Stackoverflow tag(s) predictor

In [1]:

```
import warnings
warnings.filterwarnings("ignore")
import pandas as pd
import sqlite3
import csv
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
from wordcloud import WordCloud
import re
import os
from sqlalchemy import create_engine # database connection
import datetime as dt
from nltk.corpus import stopwords
from nltk.tokenize import word_tokenize
from nltk.stem.snowball import SnowballStemmer
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.multiclass import OneVsRestClassifier
from sklearn.linear_model import SGDClassifier
from sklearn import metrics
from sklearn.metrics import f1_score,precision_score,recall_score
from sklearn import svm
from sklearn.linear_model import LogisticRegression
from skmultilearn.adapt import mlknn
from skmultilearn.problem_transform import ClassifierChain
from skmultilearn.problem_transform import BinaryRelevance
from skmultilearn.problem_transform import LabelPowerset
from sklearn.naive_bayes import GaussianNB
from datetime import datetime
```

Stack Overflow: Tag Prediction

1. Business Problem

1.1 Description

Description

Stack Overflow is the largest, most trusted online community for developers to learn, share their programming knowledge, and build their careers.

Stack Overflow is something which every programmer use one way or another. Each month, over 50 million developers come to Stack Overflow to learn, share their knowledge, and build their careers. It features questions and answers on a wide range of topics in computer programming. The website serves as a platform for users to ask and answer questions, and, through membership and active participation, to vote questions and answers up or down and edit questions and answers in a fashion similar to a wiki or Digg. As of April 2014

Stack Overflow has over 4,000,000 registered users, and it exceeded 10,000,000 questions in late August 2015. Based on the type of tags assigned to questions, the top eight most discussed topics on the site are: Java, JavaScript, C#, PHP, Android, jQuery, Python and HTML.

Problem Statemtent

Suggest the tags based on the content that was there in the question posted on Stackoverflow.

Source: https://www.kaggle.com/c/facebook-recruiting-iii-keyword-extraction/

1.2 Source / useful links

Data Source : https://www.kaggle.com/c/facebook-recruiting-iii-keyword-extraction/data (https://www.kaggle.com/c/facebook-recruiting-iii-keyword-extraction/data)
Youtube : https://youtu.be/nNDqbUhtIRg (https://youtu.be/nNDqbUhtIRg)
Research paper : https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/tagging-1.pdf (https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/tagging-1.pdf)
Research paper : https://dl.acm.org/citation.cfm?id=2660970&dl=ACM&coll=DL (https://dl.acm.org/citation.cfm?id=2660970&dl=ACM&coll=DL)

1.3 Real World / Business Objectives and Constraints

1. Predict as many tags as possible with high precision and recall.
2. Incorrect tags could impact customer experience on StackOverflow.
3. No strict latency constraints.

2. Machine Learning problem

2.1 Data

2.1.1 Data Overview

Refer: https://www.kaggle.com/c/facebook-recruiting-iii-keyword-extraction/data (https://www.kaggle.com/c/facebook-recruiting-iii-keyword-extraction/data)
All of the data is in 2 files: Train and Test.

Train.csv contains 4 columns: Id,Title,Body,Tags.

Test.csv contains the same columns but without the Tags, which you are to predict.

Size of Train.csv - 6.75GB

Size of Test.csv - 2GB

Number of rows in Train.csv = 6034195

The questions are randomized and contains a mix of verbose text sites as well as sites related to math and programming. The number of questions from each site may vary, and no filtering has been performed on the questions (such as closed questions).

Data Field Explaination

Dataset contains 6,034,195 rows. The columns in the table are:

Id - Unique identifier for each question

Title - The question's title

Body - The body of the question

Tags - The tags associated with the question in a space-seperated format (all lowercase, should not contain tabs '\t' or ampersands '&')

2.1.2 Example Data point

Title: Implementing Boundary Value Analysis of Software Testing in a C++ program?
Body :

```
        #include<
        iostream>\n
        #include<
        stdlib.h>\n\n
        using namespace std;\n\n
        int main()\n
        {\n
                 int n,a[n],x,c,u[n],m[n],e[n][4];\n
                 cout<<"Enter the number of variables";\n         cin>>n;\n
\n
                 cout<<"Enter the Lower, and Upper Limits of the variable
s";\n
                 for(int y=1; y<n+1; y++)\n
                 {\n
                    cin>>m[y];\n
                    cin>>u[y];\n
                 }\n
                 for(x=1; x<n+1; x++)\n
                 {\n
                    a[x] = (m[x] + u[x])/2;\n
                 }\n
                 c=(n*4)-4;\n
                 for(int a1=1; a1<n+1; a1++)\n
                 {\n\n
                    e[a1][0] = m[a1];\n
                    e[a1][1] = m[a1]+1;\n
                    e[a1][2] = u[a1]-1;\n
                    e[a1][3] = u[a1];\n
                 }\n
                 for(int i=1; i<n+1; i++)\n
                 {\n
                    for(int l=1; l<=i; l++)\n
                    {\n
                        if(l!=1)\n
                        {\n
                            cout<<a[l]<<"\\t";\n
                        }\n
                    }\n
                    for(int j=0; j<4; j++)\n
                    {\n
                        cout<<e[i][j];\n
                        for(int k=0; k<n-(i+1); k++)\n
                        {\n
                            cout<<a[k]<<"\\t";\n
                        }\n
                        cout<<"\\n";\n
                    }\n
                 }    \n\n
                 system("PAUSE");\n
                 return 0;    \n
```

```
            }\n


\n\n

        <p>The answer should come in the form of a table like</p>\n\n
        <pre><code>
        1            50              50\n
        2            50              50\n
        99           50              50\n
        100          50              50\n
        50           1               50\n
        50           2               50\n
        50           99              50\n
        50           100             50\n
        50           50              1\n
        50           50              2\n
        50           50              99\n
        50           50              100\n
        </code></pre>\n\n
        <p>if the no of inputs is 3 and their ranges are\n
        1,100\n
        1,100\n
        1,100\n
        (could be varied too)</p>\n\n
        <p>The output is not coming,can anyone correct the code or tell me what
    \'s wrong?</p>\n'

Tags : 'c++ c'
```

2.2 Mapping the real-world problem to a Machine Learning Problem

2.2.1 Type of Machine Learning Problem

It is a multi-label classification problem
Multi-label Classification: Multilabel classification assigns to each sample a set of target labels. This can be thought as predicting properties of a data-point that are not mutually exclusive, such as topics that are relevant for a document. A question on Stackoverflow might be about any of C, Pointers, FileIO and/or memory-management at the same time or none of these.
__Credit__: http://scikit-learn.org/stable/modules/multiclass.html

2.2.2 Performance metric

Micro-Averaged F1-Score (Mean F Score) : The F1 score can be interpreted as a weighted average of the precision and recall, where an F1 score reaches its best value at 1 and worst score at 0. The relative contribution of precision and recall to the F1 score are equal. The formula for the F1 score is:

*F1 = 2 * (precision * recall) / (precision + recall)*

In the multi-class and multi-label case, this is the weighted average of the F1 score of each class.

'Micro f1 score':
Calculate metrics globally by counting the total true positives, false negatives and false positives. This is a better metric when we have class imbalance.

'Macro f1 score':
Calculate metrics for each label, and find their unweighted mean. This does not take label imbalance into account.

https://www.kaggle.com/wiki/MeanFScore (https://www.kaggle.com/wiki/MeanFScore)
http://scikit-learn.org/stable/modules/generated/sklearn.metrics.f1_score.html (http://scikit-learn.org/stable/modules/generated/sklearn.metrics.f1_score.html)

Hamming loss : The Hamming loss is the fraction of labels that are incorrectly predicted.
https://www.kaggle.com/wiki/HammingLoss (https://www.kaggle.com/wiki/HammingLoss)

3. Exploratory Data Analysis

3.1 Data Loading and Cleaning

3.1.1 Using Pandas with SQLite to Load the data

In [2]:

```
#Creating db file from csv
#Learn SQL: https://www.w3schools.com/sql/default.asp
if not os.path.isfile('train.db'):
    start = datetime.now()
    disk_engine = create_engine('sqlite:///train.db')
    start = dt.datetime.now()
    chunksize = 180000
    j = 0
    index_start = 1
    for df in pd.read_csv('Train.csv', names=['Id', 'Title', 'Body', 'Tags'], chunksize=chu
        df.index += index_start
        j+=1
        print('{} rows'.format(j*chunksize))
        df.to_sql('data', disk_engine, if_exists='append')
        index_start = df.index[-1] + 1
    print("Time taken to run this cell :", datetime.now() - start)
```

3.1.2 Counting the number of rows

In [3]:

```
if os.path.isfile('train.db'):
    start = datetime.now()
    con = sqlite3.connect('train.db')
    num_rows = pd.read_sql_query("""SELECT count(*) FROM data""", con)
    #Always remember to close the database
    print("Number of rows in the database :","\n",num_rows['count(*)'].values[0])
    con.close()
    print("Time taken to count the number of rows :", datetime.now() - start)
else:
    print("Please download the train.db file from drive or run the above cell to genarate t
```

```
Number of rows in the database :
 6034196
Time taken to count the number of rows : 0:00:04.153227
```

In [4]:

```
num_rows
```

Out[4]:

	count(*)
0	6034196

3.1.3 Checking for duplicates

In [5]:

```
#Learn SQL: https://www.w3schools.com/sql/default.asp
if os.path.isfile('train.db'):
    start = datetime.now()
    con = sqlite3.connect('train.db')
    df_no_dup = pd.read_sql_query('SELECT Title, Body, Tags, COUNT(*) as cnt_dup FROM data
    con.close()
    print("Time taken to run this cell :", datetime.now() - start)
else:
    print("Please download the train.db file from drive or run the first to genarate train.
```

```
Time taken to run this cell : 0:05:25.691910
```

In [6]:

```
df_no_dup.head()
# we can observe that there are duplicates
```

Out[6]:

	Title	Body	Tags	cnt_dup
0	Implementing Boundary Value Analysis of S...	<pre> <code>#include&lt;iostream&gt;\n#include&...	c++ c	1
1	Dynamic Datagrid Binding in Silverlight?	<p>I should do binding for datagrid dynamicall...	c# silverlight data-binding	1
2	Dynamic Datagrid Binding in Silverlight?	<p>I should do binding for datagrid dynamicall...	c# silverlight data-binding columns	1
3	java.lang.NoClassDefFoundError: javax/serv...	<p>I followed the guide in <a href="http://sta...	jsp jstl	1
4	java.sql.SQLException:[Microsoft] [ODBC Dri...	<p>I use the following code</p>\n\n<pre> <code>...	java jdbc	2

In [7]:

```
print("number of duplicate questions :", num_rows['count(*)'].values[0]- df_no_dup.shape[0]
```

```
number of duplicate questions : 1827881 ( 30.292038906260256 % )
```

In [8]:

```
# number of times each question appeared in our database
df_no_dup.cnt_dup.value_counts()
```

Out[8]:

```
1    2656284
2    1272336
3     277575
4         90
5         25
6          5
Name: cnt_dup, dtype: int64
```

