Bayesian Machine Learning and Email Spam Classification

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The Spam Problem

- Spam means unsolicited email message(s)
- Costs businesses and individuals
  - Time and money
- Spam as a vehicle for malicious software
  - The Ransomware Tsunami
- Artificial intelligence can be used for spam detection
- We focused on two Bayesian classifiers
  - Bernoulli Multivariate Model
  - Multinomial Event Model + Thresholding

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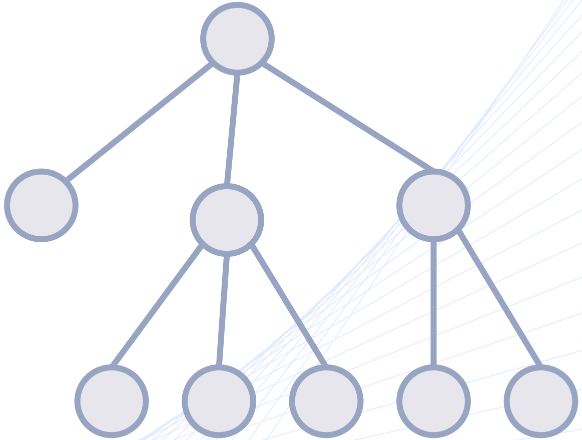
Related Work

- There are multiple spam email classifiers
  - Bayesian Classifiers
  - Random Forests (DT)
  - Support Vector Machines
  - K-Nearest Neighbor
- Classifiers can be used as ensemble
- Ensembles and Random Forests perform better
- Multinomial is known to be better



Bayesian Machine Learning - Naive Bayesian

- Bayesian Machine Learning
  - A probabilistic machine learning approach
  - Learning from prior probability distributions

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

$$P(\theta|D,m) = \frac{P(D|\theta,m)P(\theta|m)}{P(D|m)}$$

- Naive Bayesian
  - Subfield of Bayesian Machine Learning
  - Assumption:
    - Features are mutually independent
    - Distribution of the data

Bernoulli Multivariate Event Model

- A Naive-Bayesian approach
  - Email is presented as a vector
  - Value for each words will be 0 (not presented) or 1 (presented)
- Assumption:
  - Classification of instances are mutually independent
  - The appearance of words are mutually independent

$$P[t][c] = \frac{NumberOfDocs_{ct} + 1}{NumberOfDocs_{c} + 2}$$

Term t in the document: *PredictScore[class] = PredictScore x P[t][c]*

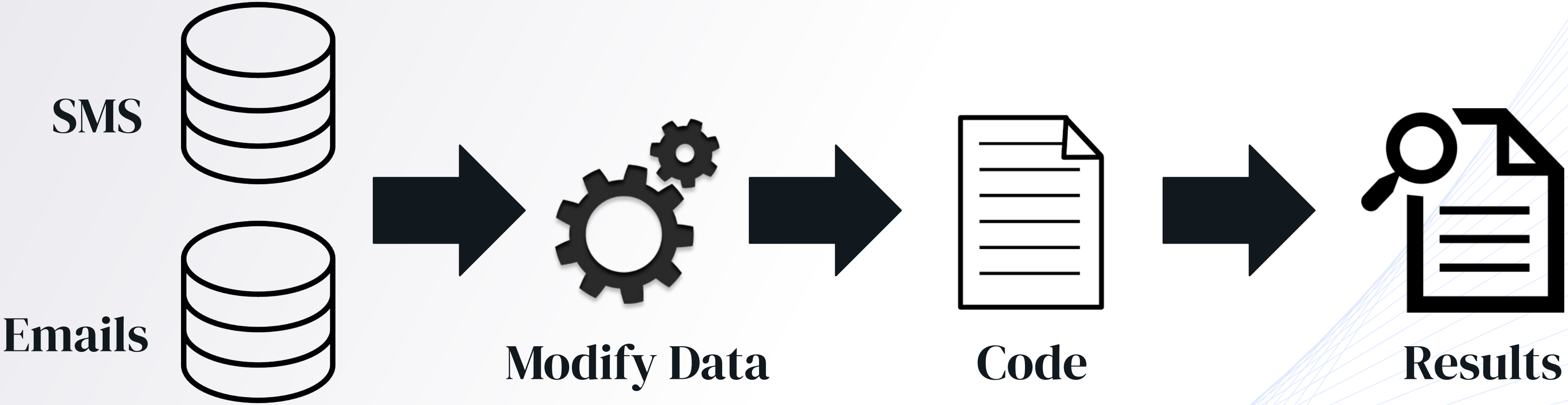
Term t not in the document: *PredictScore[class] = PredictScore x (1 -P[t][c])*

