ldots, x\_M$

	y	x_1	x_2	x_3	x_4
i	**allergic?**	**hives?**	**sneezing?**	**red eye?**	**has cat?**
1	-	Y	N	N	N
2	-	N	Y	N	N
3	+	Y	Y	N	N
4	-	Y	N	Y	Y
5	+	N	Y	Y	N

Medical Diagnosis Dataset

Doctor diagnoses the patient as sick or not **y ∈ {+, -}**

based on attributes of the patient **x_1, x_2, ..., x_M**

	y	x_1	x_2	x_3	x_4
i	allergic?	hives?	sneezing?	red eye?	has cat?
1	$y^{(1)}$ -	$x_1^{(1)}$ Y	$x_2^{(1)}$ N	$x_3^{(1)}$ N	$x_4^{(1)}$ N
2	$y^{(2)}$ -	$x_1^{(2)}$ N	$x_2^{(2)}$ Y	$x_3^{(2)}$ N	$x_4^{(2)}$ N
3	$y^{(3)}$ +	$x_1^{(3)}$ Y	$x_2^{(3)}$ Y	$x_3^{(3)}$ N	$x_4^{(3)}$ N
4	$y^{(4)}$ -	$x_1^{(4)}$ Y	$x_2^{(4)}$ N	$x_3^{(4)}$ Y	$x_4^{(4)}$ Y
5	$y^{(5)}$ +	$x_1^{(5)}$ N	$x_2^{(5)}$ Y	$x_3^{(5)}$ Y	$x_4^{(5)}$ N

Medical Diagnosis Dataset

Doctor diagnoses the patient as sick or not **$y \in \{+, -\}$**

based on attributes of the patient **$x\_1, x\_2, \ldots, x\_M$**

	y	x_1	x_2	x_3	x_4	
i	allergic?	hives?	sneezing?	red eye?	has cat?	
1	$y^{(1)}$ -	$x_1^{(1)}$ Y	$x_2^{(1)}$ N	$x_3^{(1)}$ N	$x_4^{(1)}$ N	$\mathbf{x}^{(1)}$
2	$y^{(2)}$ -	$x_1^{(2)}$ N	$x_2^{(2)}$ Y	$x_3^{(2)}$ N	$x_4^{(2)}$ N	$\mathbf{x}^{(2)}$
3	$y^{(3)}$ +	$x_1^{(3)}$ Y	$x_2^{(3)}$ Y	$x_3^{(3)}$ N	$x_4^{(3)}$ N	$\mathbf{x}^{(3)}$
4	$y^{(4)}$ -	$x_1^{(4)}$ Y	$x_2^{(4)}$ N	$x_3^{(4)}$ Y	$x_4^{(4)}$ Y	$\mathbf{x}^{(4)}$
5	$y^{(5)}$ +	$x_1^{(5)}$ N	$x_2^{(5)}$ Y	$x_3^{(5)}$ Y	$x_4^{(5)}$ N	$\mathbf{x}^{(5)}$

N = 5 training examples

M = 4 attributes

Our First Machine Learning Task

Learning to diagnose heart disease as a **(supervised) binary classification task**

labels | features

i	allergic?	hives?	sneezing?	red eye?	has cat?
1	-	Y	N	N	N
2	-	N	Y	N	N
3	+	Y	Y	N	N
4	-	Y	N	Y	Y
5	+	N	Y	Y	N

examples

Our First Machine Learning Task

Learning to diagnose heart disease as a **(supervised) <u>binary classification</u> task**

	labels	features			
i	allergic?	hives?	sneezing?	red eye?	has cat?
1	-	Y	N	N	N
2	-	N	Y	N	N
3	+	Y	Y	N	N
4	-	Y	N	Y	Y
5	+	N	Y	Y	N

examples

Our First Machine Learning Task

Learning to diagnose heart disease as a **(supervised) <u>classification</u> task**

		labels	features			
	i	allergy	hives?	sneezing?	red eye?	has cat?
examples	1	none	Y	N	N	N
	2	none	N	Y	N	N
	3	dust	Y	Y	N	N
	4	none	Y	N	Y	Y
	5	mold	N	Y	Y	N

