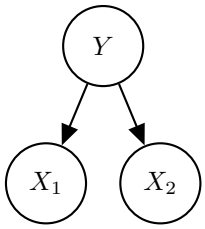
CS 188 Introduction to
Summer 2021 Artificial Intelligence

# Final Review ML

## Q1. Naïve Bayes

You are given a naïve bayes model, shown below, with label Y and features $X_1$ and $X_2$. The conditional probabilities for the model are parametrized by $p_1$, $p_2$ and $q$.




| $X_1$ | $Y$ | $P(X_1\|Y)$ |
|---|---|---|
| 0 | 0 | $p_1$ |
| 1 | 0 | $1-p_1$ |
| 0 | 1 | $1-p_1$ |
| 1 | 1 | $p_1$ |

| $X_2$ | $Y$ | $P(X_2\|Y)$ |
|---|---|---|
| 0 | 0 | $p_2$ |
| 1 | 0 | $1-p_2$ |
| 0 | 1 | $1-p_2$ |
| 1 | 1 | $p_2$ |

| $Y$ | $P(Y)$ |
|---|---|
| 0 | $1-q$ |
| 1 | $q$ |

**Note that some of the parameters are shared** (e.g. $P(X_1 = 0|Y = 0) = P(X_1 = 1|Y = 1) = p_1$).

**(a)** Given a new data point with $X_1 = 1$ and $X_2 = 1$, what is the probability that this point has label $Y = 1$? Express your answer in terms of the parameters $p_1, p_2$ and $q$ (you might not need all of them).

$P(Y = 1|X_1 = 1, X_2 = 1) =$ _____

The model is trained with the following data:

| sample number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $X_1$ | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 |
| $X_2$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| $Y$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |

**(b)** What are the maximum likelihood estimates for $p_1, p_2$ and $q$?

$p_1 =$ _____ $p_2 =$ _____ $q =$ _____

# Q2. Machine Learning: Potpourri

**(a)** What it the **minimum** number of parameters needed to fully model a joint distribution $P(Y, F_1, F_2, ..., F_n)$ over label $Y$ and $n$ features $F_i$? Assume binary class where each feature can possibly take on $k$ distinct values.

**(b)** Under the **Naive Bayes assumption**, what is the **minimum** number of parameters needed to model a joint distribution $P(Y, F_1, F_2, ..., F_n)$ over label $Y$ and $n$ features $F_i$? Assume binary class where each feature can take on $k$ distinct values.

**(c)** You suspect that you are overfitting with your Naive Bayes with Laplace Smoothing. How would you adjust the strength $k$ in Laplace Smoothing?

◯ Increase $k$ ◯ Decrease $k$

**(d)** While using Naive Bayes with Laplace Smoothing, increasing the strength $k$ in Laplace Smoothing can:

☐ Increase training error ☐ Decrease training error
☐ Increase validation error ☐ Decrease validation error

**(e)** It is possible for the perceptron algorithm to never terminate on a dataset that is linearly separable in its feature space.

◯ True ◯ False

**(f)** If the perceptron algorithm terminates, then it is guaranteed to find a max-margin separating decision boundary.

◯ True ◯ False

**(g)** In multiclass perceptron, every weight $w_y$ can be written as a linear combination of the training data feature vectors.

◯ True ◯ False

**(h)** For binary class classification, logistic regression produces a linear decision boundary.

◯ True ◯ False

**(i)** In the binary classification case, logistic regression is exactly equivalent to a single-layer neural network with a sigmoid activation and the cross-entropy loss function.

◯ True ◯ False

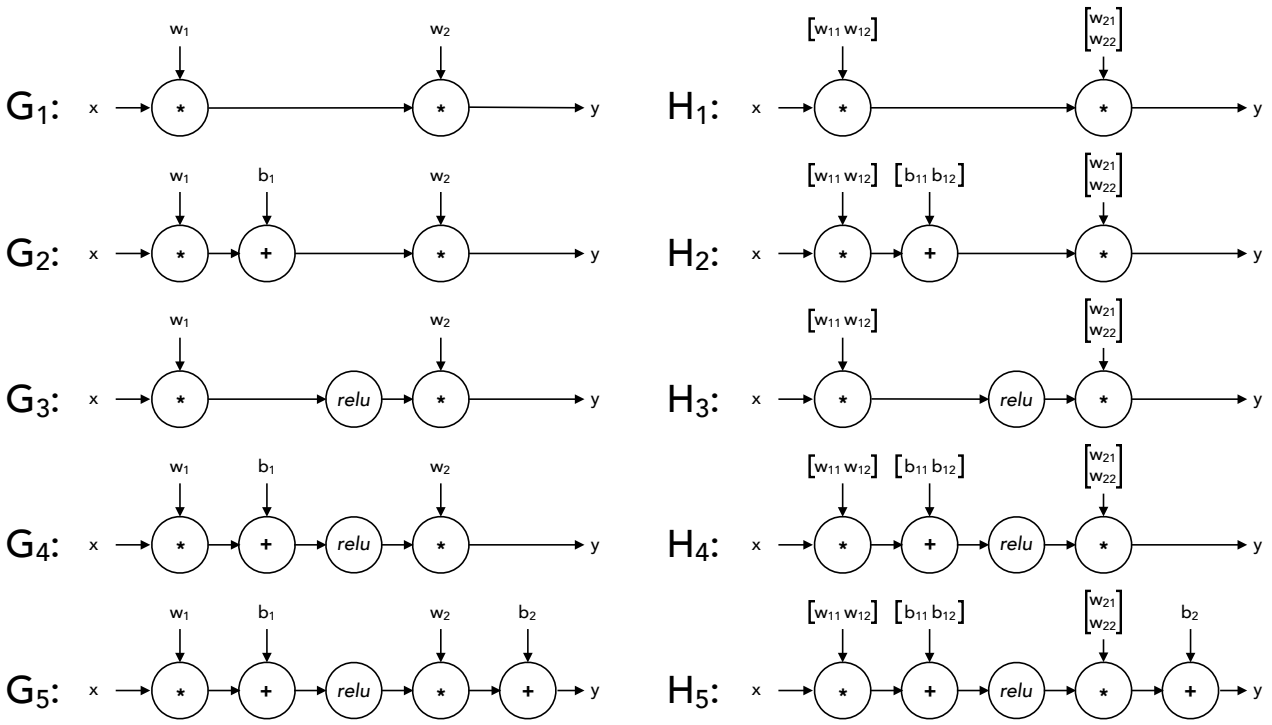
**(j)** **(i)** You train a linear classifier on 1,000 training points and discover that the training accuracy is only 50%. Which of the following, if done in isolation, has a good chance of improving your training accuracy?