3.1.4 Removing the rows where no tags are present

In [13]:

```
sd=[]
start = datetime.now()
for i in range(df_no_dup.shape[0]):
    f=df_no_dup["Tags"][i]# no of characters==0
    if f==None:# when no tag given just remove that datapoint
        df_no_dup=df_no_dup.drop(i,axis=0)     # remove this datapoint
    else:
        d=len(df_no_dup["Tags"][i].split(" "))
        sd.append(d)

print(datetime.now()-start)
```

```
0:03:36.320016
```

In [14]:

```
start = datetime.now()
df_no_dup["tag_count"] = df_no_dup["Tags"].apply(lambda text: len(text.split(" ")))
# adding a new feature number of tags per question
print("Time taken to run this cell :", datetime.now() - start)
df_no_dup.head()
```

```
Time taken to run this cell : 0:00:02.329769
```

Out[14]:

	Title	Body	Tags	cnt_dup	t
0	Implementing Boundary Value Analysis of S...	<pre><code>#include&lt;iostream&gt;\n#include&...	c++ c	1	
1	Dynamic Datagrid Binding in Silverlight?	<p>I should do binding for datagrid dynamicall...	c# silverlight data-binding	1	
2	Dynamic Datagrid Binding in Silverlight?	<p>I should do binding for datagrid dynamicall...	c# silverlight data-binding columns	1	
3	java.lang.NoClassDefFoundError: javax/serv...	<p>I followed the guide in <a href="http://sta...	jsp jstl	1	
4	java.sql.SQLException:[Microsoft] [ODBC Dri...	<p>I use the following code</p>\n\n<pre><code>...	java jdbc	2	

In [15]:

```
# distribution of number of tags per question
df_no_dup.tag_count.value_counts()
```

Out[15]:

```
3    1206157
2    1111706
4     814996
1     568291
5     505158
Name: tag_count, dtype: int64
```

Creating no Duplicate database

In [16]:

```
#Creating a new database with no duplicates
if not os.path.isfile('train_no_dup.db'):
    disk_dup = create_engine("sqlite:///train_no_dup.db")
    no_dup = pd.DataFrame(df_no_dup, columns=['Title', 'Body', 'Tags'])
    no_dup.to_sql('no_dup_train',disk_dup)
```

In [17]:

```
#This method seems more appropriate to work with this much data.
#creating the connection with database file.
if os.path.isfile('train_no_dup.db'):
    start = datetime.now()
    con = sqlite3.connect('train_no_dup.db')
    tag_data = pd.read_sql_query("""SELECT Tags FROM no_dup_train""", con)
    #Always remember to close the database
    con.close()

    # Let's now drop unwanted column.
    tag_data.drop(tag_data.index[0], inplace=True)
    #Printing first 5 columns from our data frame
    tag_data.head()
    print("Time taken to run this cell :", datetime.now() - start)
else:
    print("Please download the train.db file from drive or run the above cells to genarate
```

```
Time taken to run this cell : 0:00:16.116694
```

3.2 Analysis of Tags

3.2.1 Total number of unique tags

In [18]:

```
# Importing & Initializing the "CountVectorizer" object, which
#is scikit-learn's bag of words tool.

#by default 'split()' will tokenize each tag using space.
vectorizer = CountVectorizer(tokenizer = lambda x: x.split())
# fit_transform() does two functions: First, it fits the model
# and learns the vocabulary; second, it transforms our training data
# into feature vectors. The input to fit_transform should be a list of strings.
tag_dtm = vectorizer.fit_transform(tag_data['Tags'])
#Returns:   X : array, [n_samples, n_features]
```

In [19]:

```
tag_data['Tags']
```

Out[19]:

```
1                  c# silverlight data-binding
2          c# silverlight data-binding columns
3                                     jsp jstl
4                                    java jdbc
5                facebook api facebook-php-sdk
                          ...
4206310             wordpress wordpress-plugin
4206311                         php mysql text
4206312     php codeigniter character-encoding
4206313                 php email outlook mime
4206314                                   html
Name: Tags, Length: 4206314, dtype: object
```

In [20]:

```
print("Number of data points :", tag_dtm.shape[0])
print("Number of unique tags :", tag_dtm.shape[1])
```

```
Number of data points : 4206314
Number of unique tags : 42048
```

In [21]:

```
#'get_feature_name()' gives us the vocabulary.
tags = vectorizer.get_feature_names()
#Lets look at the tags we have.
print("Some of the tags we have :", tags[:10])
```

```
Some of the tags we have : ['.a', '.app', '.asp.net-mvc', '.aspxauth', '.bas
h-profile', '.class-file', '.cs-file', '.doc', '.drv', '.ds-store']
```

3.2.3 Number of times a tag appeared

In [22]:

```
# https://stackoverflow.com/questions/15115765/how-to-access-sparse-matrix-elements
#Lets now store the document term matrix in a dictionary.
freqs = tag_dtm.sum(axis=0).A1
result = dict(zip(tags, freqs))
```

In [23]:

```
result
```

Out[23]:

```
{'.a': 18,
 '.app': 37,
 '.asp.net-mvc': 1,
 '.aspxauth': 21,
 '.bash-profile': 138,
 '.class-file': 53,
 '.cs-file': 14,
 '.doc': 47,
 '.drv': 1,
 '.ds-store': 8,
 '.each': 184,
 '.emf': 33,
 '.exe': 27,
 '.exe.config': 1,
 '.hgtags': 6,
 '.htaccess': 14884,
 '.htpasswd': 61,
 '.ico': 10,
```

In [24]:

```
#Saving this dictionary to csv files.
if not os.path.isfile('data/tag_counts_dict_dtm.csv'):
    with open('data/tag_counts_dict_dtm.csv', 'w') as csv_file:
        writer = csv.writer(csv_file)
        for key, value in result.items():
            writer.writerow([key, value])
tag_df = pd.read_csv("data/tag_counts_dict_dtm.csv", names=['Tags', 'Counts'])
tag_df.head()
```

Out[24]:

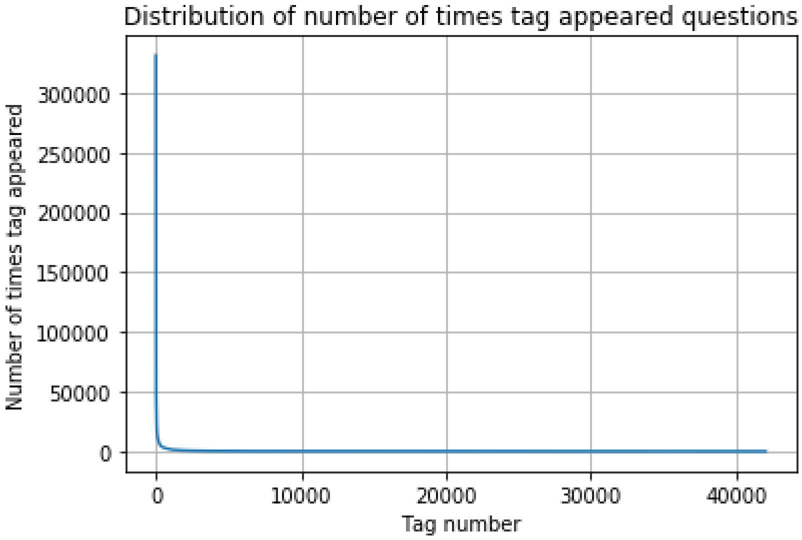
	Tags	Counts
0	.a	18
1	.app	37
2	.asp.net-mvc	1
3	.aspxauth	21
4	.bash-profile	138

In [25]:

```
tag_df_sorted = tag_df.sort_values(['Counts'], ascending=False)
tag_counts = tag_df_sorted['Counts'].values
```

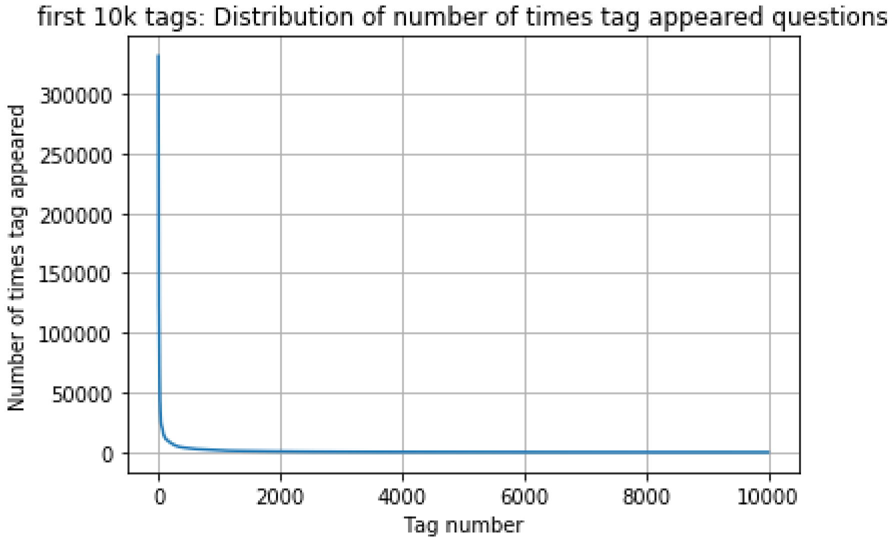
In [26]:

```
plt.plot(tag_counts)
plt.title("Distribution of number of times tag appeared questions")
plt.grid()
plt.xlabel("Tag number")
plt.ylabel("Number of times tag appeared")
plt.show()
```



In [27]:

```
plt.plot(tag_counts[0:10000])
plt.title('first 10k tags: Distribution of number of times tag appeared questions')
plt.grid()
plt.xlabel("Tag number")
plt.ylabel("Number of times tag appeared")
plt.show()
print(len(tag_counts[0:10000:25]), tag_counts[0:10000:25])
```

