Bugzilla-Severity-Detection-Research

June 4, 2018

1 Bugzilla Severity Detection

1.1 Brief introduction about bug report status

RESOLVED

```
**RESOLVED**

A resolution has been taken, and it is awaiting verification by QA.
From here bugs are either re-opened and become REOPENED, are marked
VERIFIED, or are closed for good and marked CLOSED.SED.
```

VERIFIED

```
QA has looked at the bug and the resolution and agrees that the
appropriate resolution has been taken. Bugs remain in this state
until the product they were reported against actually ships, at
which point they become CLOSED.
```

CLOSED

```
The bug is considered dead, the resolution is correct. Any zombie
bugs who choose to walk the earth again must do so by becoming
REOPENED.
```

1.2 Imports

```
In [18]: import csv
         import re
         import json
         import numpy as np
         import os
         import pandas as pd
         import sys
         import warnings
         import re
```

```
import itertools

from sklearn.manifold import *
from sklearn.svm import *
import matplotlib.pyplot as plt
from sklearn.decomposition import PCA
from gensim import *
import nltk
from sklearn.linear_model import LogisticRegression
from nltk.tokenize import *

from sklearn.neural_network import MLPClassifier

from sklearn import preprocessing
from collections import defaultdict
import matplotlib.pyplot as plt
from sklearn import svm
from sklearn.feature_extraction.text import *
from sklearn.metrics import *
from sklearn.naive_bayes import *
from sklearn.model_selection import *
%matplotlib inline
warnings.filterwarnings("ignore")
```

1.3 Retrieving data from preprocessed csv files

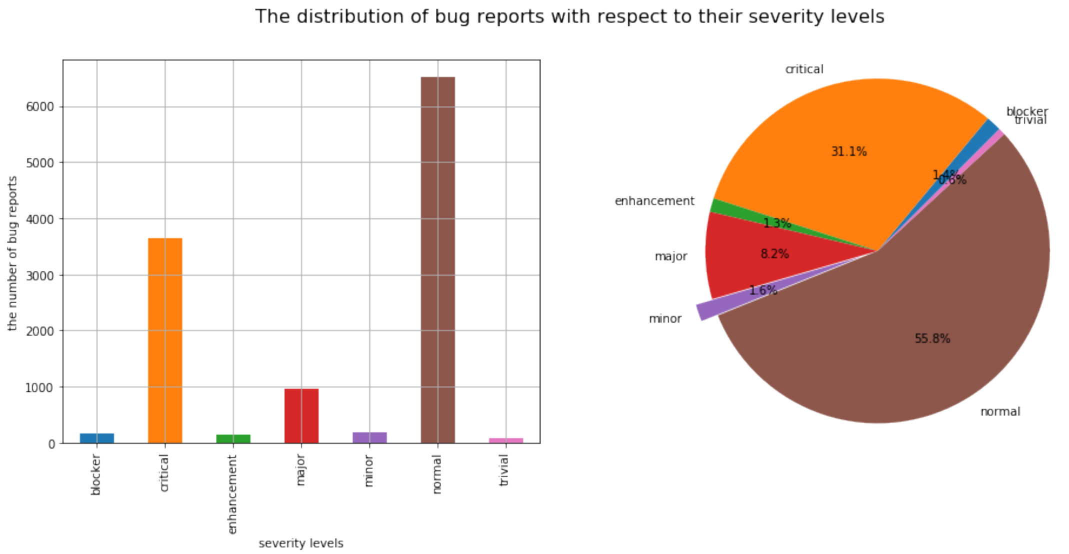
```
In [19]: verified = pd.read_csv('summaryList.csv', error_bad_lines=False, quotechar="'", encodin
         print("Total number of sentences: ", verified.size)
         verified.head(5)
```

```
Total number of sentences:  58430
```

```
Out[19]:                                              summary     severity    status  \
         0  [regression] all font-weight are displayed as ...       normal  VERIFIED
         1  getter/setter bytecodes assume number of atoms...       normal  VERIFIED
         2  JS_Assert(char * s = 0x1012279c "!flbase[flind...     critical  VERIFIED
         3  [FIX]Combobox popups don't have the width of t...        minor  VERIFIED
         4  Add a strict warning for when an object litera...  enhancement  VERIFIED

                    assigned_to  bug_id
         0  masayuki@d-toybox.com  365613
         1          igor@mir2.org  365692
         2        general@js.bugs  365716
         3       bzbarsky@mit.edu  365837
         4     mrbkap@mozilla.com  365869
```

1.4 Multiclass text classification using tf-idf scores of documents

In [20]:
```
severity_count = verified.groupby(['severity']).size()  # returns a series object
total = severity_count.sum()
severity_percentage = severity_count / total * 100
fig, axes = plt.subplots(nrows=1, ncols=2, figsize=(16, 6))
explode = ( 0,0,0,0,0.1, 0, 0)

ax1 = severity_count.plot("bar", ax=axes[0])
ax1.set_ylabel("the number of bug reports")
ax1.set_xlabel("severity levels")
ax1.grid(True)

ax2 = severity_percentage.plot("pie", ax=axes[1], explode=explode, autopct='%1.1f%%', s
ax2.set_ylabel("")
ax2.axis("equal")

plt.suptitle('The distribution of bug reports with respect to their severity levels', f
plt.show()
```



