Automatic Tag Prediction for Stack OverFlow

- Work by Rohit SVK, Akhil Batra, Nithiya Shree

Group - 35

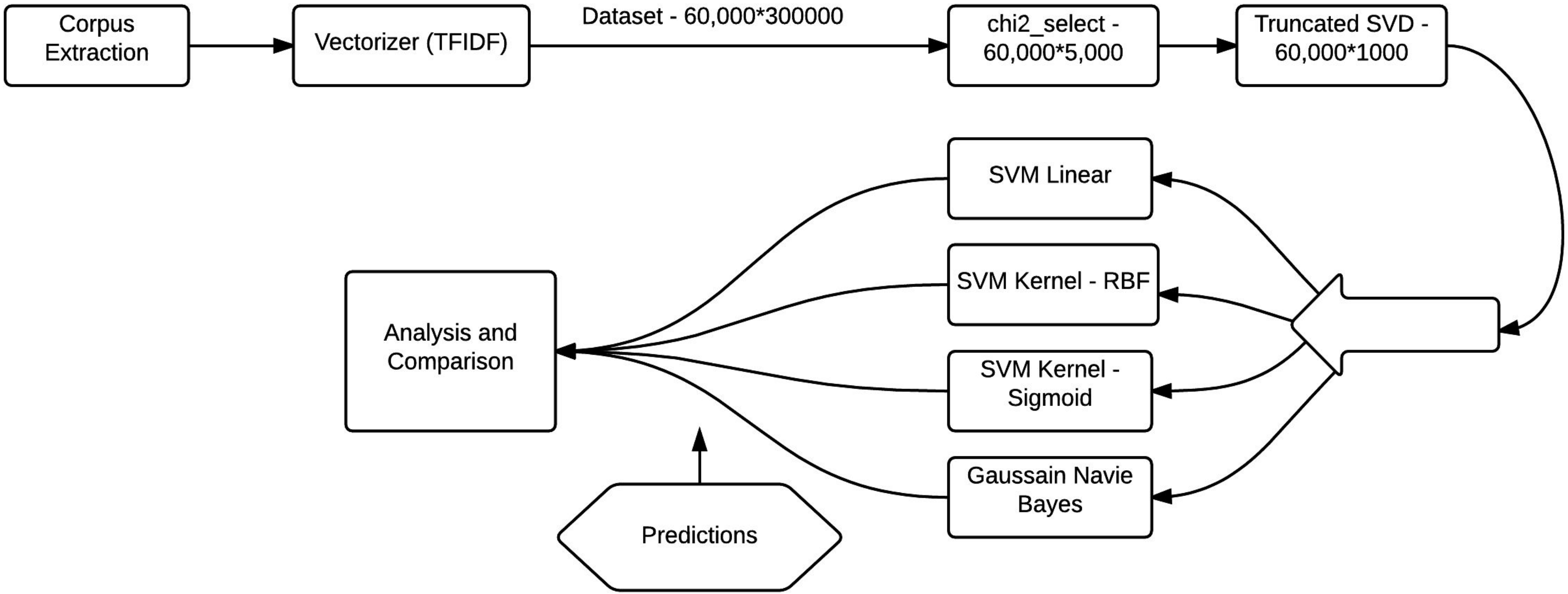
Problem Statement

- Implementing an automated tag recommendation system for Question - Answers knowledge system like Stack Over Flow.
- Since a Question – Answer site may host millions of questions with tags and other data, this information can be used as a training and test dataset for approaches that automatically suggest tags for new questions based on the historical similarity of the old Question - Answers.

Dataset

- Dataset is initially downloaded and populated from Stack Overflow Data store in our database.
- Database Schema is mentioned in the link below.
  - Http://data.stackexchange.com/stackoverflow/query
- Our dataset consists of 1000 famous tags .
- Each tag has 60 questions corresponding to it.
- These tags and corresponding questions are used as both training data and test data .