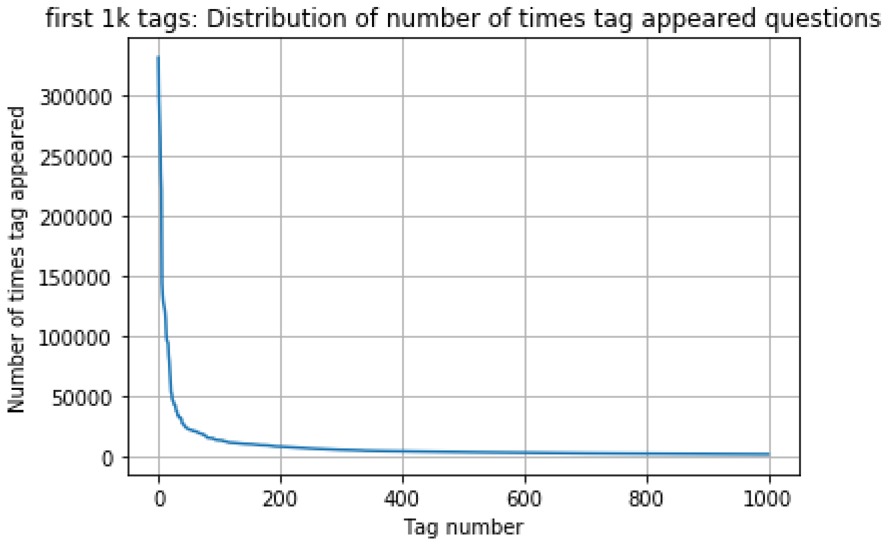


```
400 [331505  44829  22429  17728  13364  11162  10029   9148   8054   7151
   6466   5865   5370   4983   4526   4281   4144   3929   3750   3593
   3453   3299   3123   2989   2891   2738   2647   2527   2431   2331
   2259   2186   2097   2020   1959   1900   1828   1770   1723   1673
   1631   1574   1532   1479   1448   1406   1365   1328   1300   1266
   1245   1222   1197   1181   1158   1139   1121   1101   1076   1056
   1038   1023   1006    983    966    952    938    926    911    891
    882    869    856    841    830    816    804    789    779    770
    752    743    733    725    712    702    688    678    671    658
    650    643    634    627    616    607    598    589    583    577
    568    559    552    545    540    533    526    518    512    506
    500    495    490    485    480    477    469    465    457    450
    447    442    437    432    426    422    418    413    408    403
    398    393    388    385    381    378    374    370    367    365
    361    357    354    350    347    344    342    339    336    332
    330    326    323    319    315    312    309    307    304    301
    299    296    293    291    289    286    284    281    278    276
    275    272    270    268    265    262    260    258    256    254
    252    250    249    247    245    243    241    239    238    236
    234    233    232    230    228    226    224    222    220    219
    217    215    214    212    210    209    207    205    204    203
    201    200    199    198    196    194    193    192    191    189
    188    186    185    183    182    181    180    179    178    177
    175    174    172    171    170    169    168    167    166    165
    164    162    161    160    159    158    157    156    156    155
    154    153    152    151    150    149    149    148    147    146
    145    144    143    142    142    141    140    139    138    137
    137    136    135    134    134    133    132    131    130    130
    129    128    128    127    126    126    125    124    124    123
    123    122    122    121    120    120    119    118    118    117
    117    116    116    115    115    114    113    113    112    111
    111    110    109    109    108    108    107    106    106    106
    105    105    104    104    103    103    102    102    101    101
    100    100     99     99     98     98     97     97     96     96
```

```
      95     95     94     94     93     93     93     92     92     91
      91     90     90     89     89     88     88     87     87     86
      86     86     85     85     84     84     83     83     83     82
      82     82     81     81     80     80     80     79     79     78
      78     78     78     77     77     76     76     76     75     75
      75     74     74     74     73     73     73     73     72     72]
```

In [28]:

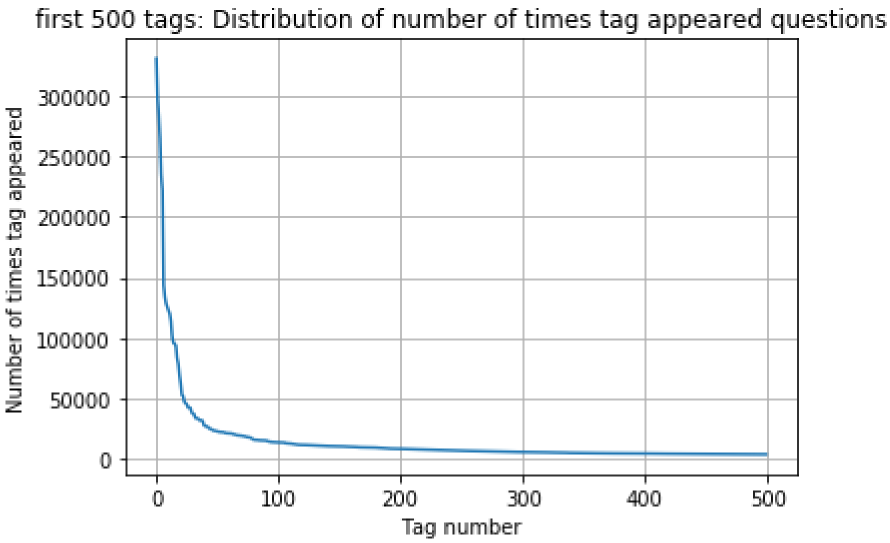
```
plt.plot(tag_counts[0:1000])
plt.title('first 1k tags: Distribution of number of times tag appeared questions')
plt.grid()
plt.xlabel("Tag number")
plt.ylabel("Number of times tag appeared")
plt.show()
print(len(tag_counts[0:1000:5]), tag_counts[0:1000:5])
```



```
200 [331505 221533 122769  95160  62023  44829  37170  31897  26925  24537
  22429  21820  20957  19758  18905  17728  15533  15097  14884  13703
  13364  13157  12407  11658  11228  11162  10863  10600  10350  10224
  10029   9884   9719   9411   9252   9148   9040   8617   8361   8163
   8054   7867   7702   7564   7274   7151   7052   6847   6656   6553
   6466   6291   6183   6093   5971   5865   5760   5577   5490   5411
   5370   5283   5207   5107   5066   4983   4891   4785   4658   4549
   4526   4487   4429   4335   4310   4281   4239   4228   4195   4159
   4144   4088   4050   4002   3957   3929   3874   3849   3818   3797
   3750   3703   3685   3658   3615   3593   3564   3521   3505   3483
   3453   3427   3396   3363   3326   3299   3272   3232   3196   3168
   3123   3094   3073   3050   3012   2989   2984   2953   2934   2903
   2891   2844   2819   2784   2754   2738   2726   2708   2681   2669
   2647   2621   2604   2594   2556   2527   2510   2482   2460   2444
   2431   2409   2395   2380   2363   2331   2312   2297   2290   2281
   2259   2246   2222   2211   2198   2186   2162   2142   2132   2107
   2097   2078   2057   2045   2036   2020   2011   1994   1971   1965
   1959   1952   1940   1932   1912   1900   1879   1865   1855   1841
   1828   1821   1813   1801   1782   1770   1760   1747   1741   1734
   1723   1707   1697   1688   1683   1673   1665   1656   1646   1639]
```

In [29]:

```
plt.plot(tag_counts[0:500])
plt.title('first 500 tags: Distribution of number of times tag appeared questions')
plt.grid()
plt.xlabel("Tag number")
plt.ylabel("Number of times tag appeared")
plt.show()
print(len(tag_counts[0:500:5]), tag_counts[0:500:5])
```



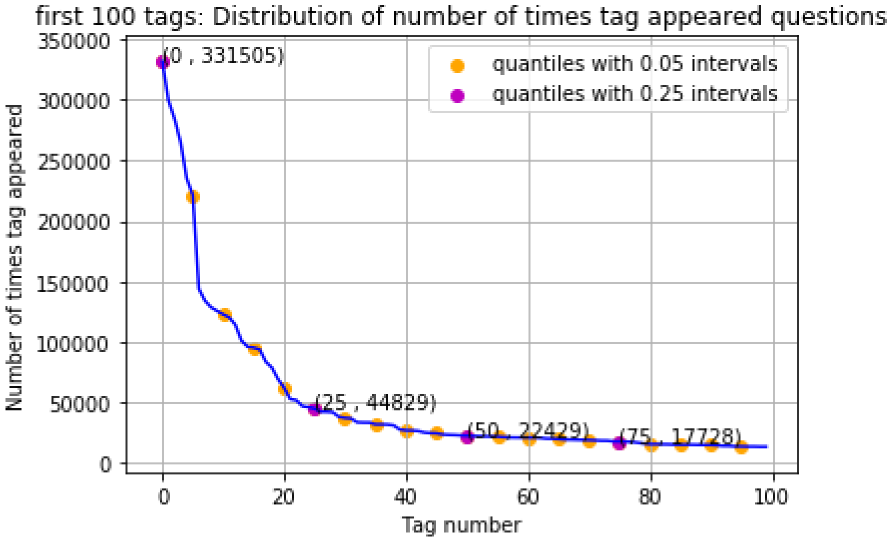
```
100 [331505 221533 122769  95160  62023  44829  37170  31897  26925  24537
  22429  21820  20957  19758  18905  17728  15533  15097  14884  13703
  13364  13157  12407  11658  11228  11162  10863  10600  10350  10224
  10029   9884   9719   9411   9252   9148   9040   8617   8361   8163
   8054   7867   7702   7564   7274   7151   7052   6847   6656   6553
   6466   6291   6183   6093   5971   5865   5760   5577   5490   5411
   5370   5283   5207   5107   5066   4983   4891   4785   4658   4549
   4526   4487   4429   4335   4310   4281   4239   4228   4195   4159
   4144   4088   4050   4002   3957   3929   3874   3849   3818   3797
   3750   3703   3685   3658   3615   3593   3564   3521   3505   3483]
```

In [30]:

```
plt.plot(tag_counts[0:100], c='b')
plt.scatter(x=list(range(0,100,5)), y=tag_counts[0:100:5], c='orange', label="quantiles wit
# quantiles with 0.25 difference
plt.scatter(x=list(range(0,100,25)), y=tag_counts[0:100:25], c='m', label = "quantiles with

for x,y in zip(list(range(0,100,25)), tag_counts[0:100:25]):
    plt.annotate(s="({} , {})".format(x,y), xy=(x,y), xytext=(x-0.05, y+500))

plt.title('first 100 tags: Distribution of number of times tag appeared questions')
plt.grid()
plt.xlabel("Tag number")
plt.ylabel("Number of times tag appeared")
plt.legend()
plt.show()
print(len(tag_counts[0:100:5]), tag_counts[0:100:5])
```



```
20 [331505 221533 122769  95160  62023  44829  37170  31897  26925  24537
  22429  21820  20957  19758  18905  17728  15533  15097  14884  13703]
```

In [31]:

```
# Store tags greater than 10K in one list
lst_tags_gt_10k = tag_df[tag_df.Counts>10000].Tags
#Print the length of the list
print ('{} Tags are used more than 10000 times'.format(len(lst_tags_gt_10k)))
# Store tags greater than 100K in one list
lst_tags_gt_100k = tag_df[tag_df.Counts>100000].Tags
#Print the length of the list.
print ('{} Tags are used more than 100000 times'.format(len(lst_tags_gt_100k)))
```

```
153 Tags are used more than 10000 times
14 Tags are used more than 100000 times
```

Observations:

1. There are total 153 tags which are used more than 10000 times.
2. 14 tags are used more than 100000 times.
3. Most frequent tag (i.e. c#) is used 331505 times.
4. Since some tags occur much more frequenctly than others, Micro-averaged F1-score is the appropriate metric for this probelm.

metric for this problem.