In [21]:
```
summaries = [verified.values[id][0] for id in range(len(verified.values))]
severities = [verified.values[id][1] for id in range(len(verified.values))]
```

In [22]:
```
def clean_str(string):
    """
    Tokenization/string cleaning for all datasets except for SST.
    Original taken from https://github.com/yoonkim/CNN_sentence/blob/master/process_dat
    """
    string = re.sub(r"[^A-Za-z0-9(),!?\'\`]", " ", string)
```

```
            string = re.sub(r"\'s", " \'s", string)
            string = re.sub(r"\'ve", " \'ve", string)
            string = re.sub(r"n\'t", " n\'t", string)
            string = re.sub(r"\'re", " \'re", string)
            string = re.sub(r"\'d", " \'d", string)
            string = re.sub(r"\'ll", " \'ll", string)
            string = re.sub(r",", " , ", string)
            string = re.sub(r"!", " ! ", string)
            string = re.sub(r"\(", " \( ", string)
            string = re.sub(r"\)", " \) ", string)
            string = re.sub(r"\?", " \? ", string)
            string = re.sub(r"\s{2,}", " ", string)
            return string.strip().lower()
        tokenized = [clean_str(s).split() for s in summaries]
```

```
In [23]: vectorizer = TfidfVectorizer(analyzer='word',tokenizer=word_tokenize, stop_words='engli
         tvec_weights = vectorizer.fit_transform(summaries)
         X = tvec_weights.todense()
         Y = np.asarray(severities)
```

```
In [24]: X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.1)
```

1.4.1 Multinomial Naive Bayes

```
In [25]: MultiNB = MultinomialNB()
         MultiNB.fit(X_train, Y_train)

         scores = cross_val_score(MultiNB, X_test, Y_test, cv=5, n_jobs=-1)

         print(MultiNB)
         print("Accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std() * 2))
```

```
MultinomialNB(alpha=1.0, class_prior=None, fit_prior=True)
Accuracy: 0.73 (+/- 0.04)
```

```
In [26]: Y_expect = Y_test
         Y_predict = MultiNB.predict(X_test)
         print("Accuracy: %4.2f " % (accuracy_score(Y_expect, Y_predict)))
         print(confusion_matrix(Y_expect, Y_predict))
         print(recall_score(Y_expect, Y_predict, average=None))
         print(precision_score(Y_expect, Y_predict,average=None))
```

```
Accuracy: 0.75
[[  0   7   0   0   0  15   0]
 [  0 265   0   0   0  96   0]
 [  0   0   0   0   0  20   0]
 [  0   7   0   0   0  85   0]
 [  0   1   0   0   0  20   0]
```

```
 [  0  36   0   0   0 612   0]
 [  0   0   0   0   0   5   0]]
[ 0.    0.73  0.    0.    0.    0.94  0.  ]
[ 0.    0.84  0.    0.    0.    0.72  0.  ]
```

1.4.2 Linear SVM

```
In [27]: lsvm = LinearSVC(dual=False, max_iter=10000)
         lsvm.fit(X_train, Y_train)

         scores = cross_val_score(lsvm, X_test, Y_test, cv=5, n_jobs=-1)

         print(lsvm)
         print("Accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std() * 2))
         print(scores)
```

```
LinearSVC(C=1.0, class_weight=None, dual=False, fit_intercept=True,
     intercept_scaling=1, loss='squared_hinge', max_iter=10000,
     multi_class='ovr', penalty='l2', random_state=None, tol=0.0001,
     verbose=0)
Accuracy: 0.76 (+/- 0.04)
[ 0.79  0.74  0.76  0.76  0.77]
```

```
In [28]: Y_expect = Y_test
         Y_predict = lsvm.predict(X_test)
         print("Accuracy: %4.2f" % (accuracy_score(Y_expect, Y_predict)))
         print(confusion_matrix(Y_expect, Y_predict))
         print(recall_score(Y_expect, Y_predict, average=None))
         print(precision_score(Y_expect, Y_predict,average=None))
```

```
Accuracy: 0.77
[[  1   7   0   2   0  12   0]
 [  0 290   0   1   0  70   0]
 [  0   0   0   0   0  20   0]
 [  0  11   0   6   0  75   0]
 [  0   1   0   0   0  19   1]
 [  0  36   3   9   0 600   0]
 [  0   0   0   0   0   4   1]]
[ 0.05  0.8   0.    0.07  0.    0.93  0.2 ]
[ 1.    0.84  0.    0.33  0.    0.75  0.5 ]
```

1.5 Classification among severe class

```
In [29]: df3 = verified.copy()
         sev = ['major', 'critical', 'blocker']
         df3 = df3.loc[df3['severity'].isin(sev)]
```