Multinomial Event Model

$$P(S \mid W) = P(S) * P(w1 \mid S) * P(w2 \mid S) * \ldots$$

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

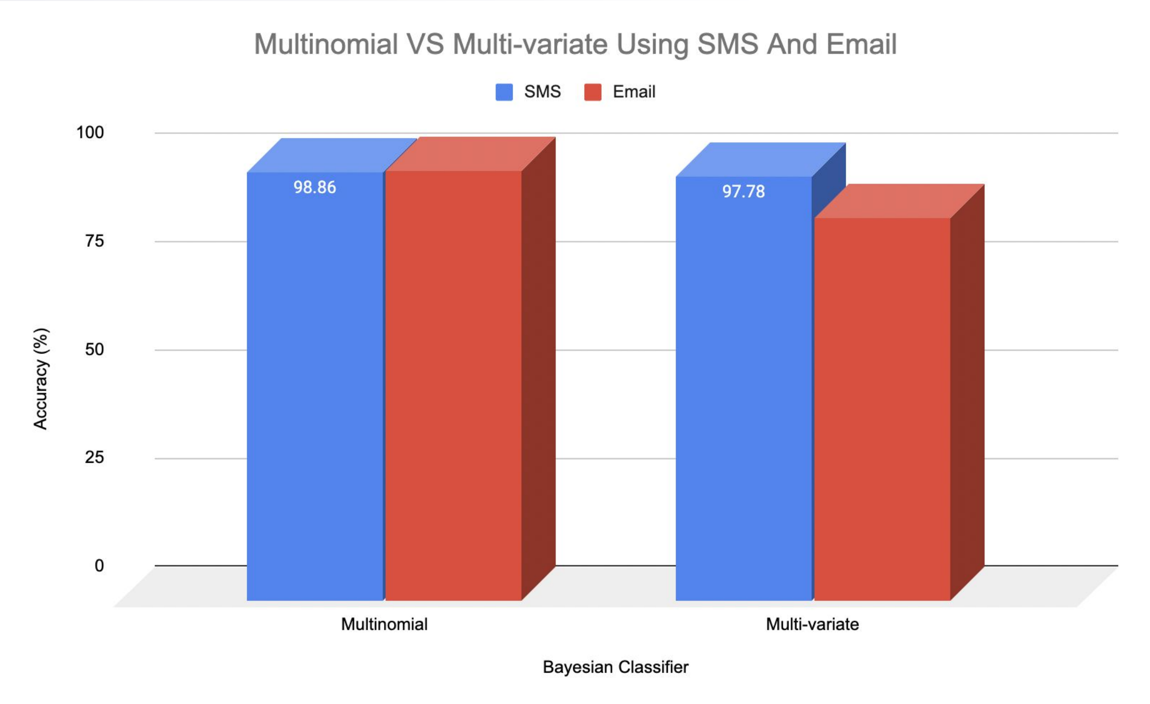
Our Approach - Thresholding



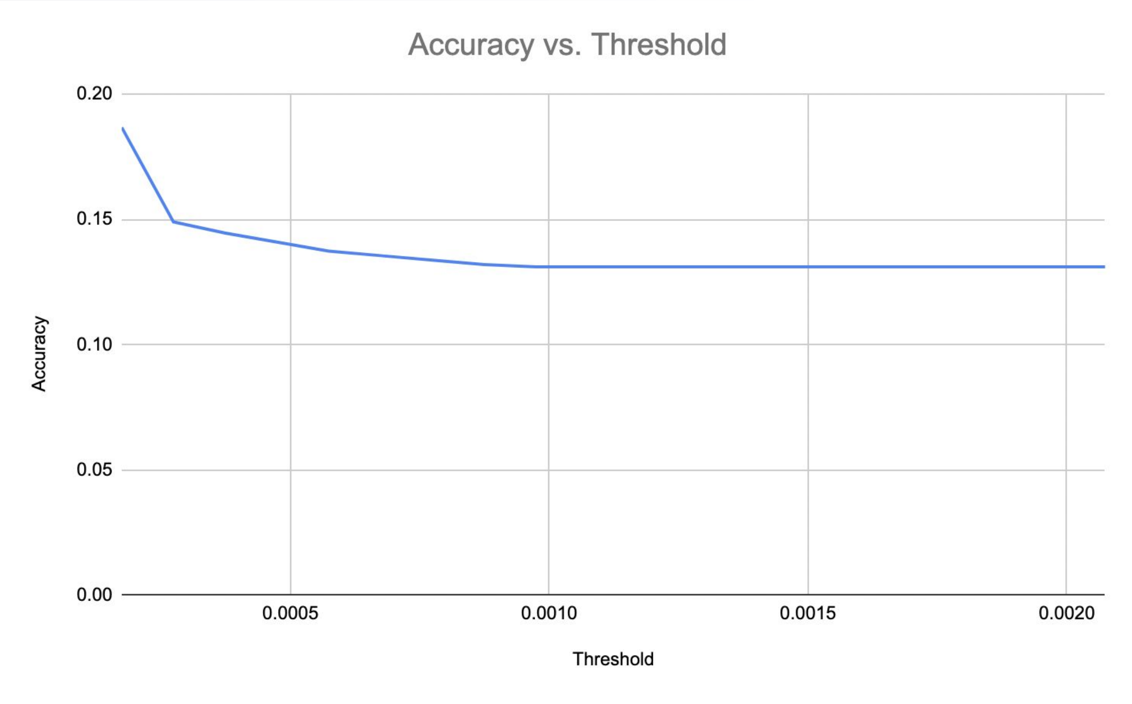
- Multinomial is a better approach
- Multinomial + Thresholding

$$P(S \mid W) = P(S) * P(w1 \mid S) * P(w2 \mid S) * \ldots$$

Performance and Testing

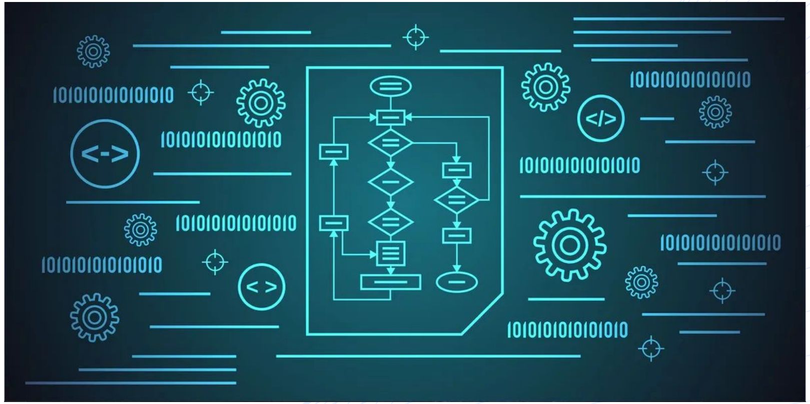


Performance and Testing



Conclusion

- (**scikit-learn**)
- We expected the multinomial implementation is to perform better for both datasets
- Thresholding did not improve the multinomial implementation
- Instead, thresholding did not improve the Naïve Bayes Multinomial implementation at all



Problem - Future Work

- Figuring out low accuracy score using Thresholding
- Other potential approaches:
    - Partitions
    - Information Gain
    - Remove stopped word or common words
    - Case sensitivity
    - Looking at other Naive-Bayesian model
        - Gaussian Model
        - Complement Naive Bayesian model
        - Categorical Naive Bayesian model
        - Out-of-core Naive Bayesian model fitting

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