3.2.4 Tags Per Question

In [32]:

```
#Storing the count of tag in each question in list 'tag_count'
tag_quest_count = tag_dtm.sum(axis=1).tolist()
#Converting list of lists into single list, we will get [[3], [4], [2], [2], [3]] and we ar
tag_quest_count=[int(j) for i in tag_quest_count for j in i]
print ('We have total {} datapoints.'.format(len(tag_quest_count)))

print(tag_quest_count[:5])
```

```
We have total 4206314 datapoints.
[3, 4, 2, 2, 3]
```

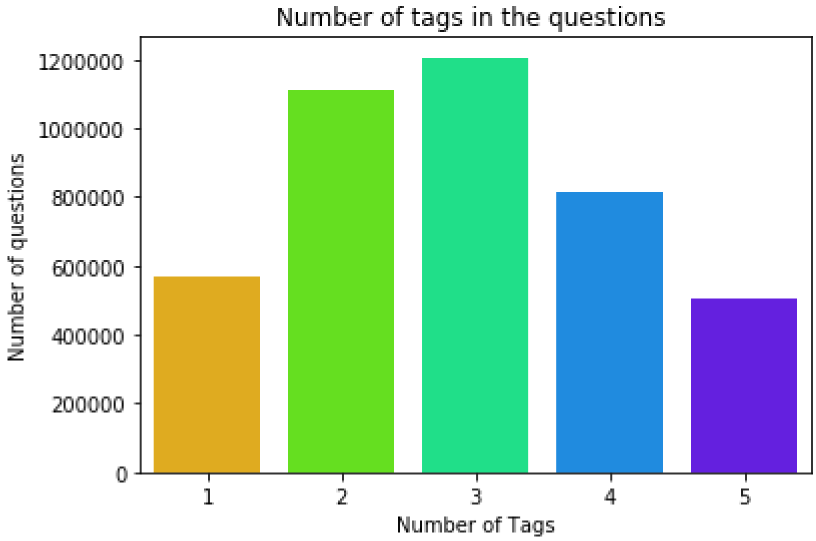
In [33]:

```
print( "Maximum number of tags per question: %d"%max(tag_quest_count))
print( "Minimum number of tags per question: %d"%min(tag_quest_count))
print( "Avg. number of tags per question: %f"% ((sum(tag_quest_count)*1.0)/len(tag_quest_cc
```

```
Maximum number of tags per question: 5
Minimum number of tags per question: 1
Avg. number of tags per question: 2.899440
```

In [34]:

```
sns.countplot(tag_quest_count, palette='gist_rainbow')
plt.title("Number of tags in the questions ")
plt.xlabel("Number of Tags")
plt.ylabel("Number of questions")
plt.show()
```



Observations:

1. Maximum number of tags per question: 5
2. Minimum number of tags per question: 1
3. Avg. number of tags per question: 2.899
4. Most of the questions are having 2 or 3 tags

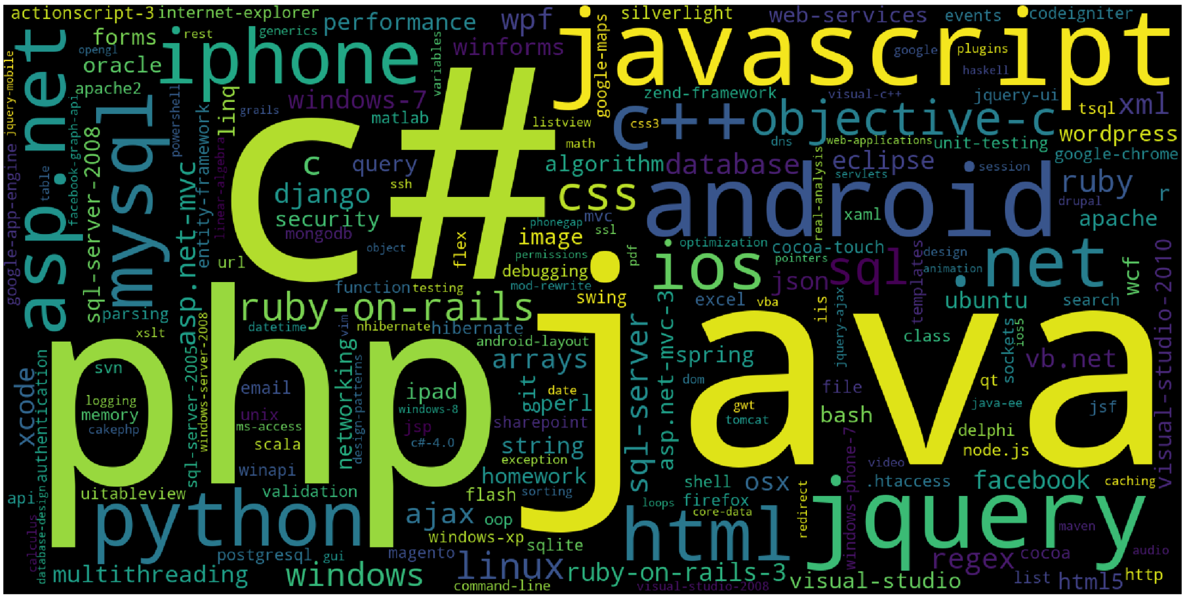
3.2.5 Most Frequent Tags

In [35]:

```
# Ploting word cloud
start = datetime.now()

# Lets first convert the 'result' dictionary to 'list of tuples'
tup = dict(result.items())
#Initializing WordCloud using frequencies of tags.
wordcloud = WordCloud(    background_color='black',
                          width=1600,
                          height=800,
                    ).generate_from_frequencies(tup)

fig = plt.figure(figsize=(30,20))
plt.imshow(wordcloud)
plt.axis('off')
plt.tight_layout(pad=0)
fig.savefig("tag.png")
plt.show()
print("Time taken to run this cell :", datetime.now() - start)
```



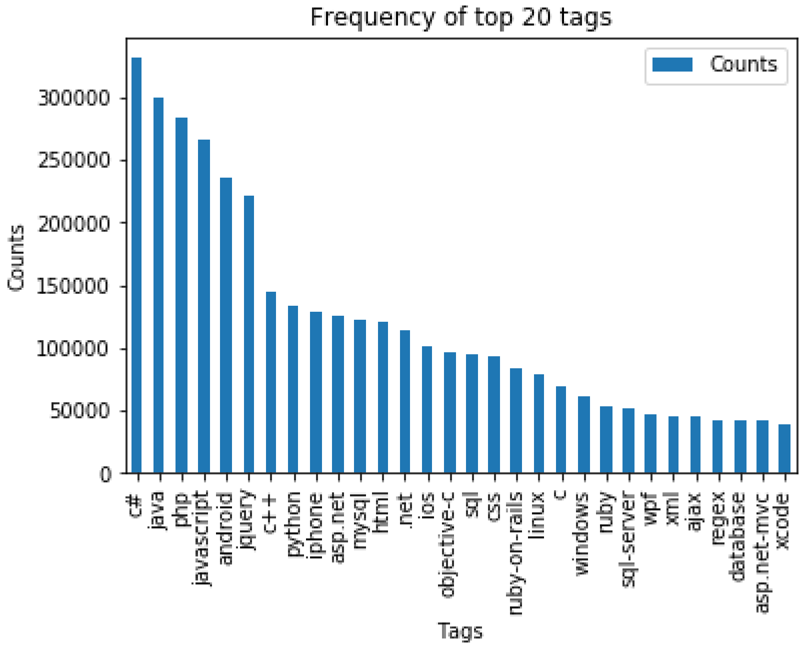
```
Time taken to run this cell : 0:00:03.085306
```

Observations:
A look at the word cloud shows that "c#", "java", "php", "asp.net", "javascript", "c++" are some of the most frequent tags.

3.2.6 The top 20 tags

In [36]:

```
i=np.arange(30)
tag_df_sorted.head(30).plot(kind='bar')
plt.title('Frequency of top 20 tags')
plt.xticks(i, tag_df_sorted['Tags'])
plt.xlabel('Tags')
plt.ylabel('Counts')
plt.show()
```



Observations:

1. Majority of the most frequent tags are programming language.
2. C# is the top most frequent programming language.
3. Android, IOS, Linux and windows are among the top most frequent operating systems.

3.3 Cleaning and preprocessing of Questions

3.3.1 Preprocessing

1. Sample 0.5M data points
2. Separate out code-snippets from Body
3. Remove Spcial characters from Question title and description (not in code)
4. Remove stop words (Except 'C')
5. Remove HTML Tags
6. Convert all the characters into small letters
7. Use SnowballStemmer to stem the words

In [37]:

```
def striphtml(data):
    cleanr = re.compile('<.*?>')
    cleantext = re.sub(cleanr, ' ', str(data))
    return cleantext
stop_words = set(stopwords.words('english'))
stemmer = SnowballStemmer("english")
```

In [38]:

```
#http://www.sqlitetutorial.net/sqlite-python/create-tables/
def create_connection(db_file):
    """ create a database connection to the SQLite database
        specified by db_file
    :param db_file: database file
    :return: Connection object or None
    """
    try:
        conn = sqlite3.connect(db_file)
        return conn
    except Error as e:
        print(e)

    return None

def create_table(conn, create_table_sql):
    """ create a table from the create_table_sql statement
    :param conn: Connection object
    :param create_table_sql: a CREATE TABLE statement
    :return:
    """
    try:
        c = conn.cursor()
        c.execute(create_table_sql)
    except Error as e:
        print(e)

def checkTableExists(dbcon):
    cursr = dbcon.cursor()
    str = "select name from sqlite_master where type='table'"
    table_names = cursr.execute(str)
    print("Tables in the databse:")
    tables =table_names.fetchall()
    print(tables[0][0])
    return(len(tables))

def create_database_table(database, query):
    conn = create_connection(database)
    if conn is not None:
        create_table(conn, query)
        checkTableExists(conn)
    else:
        print("Error! cannot create the database connection.")
    conn.close()

sql_create_table = """CREATE TABLE IF NOT EXISTS QuestionsProcessed (question text NOT NULL
create_database_table("Processed.db", sql_create_table)
```

```
Tables in the databse:
QuestionsProcessed
```

In [39]:

```
# http://www.sqlitetutorial.net/sqlite-delete/
# https://stackoverflow.com/questions/2279706/select-random-row-from-a-sqlite-table
start = datetime.now()
read_db = 'train_no_dup.db'
write_db = 'Processed.db'
if os.path.isfile(read_db):
    conn_r = create_connection(read_db)
    if conn_r is not None:
        reader =conn_r.cursor()
        reader.execute("SELECT Title, Body, Tags From no_dup_train ORDER BY RANDOM() LIMIT

if os.path.isfile(write_db):
    conn_w = create_connection(write_db)
    if conn_w is not None:
        tables = checkTableExists(conn_w)
        writer =conn_w.cursor()
        if tables != 0:
            writer.execute("DELETE FROM QuestionsProcessed WHERE 1")
            print("Cleared All the rows")
print("Time taken to run this cell :", datetime.now() - start)
```

```
Tables in the databse:
QuestionsProcessed
Cleared All the rows
Time taken to run this cell : 0:03:32.619944
```

__ we create a new data base to store the sampled and preprocessed questions __

In [40]:

```
import nltk
nltk.download('punkt')
```

```
[nltk_data] Downloading package punkt to
[nltk_data]     C:\Users\vansh\AppData\Roaming\nltk_data...
[nltk_data]   Package punkt is already up-to-date!
```