Architecture

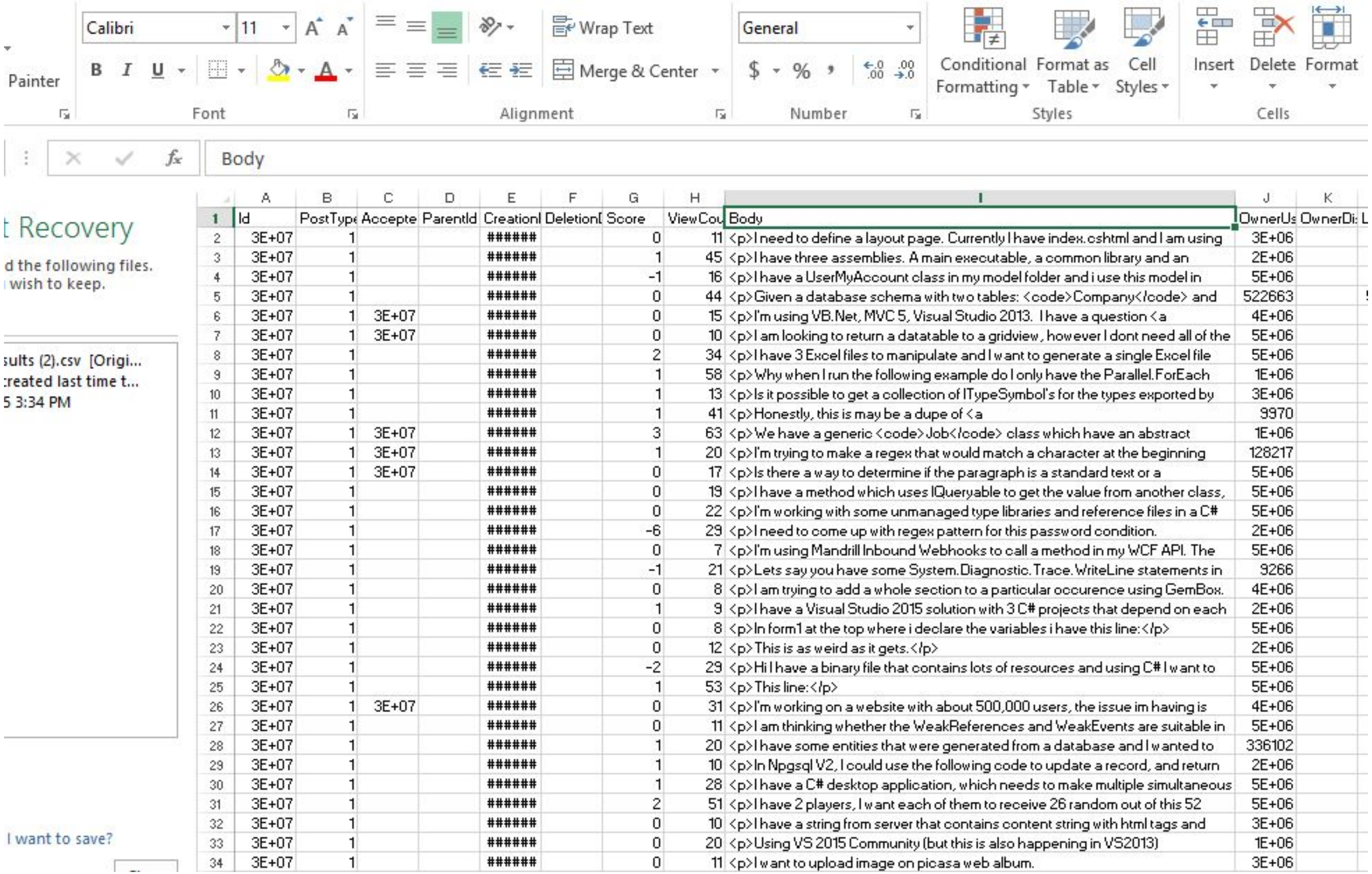


Action Plan

Data Extraction

Querying data from StackExchange dataexplorer.

- Considering 1000 popular tags (tags with most number of post counts).
- 60 questions for each tag.



