An Experience with Text Classification in *Datadays 2019*

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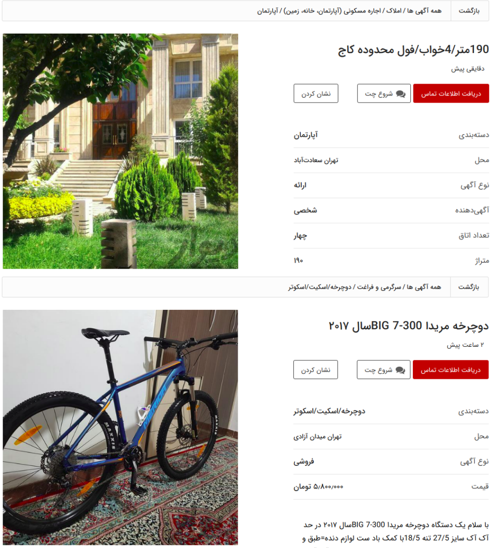
Divar Posts Dataset

- Released for DataDays 2019
- One million posts



Columns

- id
- archive_by_user
- published_at
- **cat1**
- **cat2**
- **cat3**
- city
- **title**
- **desc**
- price
- image_count
- platform
- mileage
- brand
- year
- type

The Problem: Categorization

- We need to categorize posts based on other posts features;
- We only use text features(title & description)!

Features

Cat3	Cat2	Cat1	Desc	Title
fridge-and-freezer	utensils-and-appliances	for-the-home	یخچال ارج کاملا سالم	یخچال ارج
nan	childrens-clothing-and-shoe	personal	دونه ای 28 سن 7تا 9 تقریبا رنگ مناسب دختر وپسر میباشد مقطووووووع پیامک پاسخگو نیستم	تعدادی کاپشن درحدنو
stereo-surround	audio-video	electronic-devices	سالم وباصدای فوق العاده قوی وباکیفیت. AUX رم وفلش هم میخوره یه ضبط دوتیکه LG آمپیلی دار هم دارم که داخله عکس مشخصه اونم تقدیم میکنم.یاعلی	سینماخانگی
light	cars	vehicles	همه امکانات رو داره	خودرو پژو۴۰۵
mobile-phones	mobile-tablet	Electronic-devices	بدون ضربه خوردگی و تعمیر	ایفون 6گری ۶۴گیگ

No. of Classes

- We concatenate three category columns into one; for example:

cat1	cat2	cat3	concatenate
vehicles	cars	light	vehicles::cars::light

- Then, we have 87 unique combinations of categories, eg. 87 classes in our classification task.

Feature Extraction

Feature extraction is a dimensionality reduction process, where an initial set of raw variables is reduced to more manageable groups (features) for processing, while still accurately and completely describing the original data set.

Tf-idf Vectoizer

- Tf-idf stands for term frequency-inverse document frequency
- a statistical measure used to evaluate how important a word is to a document in a collection or corpus
- the tf-idf weight is composed by two terms:

TF **Term Frequency**, which measures how frequently a term occurs in a document.

$$TF(t) = \frac{Number\ of\ times\ term\ t\ appears\ in\ a\ document}{Total\ number\ of\ terms\ in\ the\ document}$$

IDF **Inverse Document Frequency**, which measures how important a term is

$$IDF(t) = \ln \frac{Total\ number\ of\ documents}{Number\ of\ documents\ with\ term\ t\ in\ it}$$

Tf-idf Vectorizer: An Example

Consider a document containing 100 words wherein the word *cat* appears 3 times. The term frequency (i.e., tf) for cat is then $tf(cat) = \frac{3}{100} = 0.03$. Now, assume we have 10 million documents and the word cat appears in one thousand of these. Then, the inverse document frequency (i.e., idf) is calculated as $idf(cat) = \ln \frac{10{,}000{,}000}{1{,}000} = 4$. Thus, the Tf-idf weight is the product of these quantities: $tf - idf(cat) = 0.03 * 4 = 0.12$.