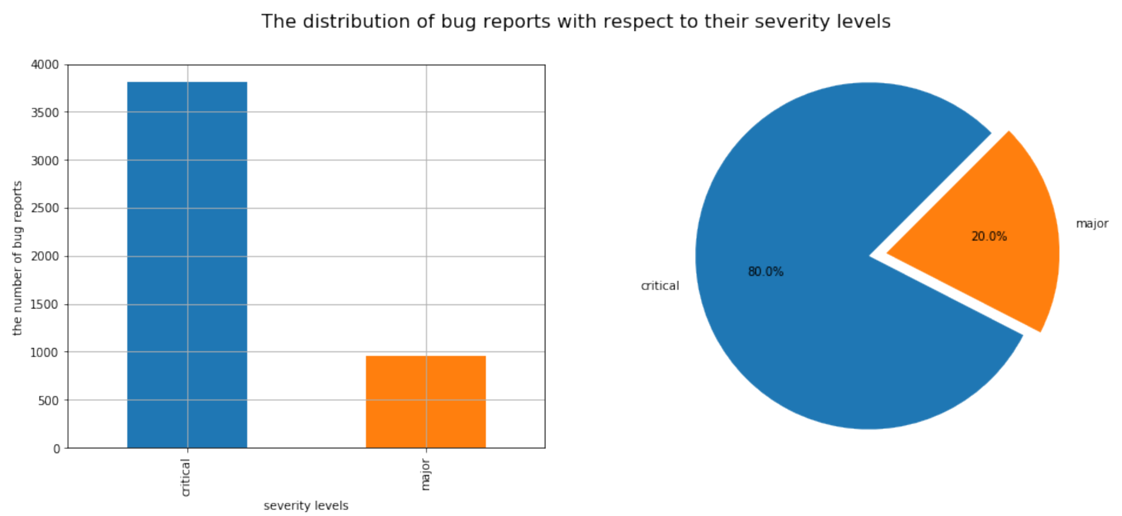
```
df3.loc[df3.severity == 'blocker', 'severity'] = "critical"
df3.head(5)
```

Out[29]:

```
                                              summary  severity    status  \
2    JS_Assert(char * s = 0x1012279c "!flbase[flind...  critical  VERIFIED
9                             large script miscompiles  critical  VERIFIED
10        compiling long XML filtering predicate hangs  critical  VERIFIED
15   Any use of setter functions causes an assertio...  critical  VERIFIED
17   [reflow branch] Crash [@ PresShell::ProcessRef...  critical  VERIFIED

             assigned_to  bug_id
2        general@js.bugs  365716
9          igor@mir2.org  366122
10         igor@mir2.org  366123
15   brendan@mozilla.org  366288
17     mats@mozilla.com   366320
```

In [30]:

```
severity_count = df3.groupby(['severity']).size()  # returns a series object
total = severity_count.sum()
severity_percentage = severity_count / total * 100
fig, axes = plt.subplots(nrows=1, ncols=2, figsize=(16, 6))
explode = (0.1, 0)

ax1 = severity_count.plot("bar", ax=axes[0])
ax1.set_ylabel("the number of bug reports")
ax1.set_xlabel("severity levels")
ax1.grid(True)

ax2 = severity_percentage.plot("pie", ax=axes[1], explode=explode, autopct='%1.1f%%', s
ax2.set_ylabel("")
ax2.axis("equal")

plt.suptitle('The distribution of bug reports with respect to their severity levels', f
plt.show()
```



```
In [31]: summaries = [df3.values[id][0] for id in range(len(df3.values))]
         severities = [df3.values[id][1] for id in range(len(df3.values))]

In [32]: vectorizer = TfidfVectorizer(analyzer='word',tokenizer=word_tokenize, stop_words='engli
         tvec_weights = vectorizer.fit_transform(summaries)
         X = tvec_weights.todense()
         Y = np.asarray(severities)
         X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.1)

In [33]: MultiNB = MultinomialNB()
         MultiNB.fit(X_train, Y_train)

         scores = cross_val_score(MultiNB, X_test, Y_test, cv=5, n_jobs=-1)

         print(MultiNB)
         print("Accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std() * 2))

         Y_expect = Y_test
         Y_predict = MultiNB.predict(X_test)
         print("Accuracy: %4.2f " % (accuracy_score(Y_expect, Y_predict)))
         print(confusion_matrix(Y_expect, Y_predict))
         print(recall_score(Y_expect, Y_predict, average=None))
         print(precision_score(Y_expect, Y_predict,average=None))

MultinomialNB(alpha=1.0, class_prior=None, fit_prior=True)
Accuracy: 0.82 (+/- 0.01)
Accuracy: 0.85
[[389   3]
 [ 69  15]]
[ 0.99  0.18]
[ 0.85  0.83]


In [34]: lsvm = LinearSVC(dual=False, max_iter=10000)
         lsvm.fit(X_train, Y_train)

         scores = cross_val_score(lsvm, X_test, Y_test, cv=5, n_jobs=-1)

         print(lsvm)
         print("Accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std() * 2))
         print(scores)

         Y_expect = Y_test
         Y_predict = lsvm.predict(X_test)
         print("Accuracy: %4.2f" % (accuracy_score(Y_expect, Y_predict)))
         print(confusion_matrix(Y_expect, Y_predict))
```

```
        print(recall_score(Y_expect, Y_predict, average=None))
        print(precision_score(Y_expect, Y_predict,average=None))
```

```
LinearSVC(C=1.0, class_weight=None, dual=False, fit_intercept=True,
     intercept_scaling=1, loss='squared_hinge', max_iter=10000,
     multi_class='ovr', penalty='l2', random_state=None, tol=0.0001,
     verbose=0)
Accuracy: 0.84 (+/- 0.04)
[ 0.83  0.82  0.85  0.83  0.87]
Accuracy: 0.89
[[369  23]
 [ 31  53]]
[ 0.94  0.63]
[ 0.92  0.7 ]
```