	A	B	C	D	E	F	G	H	I	J	K	L
1	Id	PostTyp	Accepte	ParentId	CreationI	DeletionI	Score	ViewCou	Body	OwnerUs	OwnerDi	L
2	3E+07	1			######		0	11	<p>I need to define a layout page. Currently I have index.cshtml and I am using	3E+06		
3	3E+07	1			######		1	45	<p>I have three assemblies. A main executable, a common library and an	2E+06		
4	3E+07	1			######		-1	16	<p>I have a UserMyAccount class in my model folder and i use this model in	5E+06		
5	3E+07	1			######		0	44	<p>Given a database schema with two tables: <code>Company</code> and	522663		5
6	3E+07	1	3E+07		######		0	15	<p>I'm using VB.Net, MVC 5, Visual Studio 2013. I have a question <a	4E+06		
7	3E+07	1	3E+07		######		0	10	<p>I am looking to return a datatable to a gridview, however I dont need all of the	5E+06		
8	3E+07	1			######		2	34	<p>I have 3 Excel files to manipulate and I want to generate a single Excel file	5E+06		
9	3E+07	1			######		1	58	<p>Why when I run the following example do I only have the Parallel.ForEach	1E+06		
10	3E+07	1			######		1	13	<p>Is it possible to get a collection of ITypeSymbol's for the types exported by	3E+06		
11	3E+07	1			######		1	41	<p>Honestly, this is may be a dupe of <a	9970		
12	3E+07	1	3E+07		######		3	63	<p>We have a generic <code>Job</code> class which have an abstract	1E+06		
13	3E+07	1	3E+07		######		1	20	<p>I'm trying to make a regex that would match a character at the beginning	128217		
14	3E+07	1	3E+07		######		0	17	<p>Is there a way to determine if the paragraph is a standard text or a	5E+06		
15	3E+07	1			######		0	19	<p>I have a method which uses IQueryable to get the value from another class,	5E+06		
16	3E+07	1			######		0	22	<p>I'm working with some unmanaged type libraries and reference files in a C#	5E+06		
17	3E+07	1			######		-6	29	<p>I need to come up with regex pattern for this password condition.	2E+06		
18	3E+07	1			######		0	7	<p>I'm using Mandrill Inbound Webhooks to call a method in my WCF API. The	5E+06		
19	3E+07	1			######		-1	21	<p>Lets say you have some System.Diagnostic.Trace.WriteLine statements in	9266		
20	3E+07	1			######		0	8	<p>I am trying to add a whole section to a particular occurence using GemBox.	4E+06		
21	3E+07	1			######		1	9	<p>I have a Visual Studio 2015 solution with 3 C# projects that depend on each	2E+06		
22	3E+07	1			######		0	8	<p>In form1 at the top where i declare the variables i have this line:</p>	5E+06		
23	3E+07	1			######		0	12	<p>This is as weird as it gets.</p>	2E+06		
24	3E+07	1			######		-2	29	<p>Hi I have a binary file that contains lots of resources and using C# I want to	5E+06		
25	3E+07	1			######		1	53	<p>This line:</p>	5E+06		
26	3E+07	1	3E+07		######		0	31	<p>I'm working on a website with about 500,000 users, the issue im having is	4E+06		
27	3E+07	1			######		0	11	<p>I am thinking whether the WeakReferences and WeakEvents are suitable in	5E+06		
28	3E+07	1			######		1	20	<p>I have some entities that were generated from a database and I wanted to	336102		
29	3E+07	1			######		1	10	<p>In Npgsql V2, I could use the following code to update a record, and return	2E+06		
30	3E+07	1			######		1	28	<p>I have a C# desktop application, which needs to make multiple simultaneous	5E+06		
31	3E+07	1			######		2	51	<p>I have 2 players, I want each of them to receive 26 random out of this 52	5E+06		
32	3E+07	1			######		0	10	<p>I have a string from server that contains content string with html tags and	3E+06		
33	3E+07	1			######		0	20	<p>Using VS 2015 Community (but this is also happening in VS2013)	1E+06		
34	3E+07	1			######		0	11	<p>I want to upload image on picasa web album.	3E+06		

Extraction of Feature Vector

Conversion of each question into a feature vector is done using **‘tf-idf vectorizer’** .

- tf-idf stands for term frequency - inverse document frequency.
- This algorithm is also used for stop-words filtering.

Extraction of Feature Vector

tf-idf vectorizer

- **Term frequency** is to use the raw frequency of a term in a document i.e, the number of times that term t occurs in document d .

$$\mathrm{tf}(t,d) = 0.5 + \frac{0.5 \times f_{t,d}}{\max\{f_{t,d} : t \in d\}}$$

  - where $f_{t,d}$ is the raw frequency of t .