Vectorizing the Text: Count Vectorizer

An example: We want to vectorize these 4 sentences[1]:

1. Hello, how are you!
2. Win money, win from home.
3. Call me now
4. Hello, Call you tomorrow?

[1] Example from Rahul Vasaikar

Vectorizing the Text: Count Vectorizer

1. We first build a vocabulary:
   $vocabulary =$
   $\{are, call, from, hello, home, how, me, money, now, tomorrow, win, you\}$
2. Then, we vectorize each sentence based on the occurness of each word:

	are	call	from	hello	home	how	me	money	now	tom...	win	you
1	1	0	0	1	0	1	0	0	0	0	0	1
2	0	0	1	0	1	0	0	1	0	0	2	0
3	0	1	0	0	0	0	1	0	1	0	0	0
4	0	1	0	1	0	0	0	0	0	1	0	1

Word Embedding

when the input to a neural network contains symbolic categorical features (e.g. features that take one of k distinct symbols, such as words from a closed vocabulary), it is common to associate each possible feature value (i.e., each word in the vocabulary) with a d-dimensional vector for some d. These vectors are then considered parameters of the model, and are trained jointly with the other parameters.

Page 49, Neural Network Methods in Natural Language Processing, 2017.

Word Embedding

It requires that document text be cleaned and prepared such that each word is one-hot encoded. The size of the vector space is specified as part of the model, such as 50, 100, or 300 dimensions. The vectors are initialized with small random numbers. **The embedding layer is used on the front end of a neural network and is fit in a supervised way using the Backpropagation algorithm**.[2]

[2] From the article What Are Word Embeddings for Text?

One-Hot Encoding for Word Embedding

1. Hello, how are you!
2. Win money, win from home.
3. Call me now
4. Hello, Call you tomorrow?

$vocabulary = \{are, call, from, hello, home, how, me, money, now, tomorrow, win, you\}$

Word	are	call	from	hello	home	how	me	money	now	tomorrow	win	you
Value	1	2	3	4	5	6	7	8	9	10	11	12

Sentence					
Hello, how are you!	4	6	1	12	0
Win money, win from home.	11	8	11	3	5
Call me now	2	7	9	0	0
Hello, Call you tomorrow?	4	2	12	10	0

Number of Parameters

Let's say that we want to embed sentences(or words) into a $\mathbb{R}^n$ vector space. If m is the size of vocabulary, our Embedding layer has $m * n$ parameters that can be fitted in a supervised way using the Backpropagation.

Classification Algorithms

We used different classifiers and applied different models on the data. The classifiers we tested are:

- Naive Bayes
- Linear Support Vector Machine(SVM)
- Passive Aggressive Classifier
- Convolutional Neural Network(CNN)

Naive Bayes Classifier

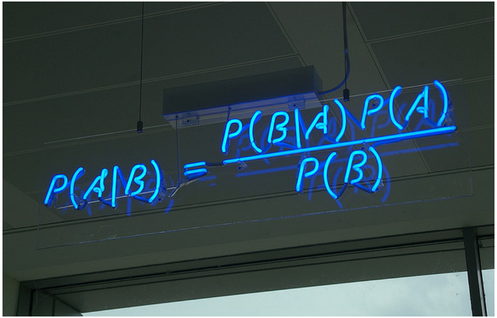


Photo by Matt Buck

Bayes Classifier: Naive One!

It is possible to show that accuracy is minimized, on average, by a very simple classifier that assigns each observation to the most likely class, given its predictor values. In other words, we should simply assign a test observation with predictor vector x_0 to the class j for which

$$P\left(Y = j \mid \mathbf{X} = \mathbf{x}\right)$$

is largest.

Bayes Classifier: Naive One!

We make two assumptions:

1. $X_1, X_2, \ldots, and\ X_m$ are independent from each other;
2. $X_1, X_2, \ldots, X_m \mid Y \sim MN(\cdot, p_1, p_2, \ldots, p_m)$

$$
\begin{aligned}
P(Y = j \mid \mathbf{X} = (x_1, x_2, \ldots, x_m)) &= \frac{P(\mathbf{X} = (x_1, x_2, \ldots, x_m) \mid Y = j) \cdot P(Y = j)}{P(\mathbf{X} = \mathbf{x})} \\
&= \frac{P(X_1 = x_1 \mid Y = j) \cdot \ldots \cdot P(X_m = x_m \mid Y = j) \cdot P(Y = j)}{P(\mathbf{X} = \mathbf{x})}.
\end{aligned}
$$

$$
\begin{aligned}
\hat{y} &= \underset{j \in classes}{\arg\max} \frac{P(X_1 = x_1 \mid Y = j) \cdot \ldots \cdot P(X_m = x_m \mid Y = j) \cdot P(Y = j)}{P(\mathbf{X} = \mathbf{x})} \\
&= \underset{j \in classes}{\arg\max}\, P(X_1 = x_1 \mid Y = j) \cdot \ldots \cdot P(X_m = x_m \mid Y = j) \cdot P(Y = j).
\end{aligned}
$$