Out[40]:

```
True
```

In [41]:

```
#http://www.bernzilla.com/2008/05/13/selecting-a-random-row-from-an-sqlite-table/

start = datetime.now()
preprocessed_data_list=[]
reader.fetchone()
questions_with_code=0
len_pre=0
len_post=0
questions_proccesed = 0
for row in reader:

    is_code = 0

    title, question, tags = row[0], row[1], row[2]

    if '<code>' in question:
        questions_with_code+=1
        is_code = 1
    x = len(question)+len(title)
    len_pre+=x

    code = str(re.findall(r'<code>(.*?)</code>', question, flags=re.DOTALL))

    question=re.sub('<code>(.*?)</code>', '', question, flags=re.MULTILINE|re.DOTALL)
    question=striphtml(question.encode('utf-8'))

    title=title.encode('utf-8')

    question=str(title)+" "+str(question)
    question=re.sub(r'[^A-Za-z]+',' ',question)
    words=word_tokenize(str(question.lower()))

    #Removing all single letter and and stopwords from question exceptt for the letter 'c'
    question=' '.join(str(stemmer.stem(j)) for j in words if j not in stop_words and (len(j

    len_post+=len(question)
    tup = (question,code,tags,x,len(question),is_code)
    questions_proccesed += 1
    writer.execute("insert into QuestionsProcessed(question,code,tags,words_pre,words_post,
    if (questions_proccesed%100000==0):
        print("number of questions completed=",questions_proccesed)

no_dup_avg_len_pre=(len_pre*1.0)/questions_proccesed
no_dup_avg_len_post=(len_post*1.0)/questions_proccesed

print( "Avg. length of questions(Title+Body) before processing: %d"%no_dup_avg_len_pre)
print( "Avg. length of questions(Title+Body) after processing: %d"%no_dup_avg_len_post)
print ("Percent of questions containing code: %d"%((questions_with_code*100.0)/questions_pr

print("Time taken to run this cell :", datetime.now() - start)
```

```
number of questions completed= 100000
number of questions completed= 200000
number of questions completed= 300000
number of questions completed= 400000
Avg. length of questions(Title+Body) before processing: 1171
Avg. length of questions(Title+Body) after processing: 326
```

```
Percent of questions containing code: 57
Time taken to run this cell : 0:09:45.271985
```

In [42]:

```
# dont forget to close the connections, or else you will end up with locks
conn_r.commit()
conn_w.commit()
conn_r.close()
conn_w.close()
```

In [43]:

```
if os.path.isfile(write_db):
    conn_r = create_connection(write_db)
    if conn_r is not None:
        reader =conn_r.cursor()
        reader.execute("SELECT question From QuestionsProcessed LIMIT 10")
        print("Questions after preprocessed")
        print('='*100)
        reader.fetchone()
        for row in reader:
            print(row)
            print('-'*100)
conn_r.commit()
conn_r.close()
```

```
Questions after preprocessed
============================================================================
========================
('sql convers script delet bad data permiss bridg tabl goal write loop conve
rs go contain acucor securitycontain tabl clean permiss acucor securitypermi
ss bridg tabl base script care end two script complet fine notic differ two
clean queri vs saliva vs hair queri hair applic context secur queri saliva a
pplic context secur',)
----------------------------------------------------------------------------
------------------------
('combin result multipl subqueri one set tri exclud row tabl base id tabl ni
tabl select result set like tri combin result subqueri one like filter big t
abl look group concat union kind seem find someth actual work anyon idea',)
----------------------------------------------------------------------------
------------------------
('version percona db packag instal ubuntu natti narwhal new percona amp ubun
tu accord page percona avail use natti someon recommend version choos',)
----------------------------------------------------------------------------
------------------------
('hide div view mvc develop mvc applic use razor syntax applic give comment
facil ad partial view load comment record db imag see comment box call run t
ime employe index view want remov div user click delet button work right ple
as check imag code applic updat script',)
----------------------------------------------------------------------------
------------------------
('sudo anoth user without specifi usernam current tri creat sudoer file ran
someth figur end result look want user abl someth like instead run root like
script run user look sudoer file tri ad line like work specifi user easi way
script run specif user without specifi command line',)
----------------------------------------------------------------------------
------------------------
('maximum size ellips net attempt use object draw ellips realli circl larg m
illion pixel though sinc pictur box draw reason size ought get either imag s
ometh approach line depend ellips locat use system draw graphic drawellips p
en rectanglef draw ellips success construct rectanglef describ dimens want e
xampl describ ellips much bigger actual visibl view space pass drawelips act
ual noth sinc part edg elips intersect visibl region instead tri draw ellips
bound produc method specifi ever throw microsoft document give indic inappro
pri argument big ellips draw far away center break',)
----------------------------------------------------------------------------
------------------------
('move new line haskel updat follow function haskel must print sale week sal
e new line work way expect problem newlin charact code tri mani way new line
charact work expect everyth print line whichi want need help thank updat fol
low work compil error error come second line formatlin type decalar caus err
or need help',)
--------------------------------------------------------------------------------
------------------------
('verita netbackup nbazd daemon wont start im new work verita netbackup inst
al server solari im plan use nbac problem nbazd daemon dont start go activ m
onitor daemon right click nbazd daemon mark start daemon dont anyth select d
aemon detail nbazd status stop start servic',)
--------------------------------------------------------------------------------
------------------------
('revers dns lookup command line like get list domain point certain ip addre
ss way get inform command line noth like host nslookup dig return hostnam ip
address help part want return edit inform nan exampl websit return inform ht
tp www domaintool com revers ip hostnam',)
--------------------------------------------------------------------------------
------------------------
```

In [44]:

```
#Taking 0.5 Million entries to a dataframe.
write_db = 'Processed.db'
if os.path.isfile(write_db):
    conn_r = create_connection(write_db)
    if conn_r is not None:
        preprocessed_data = pd.read_sql_query("""SELECT question, Tags FROM QuestionsProces
conn_r.commit()
conn_r.close()
```

In [45]:

```
preprocessed_data.head()
```

Out[45]:

	question	tags
0	determin object lock synchron block java proce...	java synchronization
1	sql convers script delet bad data permiss brid...	sql-server-2008 tsql delete script
2	combin result multipl subqueri one set tri exc...	mysql set subquery
3	version percona db packag instal ubuntu natti ...	mysql ruby ubuntu natty percona
4	hide div view mvc develop mvc applic use razor...	javascript asp.net-mvc-3

In [46]:

```
print("number of data points in sample :", preprocessed_data.shape[0])
print("number of dimensions :", preprocessed_data.shape[1])
```

```
number of data points in sample : 499999
number of dimensions : 2
```

4. Machine Learning Models

4.1 Converting tags for multilabel problems

X	y1	y2	y3	y4
x1	0	1	1	0
x1	1	0	0	0
x1	0	1	0	0

In [47]:

```
# binary='true' will give a binary vectorizer
vectorizer = CountVectorizer(tokenizer = lambda x: x.split(), binary='true')
multilabel_y = vectorizer.fit_transform(preprocessed_data['tags'])
```

__ We will sample the number of tags instead considering all of them (due to limitation of computing power) __

In [48]:

```
def tags_to_choose(n):
    t = multilabel_y.sum(axis=0).tolist()[0]
    sorted_tags_i = sorted(range(len(t)), key=lambda i: t[i], reverse=True)
    multilabel_yn=multilabel_y[:,sorted_tags_i[:n]]
    return multilabel_yn

def questions_explained_fn(n):
    multilabel_yn = tags_to_choose(n)
    x= multilabel_yn.sum(axis=1)
    return (np.count_nonzero(x==0))
```

In [49]:

```
questions_explained = []
total_tags=multilabel_y.shape[1]
total_qs=preprocessed_data.shape[0]
for i in range(500, total_tags, 100):
    questions_explained.append(np.round(((total_qs-questions_explained_fn(i))/total_qs)*100
```

In [50]:

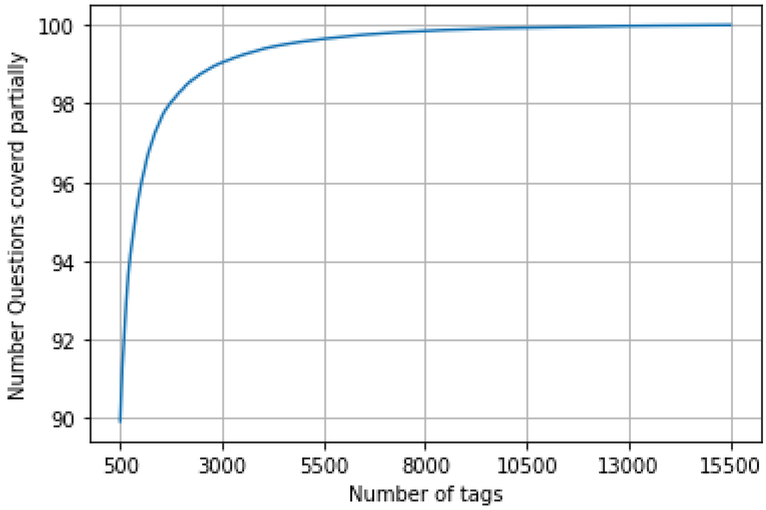
```
questions_explained
```

Out[50]:

```
[89.927,
 91.247,
 92.125,
 92.974,
 93.673,
 94.148,
 94.535,
 94.892,
 95.279,
 95.592,
 95.87,
 96.115,
 96.324,
 96.571,
 96.765,
 96.915,
 97.074,
 97.242,
```

In [51]:

```
fig, ax = plt.subplots()
ax.plot(questions_explained)
xlabel = list(500+np.array(range(-50,450,50))*50)
ax.set_xticklabels(xlabel)
plt.xlabel("Number of tags")
plt.ylabel("Number Questions coverd partially")
plt.grid()
plt.show()
# you can choose any number of tags based on your computing power, minimun is 50(it covers
print("with ",5500,"tags we are covering ",questions_explained[50],"% of questions")
```



```
with  5500 tags we are covering  99.048 % of questions
```

In [52]:

```
multilabel_yx = tags_to_choose(5500)
print("number of questions that are not covered :", questions_explained_fn(5500),"out of ",
```

```
number of questions that are not covered : 4760 out of  499999
```

In [53]:

```
print("Number of tags in sample :", multilabel_y.shape[1])
print("number of tags taken :", multilabel_yx.shape[1],"(",(multilabel_yx.shape[1]/multilab
```

```
Number of tags in sample : 30508
number of tags taken : 5500 ( 18.028058214238886 %)
```

__ We consider top 15% tags which covers 99% of the questions __

4.2 Split the data into test and train (80:20)

In [54]:

```
total_size=preprocessed_data.shape[0]
train_size=int(0.80*total_size)

x_train=preprocessed_data.head(train_size)
x_test=preprocessed_data.tail(total_size - train_size)

y_train = multilabel_yx[0:train_size,:]
y_test = multilabel_yx[train_size:total_size,:]
```

In [55]:

```
print("Number of data points in train data :", y_train.shape)
print("Number of data points in test data :", y_test.shape)
```

```
Number of data points in train data : (399999, 5500)
Number of data points in test data : (100000, 5500)
```