Extraction of Feature Vector

tf-idf vectorizer

- A high weight in tf-idf is reached by a high term frequency and a low document frequency of a term in the whole collection of documents.

$$\mathrm{tfidf}(t, d, D) = \mathrm{tf}(t, d) \times \mathrm{idf}(t, D)$$

- This weight also tends to filter out common terms.

Extraction of K best features

The algorithm used to get the best k features from a feature vector is **Chi-squared distribution**.

- Chi-squared distribution with k degrees of freedom is the distribution of a sum of the squares of k independent standard normal random variables.

$$Q = \sum_{i=1}^{k} Z_i^2 ,$$

  - where $z_1, ..., z_k$ are independent and standard normal random variables.

Dimensionality Reduction

Dimensionality reduction is done using **Truncated SVD algorithm**.

- SVD stands for **Singular value Decomposition** is a factorization of real or complex matrix.

$$\mathbf{M = U\Sigma V^*}$$

  - where **U** is a m X m real or complex unitary matrix.
  - **Σ** is a m X n rectangular diagonal matrix with non-negative real numbers on the diagonal.
  - **V*** is a n X n real or complex unitary matrix.

Dimensionality Reduction

- In a truncated SVD , only the *t* column vectors of *U* and *t* row vectors of V^* corresponding to the largest *t* largest singular values Σ_t are calculated.

$$\tilde{\mathbf{M}} = \mathbf{U}_t \Sigma_t \mathbf{V}_t^*$$

- The rest values are discarded.
- Thus, this is more quicker and more economical than the compact SVD if $t \ll r$.
- The matrix U_t is thus m X t, Σ_t is t X t diagonal, and V_t^* is t X n.

Training the data

For training the data, five different approaches have been employed :

- Linear SVM
- SVM with RBF Kernel
- SVM with Sigmoid kernel
- Multinomial Naive Bayes Classifier.
- Gaussian Naive Bayes Classifier.

Training the data

Linear SVM

- **Support Vector Machines** are supervised learning models with associated learning algorithms that analyze the data and recognize patterns which are useful for classification.
- SVM training algorithm builds a model that assigns new data points into one category or the other making it a non-probabilistic binary linear classifier.
- It has given an accuracy of 31.4 percent

Training the data

SVM with RBF Kernel

- RBF is **Radial Basis Function kernel**, is a popular kernel function used in various kernelized learning algorithms.
- The feature space of the kernel has infinite number of dimensions.
- The RBF kernel on 2 samples, is defined as

$$K(\mathbf{x}, \mathbf{x'}) = \exp\left(-\frac{||\mathbf{x} - \mathbf{x'}||^2}{2\sigma^2}\right)$$

  - $||\mathbf{x} - \mathbf{x'}||^2$ is the Euclidian distance between the 2 samples
  - □ is a free parameter
  - Accuracy = 39

