GENERAL ASSEMBLY

NAÏVE BAYES

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DATA SCIENCE PROCESS

1. Define problem.
2. Gather data.
3. Explore data.
4. Model with data.
5. Evaluate model.
6. Answer problem.

LEARNING OBJECTIVES

- By the end of this lesson, students should be able to:
    - **Intuitively explain** how Bayes' Theorem can be used as a modeling tactic.
    - **Implement** Naive Bayes in scikit-learn.
    - **Discuss** assumptions, advantages, and disadvantages of Naive Bayes as a classifier.

CONDITIONAL PROBABILITY

- Recall that we use $P(A)$ to refer to the probability that A occurs, where A is some event.

- If we want to describe the probability that A occurs given that we know something else to be true, we use $P(A|B)$.

- Note that $P(A|B)$ is usually not the same as $P(B|A)$!

BAYES' THEOREM

- Bayes' Theorem (Bayes' Rule) relates $P(A|B)$ to $P(B|A)$.

BREAKING DOWN BAYES' THEOREM

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

- $P(A)$ is the probability that A occurs given no supplemental information.
- $P(B|A)$ is the probability of B given that A is true.
- $P(B)$ is the probability that B occurs given no supplemental information.
  - $P(B)$ what we scale $P(B|A)P(A)$ by to ensure we are only looking at A within the context of B occurring.

APPLYING BAYES' THEOREM TO SPAM CLASSIFICATION

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

- Bayes' Theorem is really neatly set up as a classification model.
- We can estimate the probability – `.predict_proba()` – that an observation falls into a specific class, then classify that observation – `.predict()` – accordingly!

APPLYING BAYES' THEOREM TO SPAM CLASSIFICATION

$$P(\text{spam}|\text{words in email}) = \frac{P(\text{words in email}|\text{spam})P(\text{spam})}{P(\text{words in email})}$$

APPLYING BAYES' THEOREM TO SPAM CLASSIFICATION

$$P(\text{spam}|\text{words}) = \frac{P(w_1|\text{spam})P(w_2|w_1 \cap \text{spam})P(w_3|w_2 \cap w_1 \cap \text{spam}) \cdots P(\text{spam})}{P(w_1)P(w_2|w_1)P(w_3|w_2 \cap w_1) \cdots}$$

- This gets **really** complicated. Can we simplify this?

NAÏVE BAYES

- The Naïve Bayes classification algorithm is a:
  - classification modeling technique
  - that relies on Bayes Theorem
  - that makes one simplifying assumption.

- **We assume that our features are independent of one another.**

APPLYING BAYES' THEOREM TO SPAM CLASSIFICATION

$$P(\text{spam}|\text{words}) = \frac{P(w_1|\text{spam})P(w_2|w_1 \cap \text{spam})P(w_3|w_2 \cap w_1 \cap \text{spam}) \cdots P(\text{spam})}{P(w_1)P(w_2|w_1)P(w_3|w_2 \cap w_1) \cdots}$$

$$P(\text{spam}|\text{words}) = \frac{P(w_1|\text{spam})P(w_2|\text{spam})P(w_3|\text{spam}) \cdots P(\text{spam})}{P(w_1)P(w_2)P(w_3) \cdots}$$

NAÏVE BAYES

- **Advantages** of making this assumption of feature independence:
  - Easier to calculate probabilities.
  - Empirically, our classifications are surprisingly accurate.

- **Disadvantages** of making this assumption of feature independence:
  - It's incredibly unrealistic, especially in the case of text data.
  - While our classifications are accurate, our predicted probabilities are usually quite bad.

PROCESS OF NAÏVE BAYES

1. Decide which Naïve Bayes model to use.
    - BernoulliNB
    - MultinomialNB
    - GaussianNB

2. Decide what your priors will be.
    - Based on your data. *(default)*
    - Manually set.

3. `.fit()`, `.predict()`!

WHICH NAÏVE BAYES MODEL SHOULD I USE?

- BernoulliNB

- MultinomialNB

- GaussianNB

WHAT SHOULD MY PRIORS SHOULD BE?

$$P(\text{spam}|\text{words in email}) = \frac{P(\text{words in email}|\text{spam})P(\text{spam})}{P(\text{words in email})}$$

- Estimated from data.

- Manually set.

PROCESS OF NAÏVE BAYES

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INTERVIEW QUESTION

- Suppose we want to detect whether Amazon reviews are spam or ham. How would you do this?