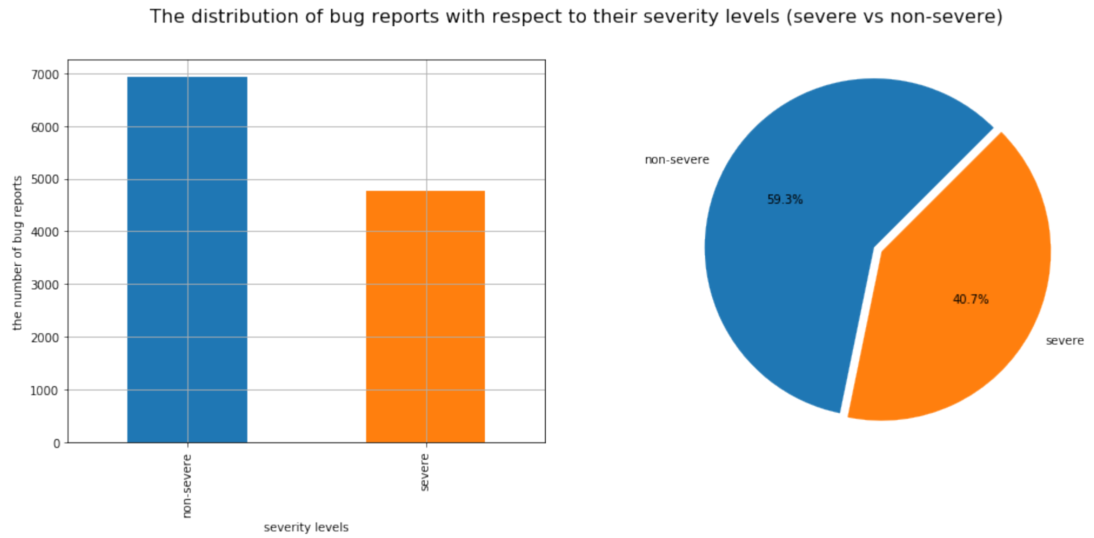
1.6 Binary class text classification using tf-idf scores of documents

```
In [35]: df1 = verified.copy()

         df1.loc[df1.severity == 'blocker', 'severity'] = "severe"
         df1.loc[df1.severity == 'critical', 'severity'] = "severe"
         df1.loc[df1.severity == 'major', 'severity'] = "severe"

         df1.loc[df1.severity == 'normal', 'severity'] = "non-severe"
         df1.loc[df1.severity == 'minor', 'severity'] = "non-severe"
         df1.loc[df1.severity == 'enhancement', 'severity'] = "non-severe"
         df1.loc[df1.severity == 'trivial', 'severity'] = "non-severe"

         df1.head()
```

```
Out[35]:                                              summary    severity    status  \
         0  [regression] all font-weight are displayed as ...  non-severe  VERIFIED
         1  getter/setter bytecodes assume number of atoms...  non-severe  VERIFIED
         2  JS_Assert(char * s = 0x1012279c "!flbase[flind...      severe  VERIFIED
         3  [FIX]Combobox popups don't have the width of t...  non-severe  VERIFIED
         4  Add a strict warning for when an object litera...  non-severe  VERIFIED

                   assigned_to  bug_id
         0  masayuki@d-toybox.com  365613
         1          igor@mir2.org  365692
         2        general@js.bugs  365716
         3       bzbarsky@mit.edu  365837
         4     mrbkap@mozilla.com  365869
```

```
In [36]: severity_count = df1.groupby(['severity']).size()  # returns a series object
         total = severity_count.sum()
         severity_percentage = severity_count / total * 100
         fig, axes = plt.subplots(nrows=1, ncols=2, figsize=(16, 6))
```

```
explode = (0, 0.05,)

ax1 = severity_count.plot("bar", ax=axes[0])
ax1.set_ylabel("the number of bug reports")
ax1.set_xlabel("severity levels")
ax1.grid(True)

ax2 = severity_percentage.plot("pie", ax=axes[1], explode=explode, autopct='%1.1f%%', s
ax2.set_ylabel("")
ax2.axis("equal")

plt.suptitle('The distribution of bug reports with respect to their severity levels (se
             fontsize=16)
plt.show()
```




```
In [37]: summaries = [df1.values[id][0] for id in range(len(df1.values))]
         severities = [df1.values[id][1] for id in range(len(df1.values))]

In [38]: vectorizer = TfidfVectorizer(analyzer='word',tokenizer=word_tokenize, stop_words='engli
         tvec_weights = vectorizer.fit_transform(summaries)
         X = tvec_weights.todense()
         Y = np.asarray(severities)

In [39]: X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.1)
```