Training the data

SVM with Sigmoid Kernel

- It uses the following kernel function

$$\tanh(\gamma\langle x, x'\rangle + r)$$

- It gives us better accuracies.
- Accuracy - 42.1

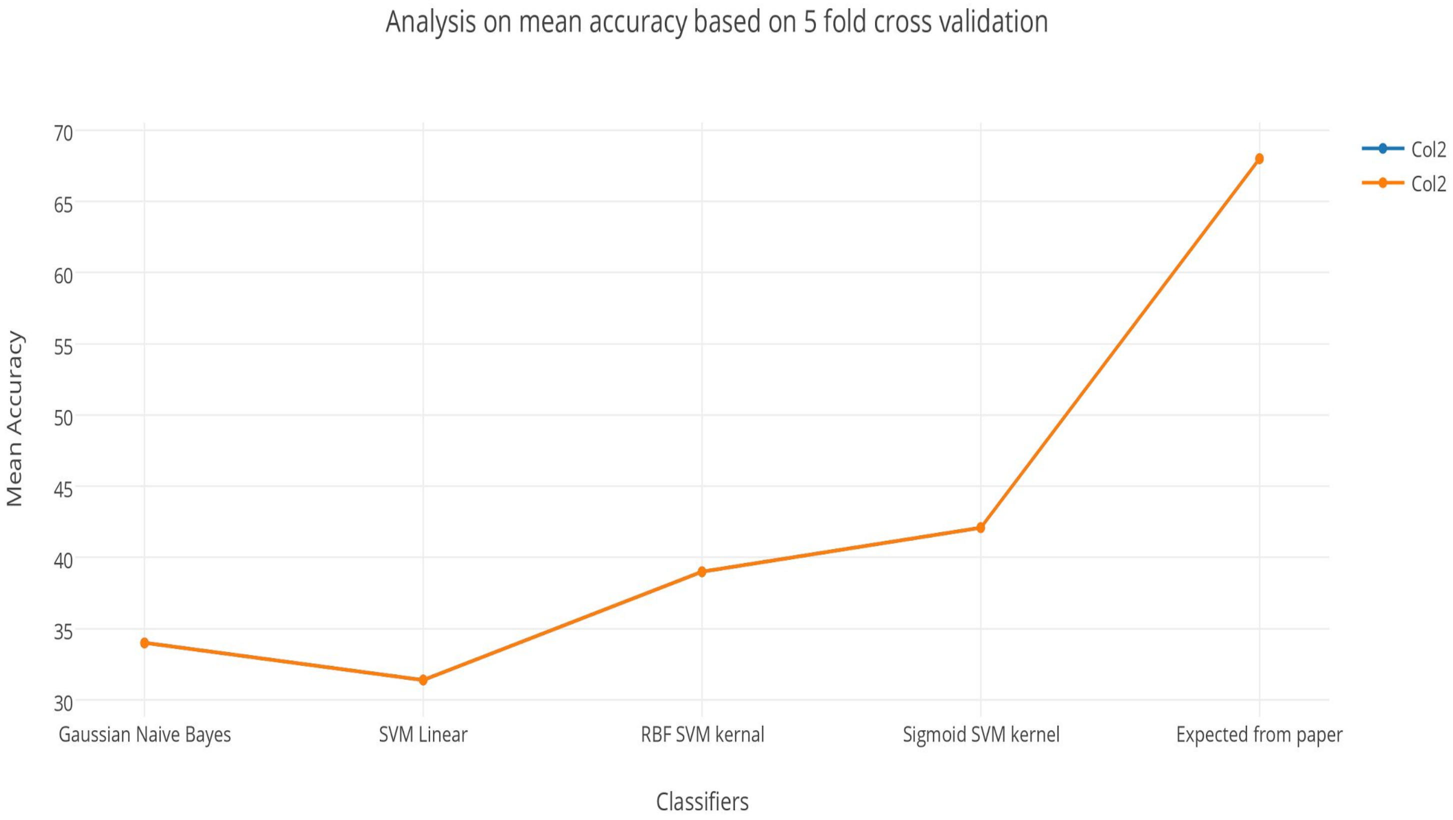
Training the data

Gaussian Naive Bayes Classifier

- Gaussian Naive Bayes classifier assumes that the continuous values are associated with each class are distributed according to a Gaussian distribution.

$$p(x = v|c) = \frac{1}{\sqrt{2\pi\sigma_c^2}}\, e^{-\frac{(v-\mu_c)^2}{2\sigma_c^2}}$$

  - where is μ_c the mean of values in **x** associated with class c.
  - σ_c^2 is variance of values of **x** associated with class c.
  - Accuracy - 34


Analysis on mean accuracy based on 5 fold cross validation
Mean Accuracy
70
65
60
55
50
45
40
35
30
Gaussian Naive Bayes
SVM Linear
RBF SVM kernal
Sigmoid SVM kernel
Expected from paper
Classifiers
Col2
Col2

Testing Test Data and analysis

- Considering 10 positive and 10 negative questions for each tag to test.
- Comparing feature vector of test question with each trained model and returning top matched models(tag).
- Analysis:

  Accuracy = NT / TT

  - NT : number of correctly classified questions for a tag.
  - TT : total number of test questions for that particular tag.

Reference

- “ A Discriminative Model Approach for Suggesting Tags Automatically for Stack Overflow Questions” –Avigit K. Saha, Ripon K. Saha, Kevin A. Schneider
    - http://www.cs.usask.ca/~kas/Publications_files/msr13-id175-p-16622-preprint.pdf
    - Conference – 10 th Working Conference on Mining Software Repositories. Mining Challenge – IEEE - 2013
- Will take hints from below paper and adding our approach to improve accuracy for the above approach.
    - “ EnTagRec: An Enhanced Tag Recommendation System for Software Information Sites”
    - Conference – ICSME 2014