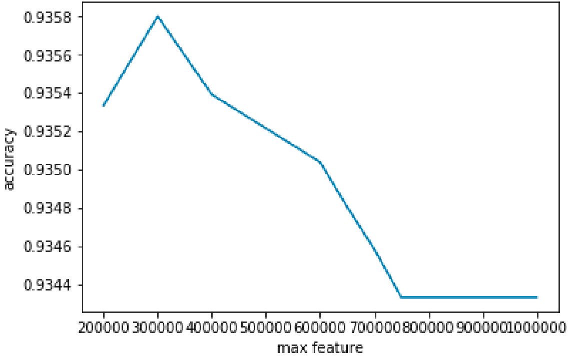
Hyperparameters

Two important hyperparameters:

1. Size of the vocabulary;
2. Laplace/ Lidstone smoothing parameter(α).
3. Prior

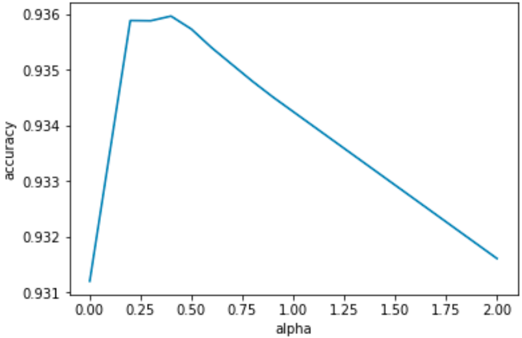
Size of Vocabulary

We can determine the size of our vocabulary.



It is convex!

Laplace/ Lidstone Smoothing Parameter(α)



It is convex!

Whether Use Prior or Not

$$\underbrace{P(c \mid x)}_{\text{Posterior Probability}} = \frac{\overbrace{P(x \mid c)}^{\text{Likelihood}}\,\overbrace{P(c)}^{\text{Class Prior Probability}}}{\underbrace{P(x)}_{\text{Predictor Prior Probability}}}$$

$$P(c \mid X) = P(x_1 \mid c) \times P(x_2 \mid c) \times \cdots \times P(x_n \mid c) \times P(c)$$

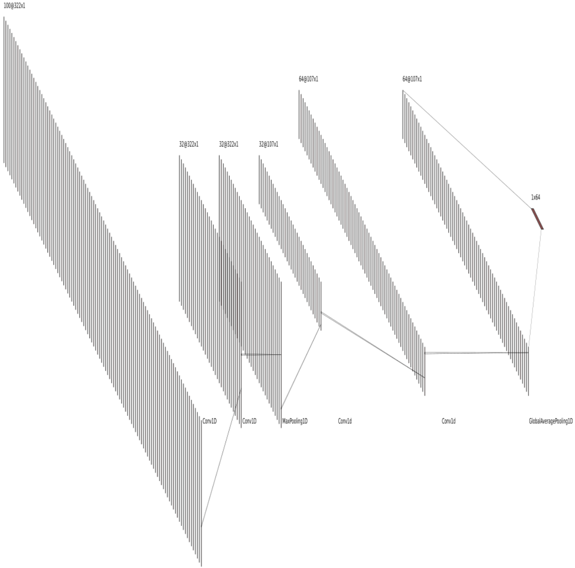
Whether Use Prior or Not

According to the dataset webpage, **distribution of dataset posts in different groups does not resemble the actual distributions**. So, if we fit a prior our accuracy with cross-validation increases, but it doesn't mean that our model is good; because model fits a wrong prior.
So we should not fit a prior(e.g. use an uninformative one).

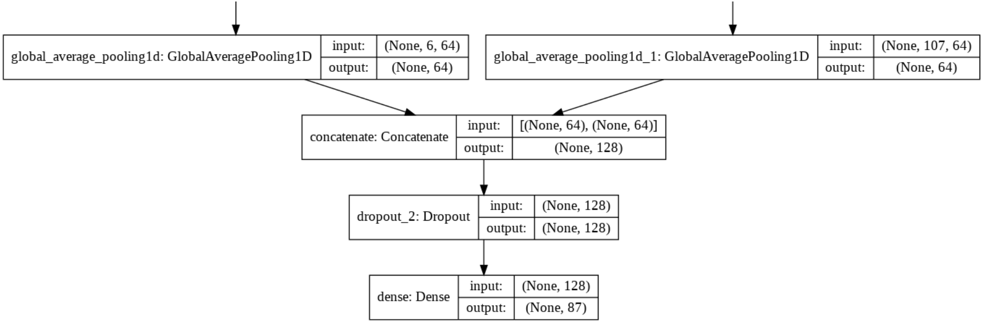
Bayes Classifier: Naive One!