1.6.1 Multinomial Naive Bayes

```
In [40]: X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.1)
         MultiNB = MultinomialNB()
         MultiNB.fit(X_train, Y_train)
```

```
scores = cross_val_score(MultiNB, X_test, Y_test, cv=5, n_jobs=-1)

print(MultiNB)
print("Accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std() * 2))
```

```
MultinomialNB(alpha=1.0, class_prior=None, fit_prior=True)
Accuracy: 0.81 (+/- 0.05)
```

```
In [41]: X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.1)
         MultiNB = MultinomialNB()
         MultiNB.fit(X_train, Y_train)

         scores = cross_val_score(MultiNB, X_test, Y_test, cv=5, n_jobs=-1)

         print(MultiNB)
         print("Accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std() * 2))
         Y_expect = Y_test
         Y_predict = MultiNB.predict(X_test)
         print("Accuracy: %4.2f " % (accuracy_score(Y_expect, Y_predict)))
         print(confusion_matrix(Y_expect, Y_predict))
         print(recall_score(Y_expect, Y_predict, average=None))
         print(precision_score(Y_expect, Y_predict,average=None))
```

```
MultinomialNB(alpha=1.0, class_prior=None, fit_prior=True)
Accuracy: 0.82 (+/- 0.06)
Accuracy: 0.83
[[652  30]
 [164 323]]
[ 0.96  0.66]
[ 0.8   0.92]
```

```
In [49]: class_names = ["non-severe", "severe"]
```

1.6.2 Linear SVM

```
In [50]: lsvm = LinearSVC(dual=False)
         lsvm.fit(X_train, Y_train)

         scores = cross_val_score(lsvm, X_test, Y_test, cv=10, n_jobs=-1)

         print(lsvm)
         print("Accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std() * 2))
```

```
LinearSVC(C=1.0, class_weight=None, dual=False, fit_intercept=True,
     intercept_scaling=1, loss='squared_hinge', max_iter=1000,
     multi_class='ovr', penalty='l2', random_state=None, tol=0.0001,
```

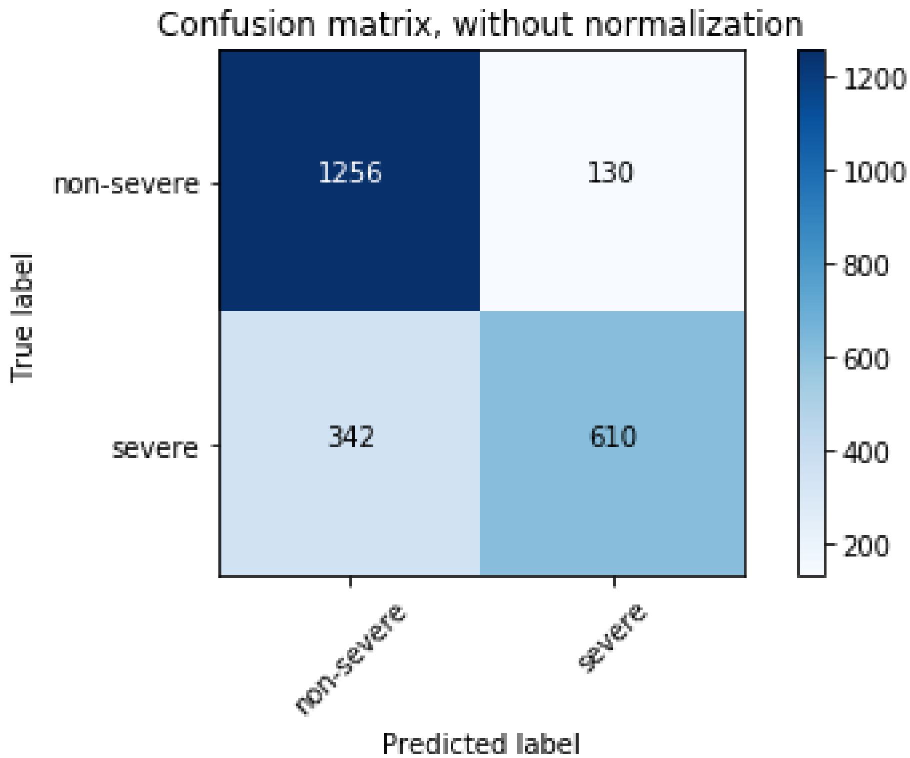
```
     verbose=0)
Accuracy: 0.84 (+/- 0.08)
```

```
In [51]: Y_expect = Y_test
         Y_predict = lsvm.predict(X_test)
         print("Accuracy: %4.2f" % (accuracy_score(Y_expect, Y_predict)))
         print(confusion_matrix(Y_expect, Y_predict))
         print(recall_score(Y_expect, Y_predict, average=None))
         print(precision_score(Y_expect, Y_predict,average=None))
```