4.3 Featurizing data

In [56]:

```
start = datetime.now()
vectorizer = TfidfVectorizer(min_df=0.00009, max_features=200000, smooth_idf=True, norm="l2
                             tokenizer = lambda x: x.split(), sublinear_tf=False, ngram_ran
x_train_multilabel = vectorizer.fit_transform(x_train['question'])
x_test_multilabel = vectorizer.transform(x_test['question'])
print("Time taken to run this cell :", datetime.now() - start)
```

```
Time taken to run this cell : 0:02:36.205814
```

In [57]:

```
print("Dimensions of train data X:",x_train_multilabel.shape, "Y :",y_train.shape)
print("Dimensions of test data X:",x_test_multilabel.shape,"Y:",y_test.shape)
```

```
Dimensions of train data X: (399999, 89487) Y : (399999, 5500)
Dimensions of test data X: (100000, 89487) Y: (100000, 5500)
```

In [58]:

```
# https://www.analyticsvidhya.com/blog/2017/08/introduction-to-multi-label-classification/
#https://stats.stackexchange.com/questions/117796/scikit-multi-label-classification
# classifier = LabelPowerset(GaussianNB())
"""
from skmultilearn.adapt import MLkNN
classifier = MLkNN(k=21)

# train
classifier.fit(x_train_multilabel, y_train)

# predict
predictions = classifier.predict(x_test_multilabel)
print(accuracy_score(y_test,predictions))
print(metrics.f1_score(y_test, predictions, average = 'macro'))
print(metrics.f1_score(y_test, predictions, average = 'micro'))
print(metrics.hamming_loss(y_test,predictions))

"""
# we are getting memory error because the multilearn package
# is trying to convert the data into dense matrix
# ---------------------------------------------------------------------------
#MemoryError                               Traceback (most recent call last)
#<ipython-input-170-f0e7c7f3e0be> in <module>()
#----> classifier.fit(x_train_multilabel, y_train)
```

Out[58]:

```
"\nfrom skmultilearn.adapt import MLkNN\nclassifier = MLkNN(k=21)\n\n# train
\nclassifier.fit(x_train_multilabel, y_train)\n\n# predict\npredictions = cl
assifier.predict(x_test_multilabel)\nprint(accuracy_score(y_test,prediction
s))\nprint(metrics.f1_score(y_test, predictions, average = 'macro'))\nprint
(metrics.f1_score(y_test, predictions, average = 'micro'))\nprint(metrics.ha
mming_loss(y_test,predictions))\n\n"
```

In [59]:

```
x_train_multilabel.shape
```

Out[59]:

```
(399999, 89487)
```

In [60]:

```
x_test_multilabel.shape
```

Out[60]:

```
(100000, 89487)
```

4.4 Applying Logistic Regression with OneVsRest Classifier

In [64]:

```
classifier = OneVsRestClassifier(SGDClassifier(loss='log', alpha=0.00001, penalty='l1'), n_
classifier.fit(x_train_multilabel, y_train)

predictions = classifier.predict(x_test_multilabel)

print("accuracy :",metrics.accuracy_score(y_test,predictions))
print("macro f1 score :",metrics.f1_score(y_test, predictions, average = 'macro'))
print("micro f1 scoore :",metrics.f1_score(y_test, predictions, average = 'micro'))
print("hamming loss :",metrics.hamming_loss(y_test,predictions))
print("Precision recall report :\n",metrics.classification_report(y_test, predictions))
```

```
accuracy : 0.08126
macro f1 score : 0.09291293571750123
micro f1 scoore : 0.37398320216916875
hamming loss : 0.00041306181818182
Precision recall report :
               precision    recall  f1-score   support

           0       0.61      0.22      0.32      7927
           1       0.79      0.44      0.56      7236
           2       0.82      0.54      0.65      6682
           3       0.74      0.44      0.55      6298
           4       0.95      0.76      0.84      5729
           5       0.87      0.67      0.75      5244
           6       0.73      0.31      0.43      3520
           7       0.88      0.60      0.71      3150
           8       0.69      0.38      0.49      3063
           9       0.79      0.41      0.54      3055
          10       0.84      0.60      0.70      2893
          11       0.56      0.18      0.27      2889
```

In [65]:

```
from sklearn.externals import joblib
joblib.dump(classifier, 'saved_models/lr_with_equal_weight_1.pkl')
```

Out[65]:

```
['saved_models/lr_with_equal_weight_1.pkl']
```

4.5 Modeling with less data points (0.5M data points) and more weight to title and 500 tags only.

In [66]:

```
sql_create_table = """CREATE TABLE IF NOT EXISTS QuestionsProcessed (question text NOT NULL
create_database_table("Titlemoreweight.db", sql_create_table)
```

```
Tables in the databse:
QuestionsProcessed
```

In [67]:

```
# http://www.sqlitetutorial.net/sqlite-delete/
# https://stackoverflow.com/questions/2279706/select-random-row-from-a-sqlite-table

read_db = 'train_no_dup.db'
write_db = 'Titlemoreweight.db'
train_datasize = 400000
if os.path.isfile(read_db):
    conn_r = create_connection(read_db)
    if conn_r is not None:
        reader =conn_r.cursor()
        # for selecting first 0.5M rows
        reader.execute("SELECT Title, Body, Tags From no_dup_train LIMIT 500001;")
        # for selecting random points
        #reader.execute("SELECT Title, Body, Tags From no_dup_train ORDER BY RANDOM() LIMIT

if os.path.isfile(write_db):
    conn_w = create_connection(write_db)
    if conn_w is not None:
        tables = checkTableExists(conn_w)
        writer =conn_w.cursor()
        if tables != 0:
            writer.execute("DELETE FROM QuestionsProcessed WHERE 1")
            print("Cleared All the rows")
```

```
Tables in the databse:
QuestionsProcessed
Cleared All the rows
```

4.5.1 Preprocessing of questions

1. Separate Code from Body
2. Remove Spcial characters from Question title and description (not in code)
3. **Give more weightage to title : Add title three times to the question**

```
<li> Remove stop words (Except 'C') </li>
<li> Remove HTML Tags </li>
<li> Convert all the characters into small letters </li>
<li> Use SnowballStemmer to stem the words </li>
```

In [68]:

```
#http://www.bernzilla.com/2008/05/13/selecting-a-random-row-from-an-sqlite-table/
start = datetime.now()
preprocessed_data_list=[]
reader.fetchone()
questions_with_code=0
len_pre=0
len_post=0
questions_proccesed = 0
for row in reader:

    is_code = 0

    title, question, tags = row[0], row[1], str(row[2])

    if '<code>' in question:
        questions_with_code+=1
        is_code = 1
    x = len(question)+len(title)
    len_pre+=x

    code = str(re.findall(r'<code>(.*?)</code>', question, flags=re.DOTALL))

    question=re.sub('<code>(.*?)</code>', '', question, flags=re.MULTILINE|re.DOTALL)
    question=striphtml(question.encode('utf-8'))

    title=title.encode('utf-8')

    # adding title three time to the data to increase its weight
    # add tags string to the training data

    question=str(title)+" "+str(title)+" "+str(title)+" "+question

#     if questions_proccesed<=train_datasize:
#         question=str(title)+" "+str(title)+" "+str(title)+" "+question+" "+str(tags)
#     else:
#         question=str(title)+" "+str(title)+" "+str(title)+" "+question

    question=re.sub(r'[^A-Za-z0-9#+.\-]+',' ',question)
    words=word_tokenize(str(question.lower()))

    #Removing all single letter and and stopwords from question exceptt for the letter 'c'
    question=' '.join(str(stemmer.stem(j)) for j in words if j not in stop_words and (len(j

    len_post+=len(question)
    tup = (question,code,tags,x,len(question),is_code)
    questions_proccesed += 1
    writer.execute("insert into QuestionsProcessed(question,code,tags,words_pre,words_post,
    if (questions_proccesed%100000==0):
        print("number of questions completed=",questions_proccesed)

no_dup_avg_len_pre=(len_pre*1.0)/questions_proccesed
no_dup_avg_len_post=(len_post*1.0)/questions_proccesed

print( "Avg. length of questions(Title+Body) before processing: %d"%no_dup_avg_len_pre)
print( "Avg. length of questions(Title+Body) after processing: %d"%no_dup_avg_len_post)
print ("Percent of questions containing code: %d"%((questions_with_code*100.0)/questions_pr

print("Time taken to run this cell :", datetime.now() - start)
```

```
number of questions completed= 100000
number of questions completed= 200000
number of questions completed= 300000
number of questions completed= 400000
number of questions completed= 500000
Avg. length of questions(Title+Body) before processing: 1239
Avg. length of questions(Title+Body) after processing: 424
Percent of questions containing code: 57
Time taken to run this cell : 0:13:05.637048
```

In [69]:

```
# never forget to close the conections or else we will end up with database locks
conn_r.commit()
conn_w.commit()
conn_r.close()
conn_w.close()
```

__ Sample quesitons after preprocessing of data __

In [70]:

```
if os.path.isfile(write_db):
    conn_r = create_connection(write_db)
    if conn_r is not None:
        reader =conn_r.cursor()
        reader.execute("SELECT question From QuestionsProcessed LIMIT 10")
        print("Questions after preprocessed")
        print('='*100)
        reader.fetchone()
        for row in reader:
            print(row)
            print('-'*100)
conn_r.commit()
conn_r.close()
```

```
Questions after preprocessed
============================================================================
========================
('dynam datagrid bind silverlight dynam datagrid bind silverlight dynam data
grid bind silverlight bind datagrid dynam code wrote code debug code block s
eem bind correct grid come column form come grid column although necessari b
ind nthank repli advance..',)
----------------------------------------------------------------------------
------------------------
('java.lang.noclassdeffounderror javax servlet jsp tagext taglibraryvalid ja
va.lang.noclassdeffounderror javax servlet jsp tagext taglibraryvalid java.l
ang.noclassdeffounderror javax servlet jsp tagext taglibraryvalid follow gui
d link instal jstl got follow error tri launch jsp page java.lang.noclassdef
founderror javax servlet jsp tagext taglibraryvalid taglib declar instal jst
l 1.1 tomcat webapp tri project work also tri version 1.2 jstl still messag
caus solv',)
----------------------------------------------------------------------------
------------------------
('java.sql.sqlexcept microsoft odbc driver manag invalid descriptor index ja
va.sql.sqlexcept microsoft odbc driver manag invalid descriptor index java.s
ql.sqlexcept microsoft odbc driver manag invalid descriptor index use follow
code display caus solv',)
----------------------------------------------------------------------------
------------------------
('better way updat feed fb php sdk better way updat feed fb php sdk better w
ay updat feed fb php sdk novic facebook api read mani tutori still confused.
i find post feed api method like correct second way use curl someth like way
better',)
----------------------------------------------------------------------------
------------------------
('btnadd click event open two window record ad btnadd click event open two w
indow record ad btnadd click event open two window record ad open window sea
rch.aspx use code hav add button search.aspx nwhen insert record btnadd clic
k event open anoth window nafter insert record close window',)
----------------------------------------------------------------------------
------------------------
('sql inject issu prevent correct form submiss php sql inject issu prevent c
orrect form submiss php sql inject issu prevent correct form submiss php che
ck everyth think make sure input field safe type sql inject good news safe b
ad news one tag mess form submiss place even touch life figur exact html use
templat file forgiv okay entir php script get execut see data post none foru
m field post problem use someth titl field none data get post current use pr
int post see submit noth work flawless statement though also mention script
work flawless local machin use host come across problem state list input tes
t mess',)
```

```
----------------------------------------------------------------------------
------------------------
('countabl subaddit lebesgu measur countabl subaddit lebesgu measur countabl
subaddit lebesgu measur let lbrace rbrace sequenc set sigma -algebra mathcal
want show left bigcup right leq sum left right countabl addit measur defin s
et sigma algebra mathcal think use monoton properti somewher proof start app
reci littl help nthank ad han answer make follow addit construct given han a
nswer clear bigcup bigcup cap emptyset neq left bigcup right left bigcup rig
ht sum left right also construct subset monoton left right leq left right fi
nal would sum leq sum result follow',)
----------------------------------------------------------------------------
------------------------
('hql equival sql queri hql equival sql queri hql equival sql queri hql quer
i replac name class properti name error occur hql error',)
----------------------------------------------------------------------------
------------------------
('undefin symbol architectur i386 objc class skpsmtpmessag referenc error un
defin symbol architectur i386 objc class skpsmtpmessag referenc error undefi
n symbol architectur i386 objc class skpsmtpmessag referenc error import fra
mework send email applic background import framework i.e skpsmtpmessag someb
odi suggest get error collect2 ld return exit status import framework correc
t sorc taken framework follow mfmailcomposeviewcontrol question lock field u
pdat answer drag drop folder project click copi nthat',)
----------------------------------------------------------------------------
------------------------
```