Our First Machine Learning Task

Learning to diagnose heart disease as a **(supervised)** **regression** **task**

output

features

examples

i	treatment cost	hives?	sneezing?	red eye?	has cat?
1	$10	Y	N	N	N
2	$25	N	Y	N	N
3	$1000	Y	Y	N	N
4	$25	Y	N	Y	Y
5	$2000	N	Y	Y	N

Medical Diagnosis Dataset

Doctor diagnoses the patient as sick or not $y \in \{+, -\}$

based on attributes of the patient $x\_1, x\_2, \ldots, x\_M$

	y	x_1	x_2	x_3	x_4	
i	**allergic?**	**hives?**	**sneezing?**	**red eye?**	**has cat?**	
1	$y^{(1)}$ -	$x_1^{(1)}$ Y	$x_2^{(1)}$ N	$x_3^{(1)}$ N	$x_4^{(1)}$ N	$\mathbf{x}^{(1)}$
2	$y^{(2)}$ -	$x_1^{(2)}$ N	$x_2^{(2)}$ Y	$x_3^{(2)}$ N	$x_4^{(2)}$ N	$\mathbf{x}^{(2)}$
3	$y^{(3)}$ +	$x_1^{(3)}$ Y	$x_2^{(3)}$ Y	$x_3^{(3)}$ N	$x_4^{(3)}$ N	$\mathbf{x}^{(3)}$
4	$y^{(4)}$ -	$x_1^{(4)}$ Y	$x_2^{(4)}$ N	$x_3^{(4)}$ Y	$x_4^{(4)}$ Y	$\mathbf{x}^{(4)}$
5	$y^{(5)}$ +	$x_1^{(5)}$ N	$x_2^{(5)}$ Y	$x_3^{(5)}$ Y	$x_4^{(5)}$ N	$\mathbf{x}^{(5)}$

N = 5 training examples

M = 4 attributes

Example hypothesis function:

$$h(\mathbf{x}) = \begin{cases} + & \text{if sneezing} = Y \\ - & \text{otherwise} \end{cases}$$

Supervised Machine Learning

- **Problem Setting**
  - ➔ Set of possible inputs, $x \in X$ (all possible patients)
  - ➔ Set of possible outputs, $y \in Y$ (all possible diagnoses)
  - ➔ Exists an unknown target function, $c^* : X \rightarrow Y$ (the doctor's brain)
  - ➔ Set, $\mathcal{H}$, of candidate hypothesis functions, $h : X \rightarrow Y$ (all possible algorithms)

- **Learner** is given **N training examples** $D = \{(x(1), y(1)), (x(2), y(2)), \ldots, (x(N), y(N))\}$
  where
  $y(i) = c^*(x(i))$ (history of patients and their diagnoses)

- **Learner** produces a hypothesis function, $\hat{y} = h(x)$, that best approximates unknown target function $y = c^*(x)$ on the training data

Error Rate

- **Consider a hypothesis h its…**

  …error rate over all training data: **error(h, D_train)**

  …error rate over all test data: **error(h, D_test)**

  …true error over all data: **error_true(h)**

This is the quantity we care most about! But, in practice, **error_true(h)** is unknown.

Algorithms for Classification

Algorithm 1 **majority vote:** predict the most common label in the training dataset

	y	x_1	x_2	x_3	x_4
predictions	**allergic?**	**hives?**	**sneezing?**	**red eye?**	**has cat?**
-	-	Y	N	N	N
-	-	N	Y	N	N
-	+	Y	Y	N	N
-	-	Y	N	Y	Y
-	+	N	Y	Y	N

Algorithms for Classification

Algorithm 2 **memorizer:** if a set of features exists in the training dataset, predict its corresponding label; otherwise, predict a random label

	y	x_1	x_2	x_3	x_4
predictions	**allergic?**	**hives?**	**sneezing?**	**red eye?**	**has cat?**
-	-	Y	N	N	N
-	-	N	Y	N	N
+	+	Y	Y	N	N
-	-	Y	N	Y	Y
+	+	N	Y	Y	N

The memorizer always gets zero training error!