Let's dive into code!

CNN Over Embedding Layer



CNN Over Embedding Layer

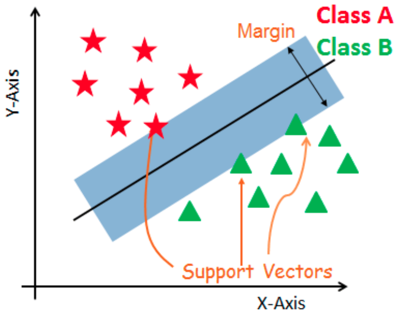


CNN Over Embedding Layer

	سامسونگ	سونی	لوستر	پراید
سامسونگ	0	1.9844	6.6001	4.9251
سونی	1.9844	0	6.3962	4.8678
لوستر	6.6001	6.3962	0	5.8193
پراید	4.9251	4.8678	5.8193	0

Support Vector Machines

SVM constructs a hyperplane in multidimensional space to separate different classes. SVM generates optimal hyperplane in an iterative manner, which is used to minimize an error. The core idea of SVM is to find a maximum marginal hyperplane(MMH) that best divides the dataset into classes.

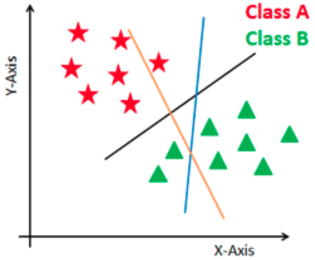


How does SVM work?

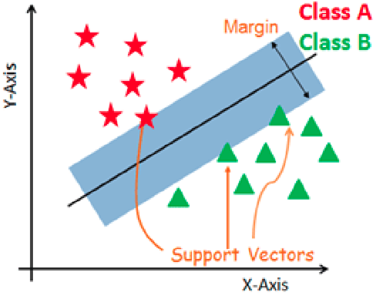
The main objective is to segregate the given dataset in the best possible way. The distance between the either nearest points is known as the margin. The objective is to select a hyperplane with the maximum possible margin between support vectors in the given dataset. SVM searches for the maximum marginal hyperplane in the following steps:

How does SVM work?

1. Generate hyperplanes which segregates the classes in the best way. Left-hand side figure showing three hyperplanes black, blue and orange. Here, the blue and orange have higher classification error, but the black is separating the two classes correctly.



2. Select the right hyperplane with the maximum segregation from the either nearest data points as shown in the right-hand side figure.



Linear SVM

Let's dive into code!

Passive Aggressive

- A margin based online learning algorithm
- Perfect for classifying massive streams
- Easy to implement and very fast
- **Passive**: if correct classification, keep the model;
- **Aggressive**: if incorrect classification, update to adjust to this misclassified example
- See `http://koaning.io/passive-agressive-algorithms.html` for further reading
- Link to the original paper: `http://jmlr.csail.mit.edu/papers/volume7/crammer06a/crammer06a.pdf`

Passive Aggressive

Let's dive into code!

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Ensemble Learning

- CountVectorizer + MutinomialNB
- TfidfVectorizer + MutinomialNB
- CountVectorizer + ComplementNB
- TfidfVectorizer + ComplementNB
- CountVectorizer + SVM(Hinge)
- CountVectorizer + SVM(HingeSq.)
- TfidfVectorizer + SVM(Hinge)
- TfidfVectorizer + SVM(HingeSq.)

PCA(100PC) + Structured data

5-Layer Perceptron

Models Comparison

Name	Accuracy	Vectorizer	Classifier	Text Strategy
SVM	93.78	Tf-Idf	SVM	Dual Vectorizers
Ensemble	93.19	Count + Tf-Idf	Various!	Concat Text
P-A	92.80	Count	Passive-Agressive	Concat Text
CNN[3]	90.50	Embedding	CNN	Dual CNN

[3] Trained with 80% of data!

Thanks for your attention!

- Codes and slides(in MLSP GitHub):
  `https://github.com/ut-mlsp/Text-classification-crash-course`
- Divar posts dataset:
  `https://research.cafebazaar.ir/visage/divar_datasets/`
- Any questions?