__ Saving Preprocessed data to a Database __

In [71]:

```
#Taking 0.5 Million entries to a dataframe.
write_db = 'Titlemoreweight.db'
if os.path.isfile(write_db):
    conn_r = create_connection(write_db)
    if conn_r is not None:
        preprocessed_data = pd.read_sql_query("""SELECT question, Tags FROM QuestionsProces
conn_r.commit()
conn_r.close()
```

In [72]:

```
preprocessed_data.head()
```

Out[72]:

	question	tags
0	dynam datagrid bind silverlight dynam datagrid...	c# silverlight data-binding
1	dynam datagrid bind silverlight dynam datagrid...	c# silverlight data-binding columns
2	java.lang.noclassdeffounderror javax servlet j...	jsp jstl
3	java.sql.sqlexcept microsoft odbc driver manag...	java jdbc
4	better way updat feed fb php sdk better way up...	facebook api facebook-php-sdk

In [73]:

```
print("number of data points in sample :", preprocessed_data.shape[0])
print("number of dimensions :", preprocessed_data.shape[1])
```

```
number of data points in sample : 500000
number of dimensions : 2
```

__ Converting string Tags to multilable output variables __

In [74]:

```
vectorizer = CountVectorizer(tokenizer = lambda x: x.split(), binary='true')
multilabel_y = vectorizer.fit_transform(preprocessed_data['tags'])
```

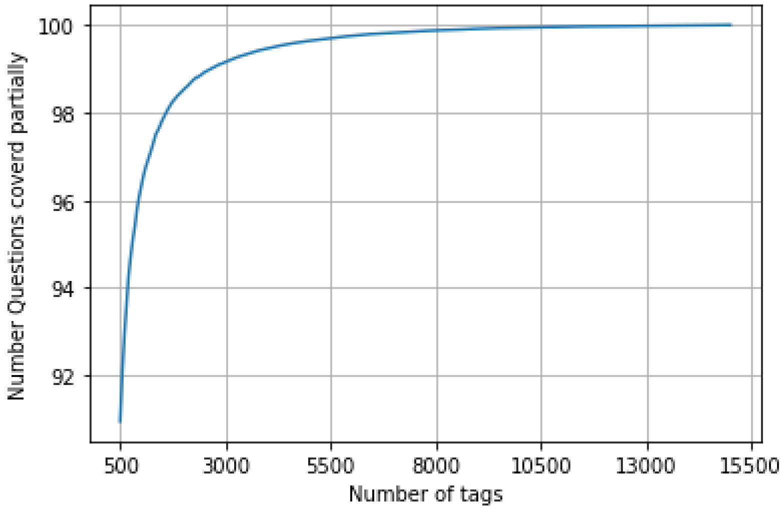
__ Selecting 500 Tags __

In [75]:

```
questions_explained = []
total_tags=multilabel_y.shape[1]
total_qs=preprocessed_data.shape[0]
for i in range(500, total_tags, 100):
    questions_explained.append(np.round(((total_qs-questions_explained_fn(i))/total_qs)*100
```

In [76]:

```
fig, ax = plt.subplots()
ax.plot(questions_explained)
xlabel = list(500+np.array(range(-50,450,50))*50)
ax.set_xticklabels(xlabel)
plt.xlabel("Number of tags")
plt.ylabel("Number Questions coverd partially")
plt.grid()
plt.show()
# you can choose any number of tags based on your computing power, minimun is 500(it covers
print("with ",5500,"tags we are covering ",questions_explained[50],"% of questions")
print("with ",500,"tags we are covering ",questions_explained[0],"% of questions")
```



```
with  5500 tags we are covering  99.157 % of questions
with  500 tags we are covering  90.956 % of questions
```

In [77]:

```
# we will be taking 500 tags
multilabel_yx = tags_to_choose(500)
print("number of questions that are not covered :", questions_explained_fn(500),"out of ",
```

```
number of questions that are not covered : 45221 out of  500000
```

In [78]:

```
x_train=preprocessed_data.head(train_datasize)
x_test=preprocessed_data.tail(preprocessed_data.shape[0] - 400000)

y_train = multilabel_yx[0:train_datasize,:]
y_test = multilabel_yx[train_datasize:preprocessed_data.shape[0],:]
```

In [79]:

```
print("Number of data points in train data :", y_train.shape)
print("Number of data points in test data :", y_test.shape)
```

```
Number of data points in train data : (400000, 500)
Number of data points in test data : (100000, 500)
```

4.5.2 Featurizing data with TfIdf vectorizer

In [80]:

```
start = datetime.now()
vectorizer = TfidfVectorizer(min_df=0.00009, max_features=200000, smooth_idf=True, norm="l2
                             tokenizer = lambda x: x.split(), sublinear_tf=False, ngram_rar
x_train_multilabel = vectorizer.fit_transform(x_train['question'])
x_test_multilabel = vectorizer.transform(x_test['question'])
print("Time taken to run this cell :", datetime.now() - start)
```

```
Time taken to run this cell : 0:03:58.877800
```

In [81]:

```
print("Dimensions of train data X:",x_train_multilabel.shape, "Y :",y_train.shape)
print("Dimensions of test data X:",x_test_multilabel.shape,"Y:",y_test.shape)
```

```
Dimensions of train data X: (400000, 94927) Y : (400000, 500)
Dimensions of test data X: (100000, 94927) Y: (100000, 500)
```

4.5.3 Applying Logistic Regression with OneVsRest Classifier

In [82]:

```
start = datetime.now()
classifier = OneVsRestClassifier(SGDClassifier(loss='log', alpha=0.00001, penalty='l1'), n_
classifier.fit(x_train_multilabel, y_train)
predictions = classifier.predict (x_test_multilabel)


print("Accuracy :",metrics.accuracy_score(y_test, predictions))
print("Hamming loss ",metrics.hamming_loss(y_test,predictions))


precision = precision_score(y_test, predictions, average='micro')
recall = recall_score(y_test, predictions, average='micro')
f1 = f1_score(y_test, predictions, average='micro')

print("Micro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision, recall, f1)

precision = precision_score(y_test, predictions, average='macro')
recall = recall_score(y_test, predictions, average='macro')
f1 = f1_score(y_test, predictions, average='macro')

print("Macro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision, recall, f1)

print (metrics.classification_report(y_test, predictions))
print("Time taken to run this cell :", datetime.now() - start)
```

```
Accuracy : 0.23614
Hamming loss  0.00278378
Micro-average quality numbers
Precision: 0.7208, Recall: 0.3251, F1-measure: 0.4481
Macro-average quality numbers
Precision: 0.5467, Recall: 0.2564, F1-measure: 0.3331
              precision    recall  f1-score   support

           0       0.94      0.64      0.76      5519
           1       0.69      0.26      0.38      8190
           2       0.81      0.38      0.52      6529
           3       0.81      0.43      0.56      3231
           4       0.81      0.41      0.54      6430
           5       0.82      0.34      0.48      2879
           6       0.87      0.50      0.63      5086
           7       0.88      0.54      0.67      4533
           8       0.60      0.13      0.22      3000
           9       0.81      0.52      0.63      2765
          10       0.59      0.16      0.25      3051
```

In [83]:

```
joblib.dump(classifier, 'saved_models/lr_with_more_title_weight.pkl')
```

Out[83]:

```
['lr_with_more_title_weight.pkl']
```

Task 1:Use bag of words upto 4 grams and compute the micro f1 score with Logistic regression(OvR)

In [85]:

```
start = datetime.now()
vectorizer = CountVectorizer(min_df=0.00009, max_features=200000, ngram_range=(1,4),tokeniz
x_train_multilabel = vectorizer.fit_transform(x_train['question'])
x_test_multilabel = vectorizer.transform(x_test['question'])
print("Time taken to run this cell :", datetime.now() - start)
```

```
Time taken to run this cell : 4:04:07.910078
```

In [86]:

```
print("Dimensions of train data X:",x_train_multilabel.shape, "Y :",y_train.shape)
print("Dimensions of test data X:",x_test_multilabel.shape,"Y:",y_test.shape)
```

```
Dimensions of train data X: (400000, 95585) Y : (400000, 500)
Dimensions of test data X: (100000, 95585) Y: (100000, 500)
```

Logistic regression (BoW (1,4) gram without hyperparameter tunning

In [87]:

```
# this will be taking so much time try not to run it, download the lr_with_equal_weight.pkl
# This takes about 6-7 hours to run.
classifier = OneVsRestClassifier(SGDClassifier(loss='log', alpha=0.00001, penalty='l1'))
classifier.fit(x_train_multilabel, y_train)
predictions = classifier.predict(x_test_multilabel)
print("Accuracy :",metrics.accuracy_score(y_test, predictions))
print("Hamming loss ",metrics.hamming_loss(y_test,predictions))


precision = precision_score(y_test, predictions, average='micro')
recall = recall_score(y_test, predictions, average='micro')
f1 = f1_score(y_test, predictions, average='micro')

print("Micro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision, recall, f1)

precision = precision_score(y_test, predictions, average='macro')
recall = recall_score(y_test, predictions, average='macro')
f1 = f1_score(y_test, predictions, average='macro')

print("Macro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision, recall, f1)

print (metrics.classification_report(y_test, predictions))
print("Time taken to run this cell :", datetime.now() - start)
```

```
         478       0.30      0.88      0.45        24
         479       0.07      0.26      0.11        92
         480       0.31      0.60      0.41       100
         481       0.26      0.49      0.33       103
         482       0.08      0.32      0.13        74
         483       0.49      0.67      0.57       105
         484       0.06      0.19      0.09        83
         485       0.03      0.11      0.04        82
         486       0.06      0.25      0.10        71
         487       0.17      0.32      0.22       120
         488       0.04      0.11      0.06       105
         489       0.21      0.52      0.29        87
         490       0.29      0.78      0.42        32
         491       0.02      0.09      0.04        69
         492       0.05      0.14      0.07        49
         493       0.04      0.15      0.07       117
         494       0.09      0.23      0.13        61
         495       0.84      0.86      0.85       344
         496       0.12      0.23      0.16        52
```