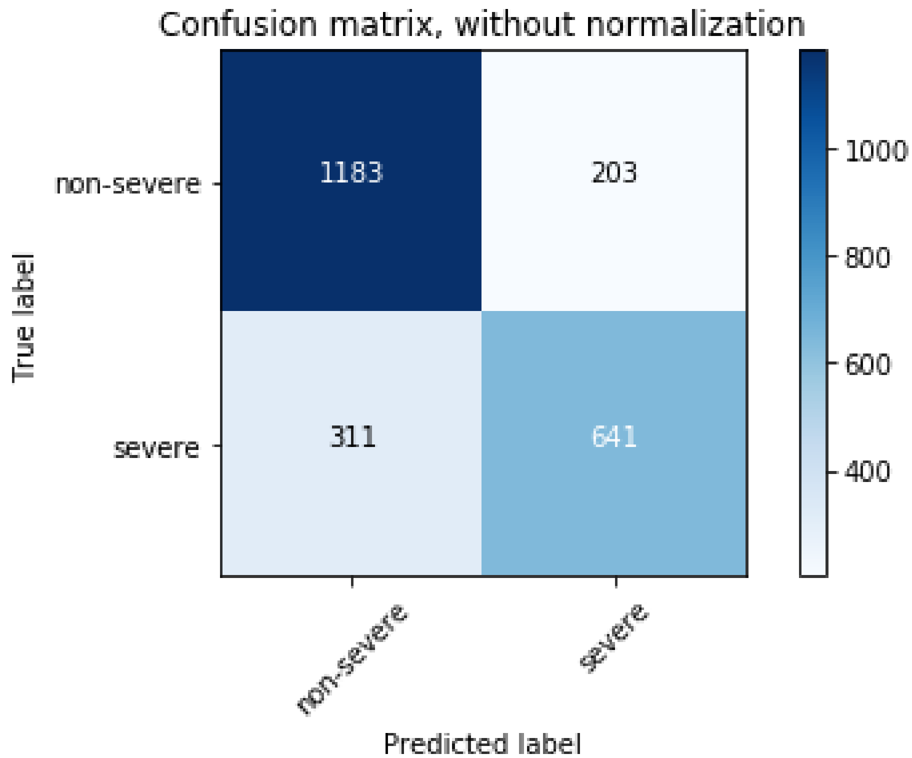
```
Accuracy: 0.83
[[627  55]
 [141 346]]
[ 0.92  0.71]
[ 0.82  0.86]
```

```
In [52]: skf = StratifiedKFold(n_splits=5)
         count=0
         total_acc = 0
         M = X
         y = Y

         for train_index, test_index in skf.split(M,y):
             count +=1
             x_train, x_test = M[train_index], M[test_index]
             y_train, y_test = y[train_index], y[test_index]
             lsvm.fit(x_train, y_train)
             y_predict = lsvm.predict(x_test)
             total_acc += accuracy_score(y_test, y_predict)

             # Compute confusion matrix
             cnf_matrix = confusion_matrix(y_test, y_predict)
             np.set_printoptions(precision=2)

             # Plot non-normalized confusion matrix
             plt.figure()
             plot_confusion_matrix(cnf_matrix, classes=class_names,
                                   title='Confusion matrix, without normalization')

             plt.show()

         print("Average accuracy: ", total_acc/count)
```

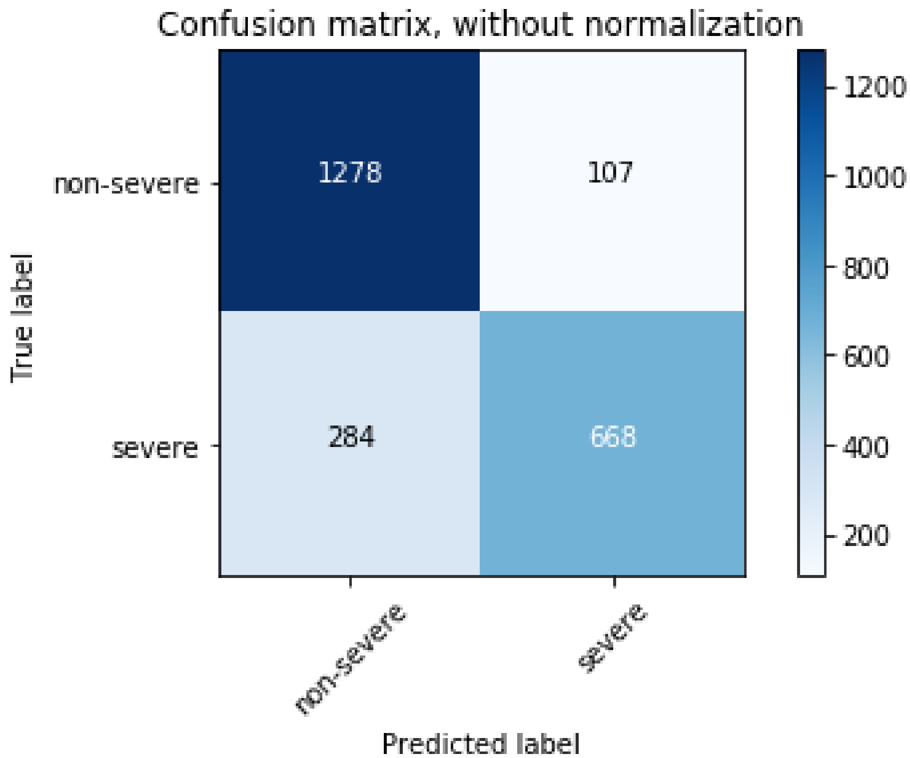
```
Confusion matrix, without normalization
[[1256  130]
 [ 342  610]]
```