☐ Add novel features ☐ Train on more data ☐ Train on less data

**(ii)** You now try training a neural network but you find that the training accuracy is still very low. Which of the following, if done in isolation, has a good chance of improving your training accuracy?

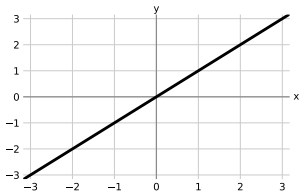
☐ Add more hidden layers ☐ Add more units to the hidden layers

# Q3. Neural Networks: Representation

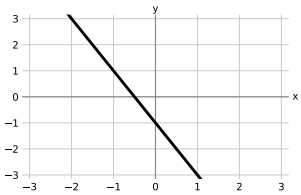



For each of the piecewise-linear functions below, mark all networks from the list above that can represent the function **exactly** on the range $x \in (-\infty, \infty)$. In the networks above, *relu* denotes the element-wise ReLU nonlinearity: $relu(z) = max(0, z)$. The networks $G_i$ use 1-dimensional layers, while the networks $H_i$ have some 2-dimensional intermediate layers.

**(a)**

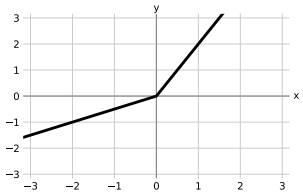


☐ $G_1$ ☐ $H_1$
☐ $G_2$ ☐ $H_2$
☐ $G_3$ ☐ $H_3$
☐ $G_4$ ☐ $H_4$
☐ $G_5$ ☐ $H_5$
◯ None of the above

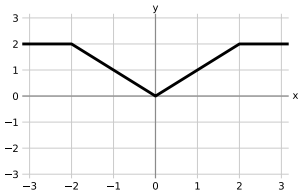


☐ $G_1$ ☐ $H_1$
☐ $G_2$ ☐ $H_2$
☐ $G_3$ ☐ $H_3$
☐ $G_4$ ☐ $H_4$
☐ $G_5$ ☐ $H_5$
◯ None of the above

**(b)**

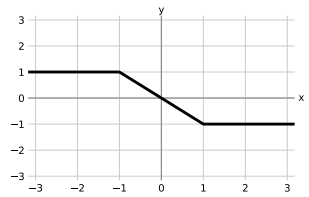


☐ $G_1$ ☐ $H_1$
☐ $G_2$ ☐ $H_2$
☐ $G_3$ ☐ $H_3$
☐ $G_4$ ☐ $H_4$
☐ $G_5$ ☐ $H_5$
◯ None of the above

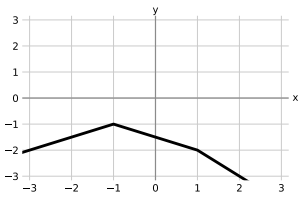


☐ $G_1$ ☐ $H_1$
☐ $G_2$ ☐ $H_2$
☐ $G_3$ ☐ $H_3$
☐ $G_4$ ☐ $H_4$
☐ $G_5$ ☐ $H_5$
◯ None of the above

**(c)**




☐ $G_1$ ☐ $H_1$
☐ $G_2$ ☐ $H_2$
☐ $G_3$ ☐ $H_3$
☐ $G_4$ ☐ $H_4$
☐ $G_5$ ☐ $H_5$
◯ None of the above




☐ $G_1$ ☐ $H_1$
☐ $G_2$ ☐ $H_2$
☐ $G_3$ ☐ $H_3$
☐ $G_4$ ☐ $H_4$
☐ $G_5$ ☐ $H_5$
◯ None of the above