Algorithms for Classification

Algorithm 3 **decision stump:** based on a single feature, x_d, predict the most common label in the training dataset among all data points that have the same value for x_d

predictions	y allergic?	x_1 hives?	x_2 sneezing?	x_3 red eye?	x_4 has cat?
-	-	Y	N	N	N
+	-	N	Y	N	N
+	+	Y	Y	N	N
-	-	Y	N	Y	Y
+	+	N	Y	Y	N

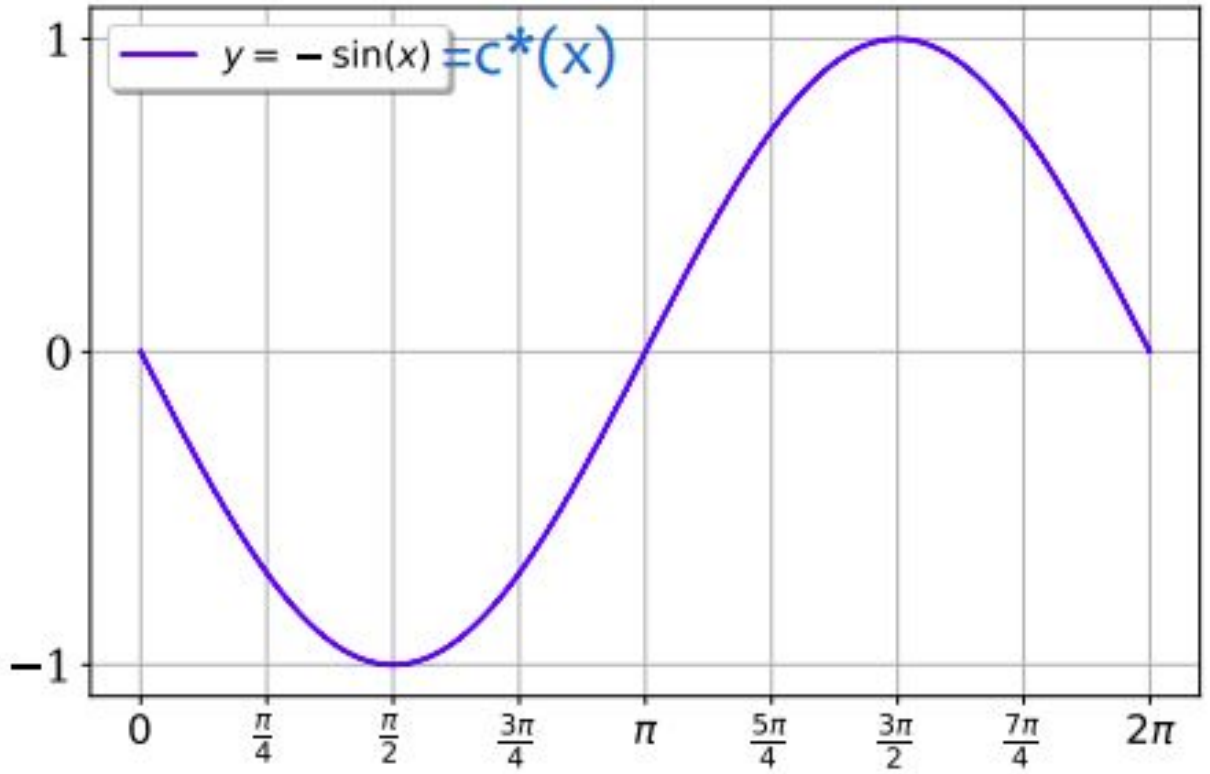
Example
decision stump:

$$h(\mathbf{x}) = \begin{cases} + & \text{if sneezing = Y} \\ - & \text{otherwise} \end{cases}$$

Nonzero training error, but perhaps still better than the memorizer

Home Exercise

Function approximation: Implement a simple function which returns -sin(x).



A few constraints are imposed:

1. You can't call any other trigonometric functions
2. You can call an existing implementation of sin(x) a few times to test your solution
3. You only need to evaluate it for x in [0, 2*pi]

Kahoot Time!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