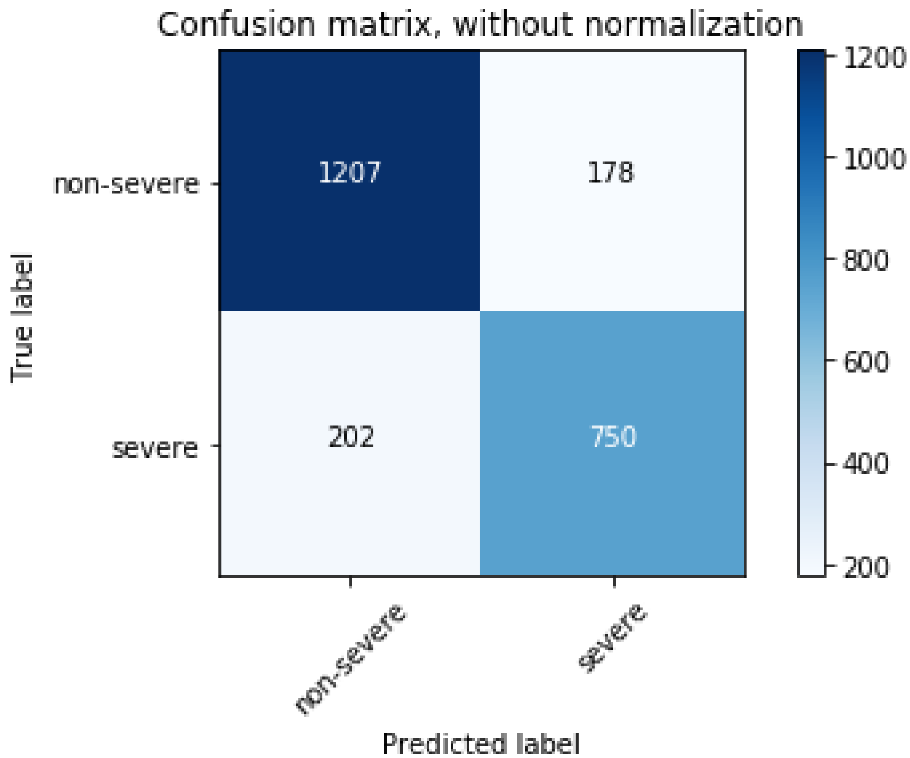

```
Confusion matrix, without normalization
[[1183  203]
 [ 311  641]]
```



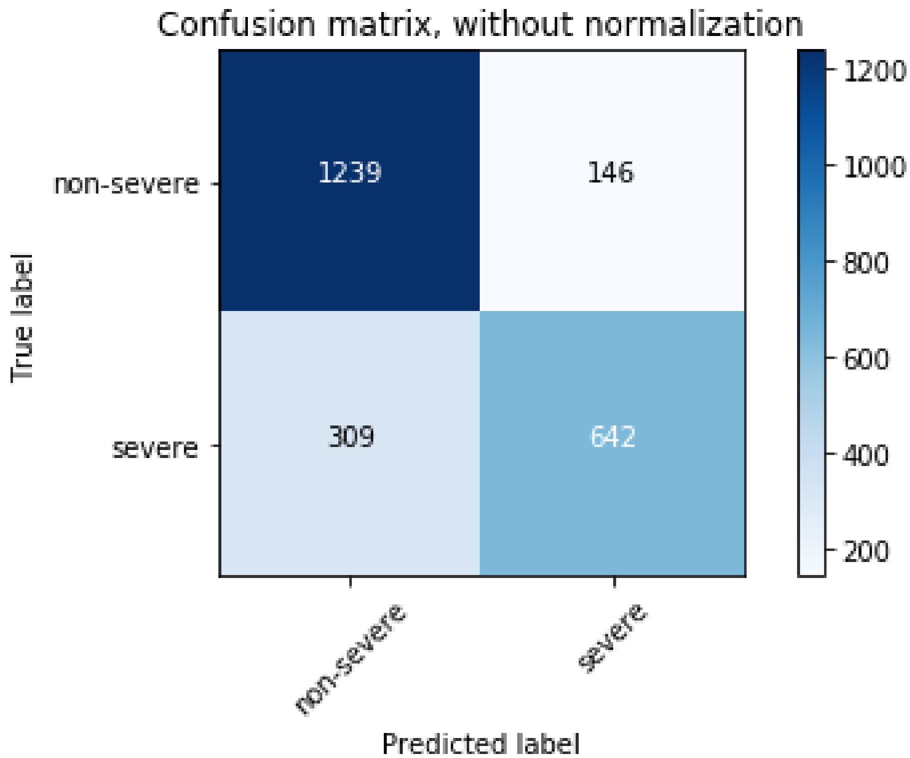

```
Confusion matrix, without normalization
[[1278  107]
 [ 284  668]]
```




```
Confusion matrix, without normalization
[[1207  178]
 [ 202  750]]
```




```
Confusion matrix, without normalization
[[1239  146]
 [ 309  642]]
```




```
Average accuracy:  0.810716897781
```

```
In [53]: scores
```

```
Out[53]: array([ 0.81,  0.8 ,  0.82,  0.84,  0.85,  0.83,  0.87,  0.91,  0.87,  0.77])
```

1.6.3 Logistic Regression

```
In [54]: lr = LogisticRegression(dual=False)
         lr.fit(X_train, Y_train)

         scores = cross_val_score(lr, X_test, Y_test, cv=5, n_jobs=-1)

         print(lr)
         print("Accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std() * 2))
```