In [88]:

```
joblib.dump(classifier, 'lr_bow_without_hyp_tuned.pkl')
```

Out[88]:

```
['lr_bow_without_hyp_tuned.pkl']
```

Task2: Hyperparameter tunning (GridsearchCV)

In [123]:

```
#https://stackoverflow.com/questions/12632992/gridsearch-for-an-estimator-inside-a-onevsres
from sklearn.multiclass import OneVsRestClassifier
from sklearn.model_selection import GridSearchCV

clf = OneVsRestClassifier(SGDClassifier(loss='log',penalty='l1'))

parameters = {
    "estimator__alpha": [0.0001,0.001,0.01,0.1,1,10]
}

model_tunning = GridSearchCV(clf, param_grid=parameters)

model_tunning.fit(x_train_multilabel, y_train)
```

Out[123]:

```
GridSearchCV(cv='warn', error_score='raise-deprecating',
             estimator=OneVsRestClassifier(estimator=SGDClassifier(alpha=0.0
001,
                                                                   average=F
alse,
                                                                   class_wei
ght=None,
                                                                   early_sto
pping=False,
                                                                   epsilon=
0.1,
                                                                   eta0=0.0,
                                                                   fit_inter
cept=True,
                                                                   l1_ratio=
0.15,
                                                                   learning_
rate='optimal',
                                                                   loss='lo
g',
                                                                   max_iter=
1000,
                                                                   n_iter_no
_change=5,
                                                                   n_jobs=No
ne,
                                                                   penalty
='l1',
                                                                   power_t=
0.5,
                                                                   random_st
ate=None,
                                                                   shuffle=T
rue,
                                                                   tol=0.00
1,
                                                                   validatio
n_fraction=0.1,
                                                                   verbose=
0,
                                                                   warm_star
t=False),
                                           n_jobs=None),
             iid='warn', n_jobs=None,
             param_grid={'estimator__alpha': [0.0001, 0.001, 0.01, 0.1, 1, 1
0]},
             pre_dispatch='2*n_jobs', refit=True, return_train_score=False,
             scoring=None, verbose=0)
```

In [125]:

```
print (model_tunning.best_score_)
print (model_tunning.best_params_)
```

```
0.189835
{'estimator__alpha': 0.001}
```

In [126]:

```
classifier = OneVsRestClassifier(SGDClassifier(loss='log', alpha=0.001, penalty='l1'))
classifier.fit(x_train_multilabel, y_train)
predictions = classifier.predict(x_test_multilabel)
print("Accuracy :",metrics.accuracy_score(y_test, predictions))
print("Hamming loss ",metrics.hamming_loss(y_test,predictions))


precision = precision_score(y_test, predictions, average='micro')
recall = recall_score(y_test, predictions, average='micro')
f1 = f1_score(y_test, predictions, average='micro')

print("Micro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision, recall, f1)

precision = precision_score(y_test, predictions, average='macro')
recall = recall_score(y_test, predictions, average='macro')
f1 = f1_score(y_test, predictions, average='macro')

print("Macro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision, recall, f1)

print (metrics.classification_report(y_test, predictions))
print("Time taken to run this cell :", datetime.now() - start)
```

```
Accuracy : 0.19534
Hamming loss  0.00310584
Micro-average quality numbers
Precision: 0.6068, Recall: 0.3028, F1-measure: 0.4040
Macro-average quality numbers
Precision: 0.4187, Recall: 0.2349, F1-measure: 0.2821
              precision    recall  f1-score   support

           0       0.88      0.62      0.73      5519
           1       0.58      0.18      0.28      8190
           2       0.77      0.31      0.44      6529
           3       0.79      0.36      0.49      3231
           4       0.78      0.38      0.51      6430
           5       0.77      0.30      0.43      2879
           6       0.86      0.47      0.61      5086
           7       0.87      0.51      0.65      4533
           8       0.55      0.14      0.22      3000
           9       0.79      0.48      0.60      2765
          10       0.59      0.14      0.23      3051
          11       0.71      0.30      0.42      3000
```

In [127]:

```
joblib.dump(classifier, 'lr_bow_with_hyp_tuned.pkl')
```

Out[127]:

```
['lr_bow_with_hyp_tuned.pkl']
```

Task3:Try OneVsRestClassifier with Linear-SVM (SGDClassifier with loss-hinge)

In [128]:

```
clf = OneVsRestClassifier(SGDClassifier(loss='hinge',penalty='l1'))

parameters = {
    "estimator__alpha": [0.0001,0.001,0.01,0.1,1,10]
}

model_tunning = GridSearchCV(clf, param_grid=parameters)

model_tunning.fit(x_train_multilabel, y_train)
```

Out[128]:

```
GridSearchCV(cv='warn', error_score='raise-deprecating',
             estimator=OneVsRestClassifier(estimator=SGDClassifier(alpha=
0.0001,
                                                                   average
=False,
                                                                   class_w
eight=None,
                                                                   early_s
topping=False,
                                                                   epsilon
=0.1,
                                                                   eta0=0.
0,
                                                                   fit_int
ercept=True,
                                                                   l1_rati
o=0.15,
                                                                   learnin
g_rate='optimal',
                                                                   loss='h
inge',
                                                                   max_ite
r=1000,
                                                                   n_iter_
no_change=5,
                                                                   n_jobs=
None,
                                                                   penalty
='l1',
                                                                   power_t
=0.5,
                                                                   random_
state=None,
                                                                   shuffle
=True,
                                                                   tol=0.0
01,
                                                                   validat
ion_fraction=0.1,
                                                                   verbose
=0,
                                                                   warm_st
art=False),
                                           n_jobs=None),
             iid='warn', n_jobs=None,
             param_grid={'estimator__alpha': [0.0001, 0.001, 0.01, 0.1, 1,
10]},
             pre_dispatch='2*n_jobs', refit=True, return_train_score=Fals
e,
             scoring=None, verbose=0)
```

In [129]:

```
print (model_tunning.best_score_)
print (model_tunning.best_params_)
```

```
0.1796775
{'estimator__alpha': 0.001}
```

In [130]:

```
classifier = OneVsRestClassifier(SGDClassifier(loss='hinge', alpha=0.001, penalty='l1'))
classifier.fit(x_train_multilabel, y_train)
predictions = classifier.predict(x_test_multilabel)
print("Accuracy :",metrics.accuracy_score(y_test, predictions))
print("Hamming loss ",metrics.hamming_loss(y_test,predictions))


precision = precision_score(y_test, predictions, average='micro')
recall = recall_score(y_test, predictions, average='micro')
f1 = f1_score(y_test, predictions, average='micro')

print("Micro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision, recall, f1)

precision = precision_score(y_test, predictions, average='macro')
recall = recall_score(y_test, predictions, average='macro')
f1 = f1_score(y_test, predictions, average='macro')

print("Macro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision, recall, f1)

print (metrics.classification_report(y_test, predictions))
print("Time taken to run this cell :", datetime.now() - start)
```

```
Accuracy : 0.19507
Hamming loss  0.00310382
Micro-average quality numbers
Precision: 0.6090, Recall: 0.2994, F1-measure: 0.4014
Macro-average quality numbers
Precision: 0.3197, Recall: 0.2267, F1-measure: 0.2492
              precision    recall  f1-score   support

           0       0.84      0.63      0.72      5519
           1       0.52      0.18      0.26      8190
           2       0.80      0.30      0.44      6529
           3       0.72      0.40      0.52      3231
           4       0.83      0.32      0.46      6430
           5       0.71      0.40      0.51      2879
           6       0.79      0.54      0.64      5086
           7       0.81      0.60      0.69      4533
           8       0.52      0.18      0.27      3000
           9       0.71      0.53      0.60      2765
          10       0.32      0.01      0.02      3051
```

In [131]:

```
joblib.dump(classifier, 'lr_svm.pkl')
```

Out[131]:

```
['lr_svm.pkl']
```

Conclusion:

In [133]:

```
from prettytable import PrettyTable
t = PrettyTable()
t.field_names= ("Featurization method","Model"," Macro Averaged F1 Score","micro f1 scoore"
t.add_row(["tf-idf", "Logistic Regression",0.09,0.37, 0.0004])
t.add_row(["tf-idf", "Logistic Regression",0.33,0.44,0.002])
t.add_row(["Bow", "Logistic Regression",0.27,0.36,0.005])
t.add_row(["Bow", "Logistic Regression",0.28,0.40,0.003])
t.add_row(["Bow", "Liner SVM classifier", 0.24,0.40,0.003])
print(t.get_string(titles = "Obeservations"))
```

```
+----------------------+----------------------+--------------------------+--
---------------+--------------+
| Featurization method |        Model         |  Macro Averaged F1 Score | m
icro f1 scoore | hamming loss |
+----------------------+----------------------+--------------------------+--
---------------+--------------+
|        tf-idf        | Logistic Regression  |           0.09           |
0.37      |    0.0004    |
|        tf-idf        | Logistic Regression  |           0.33           |
0.44      |    0.002     |
|         Bow          | Logistic Regression  |           0.27           |
0.36      |    0.005     |
|         Bow          | Logistic Regression  |           0.28           |
0.4       |    0.003     |
|         Bow          | Liner SVM classifier |           0.24           |
0.4       |    0.003     |
+----------------------+----------------------+--------------------------+--
---------------+--------------+
```

Procedure:

- Load the data to the sqlite database.
- Removing the duplicates rows and loading the data in a new database.
- Analysis on tags (Frequecny of each tag).
- Text preprocessing removing HTML tags, stopwords except "c" and stemmimg.
- Finding tags the covers 99.08% questions --5500 tags.
- Applied on Models:
  M1. Logistic regression(OvR) tfidf featurization (5500 tags)

  M2. Logistic regression(OvR) tfidf featurization and (more weight to title & 5500 tags)
- Adding more weight to title and Finding tags the covers 90.0% questions-- 500 tags
- Applied on Models:
  M3. Logistic regression(OvR) BoW featurization (more weight to title & 500 tags)

M4. Logistic regression(OvR) BOW featurization with Hyperparameter tuning (more weight to title & 500 tags)

M5. Linear SVM BOW featurization with Hyperparameter tuning (more weight to title & 500 tags)

- Summerizing all the models using pretty table