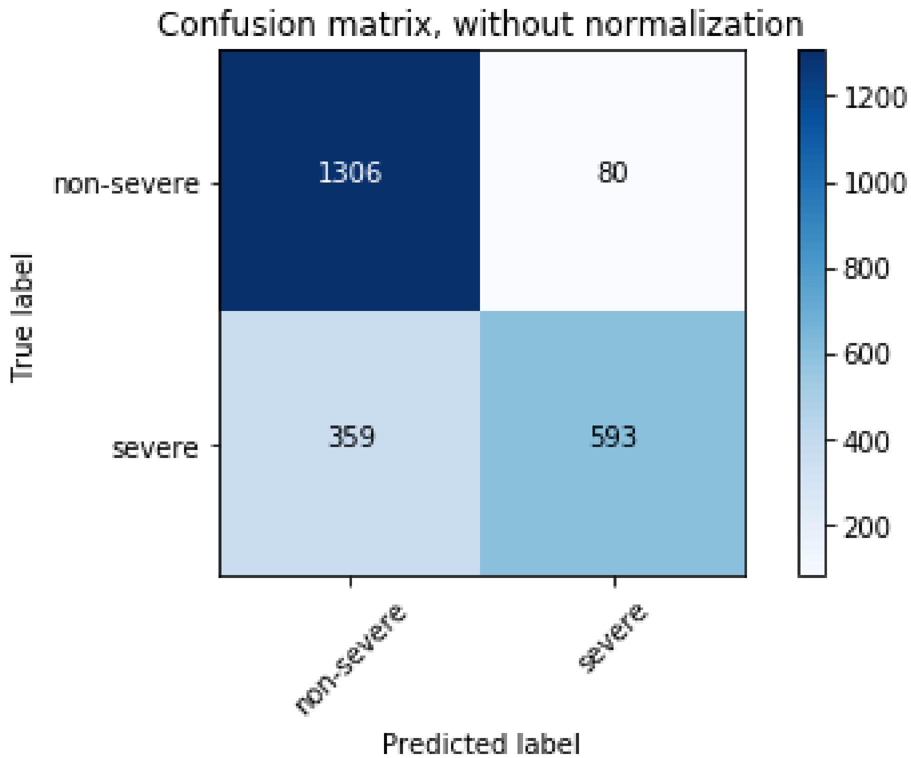
```
LogisticRegression(C=1.0, class_weight=None, dual=False, fit_intercept=True,
          intercept_scaling=1, max_iter=100, multi_class='ovr', n_jobs=1,
          penalty='l2', random_state=None, solver='liblinear', tol=0.0001,
          verbose=0, warm_start=False)
Accuracy: 0.82 (+/- 0.06)
```

In [55]:
```
Y_expect = Y_test
Y_predict = lr.predict(X_test)
print("Accuracy: %4.2f" % (accuracy_score(Y_expect, Y_predict)))
print(confusion_matrix(Y_expect, Y_predict))
print(recall_score(Y_expect, Y_predict, average=None))
print(precision_score(Y_expect, Y_predict,average=None))
```

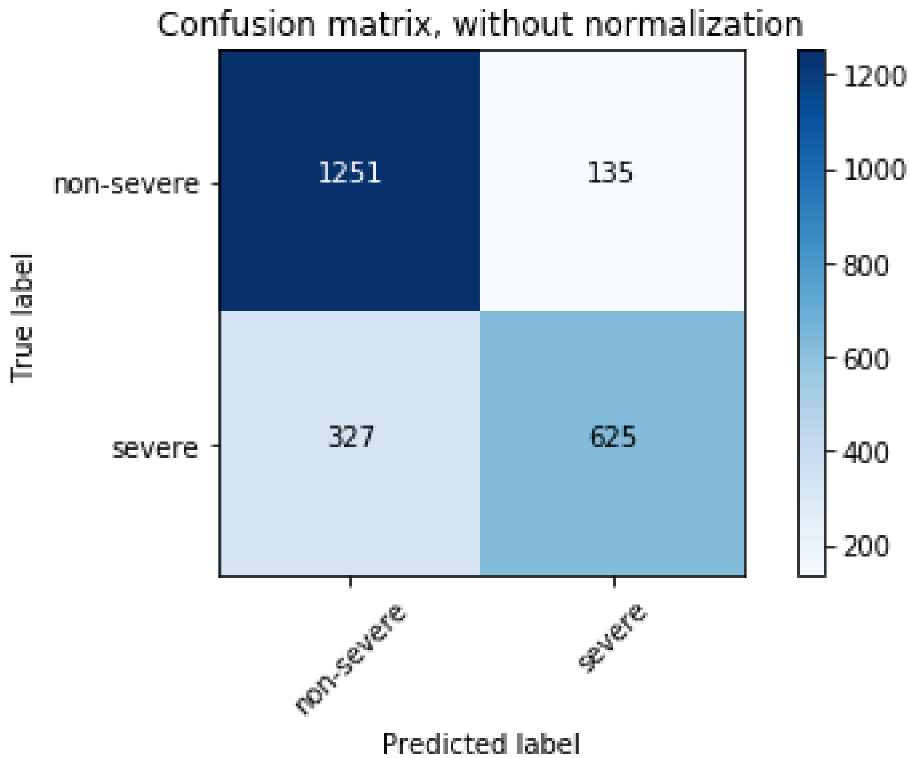
```
Accuracy: 0.85
[[649  33]
 [148 339]]
[ 0.95  0.7 ]
[ 0.81  0.91]
```

In [56]:
```
skf = StratifiedKFold(n_splits=5)
count=0
total_acc = 0
M = X
y = Y

for train_index, test_index in skf.split(M,y):
    count +=1
    x_train, x_test = M[train_index], M[test_index]
    y_train, y_test = y[train_index], y[test_index]
    lr.fit(x_train, y_train)
    y_predict = lr.predict(x_test)
    total_acc += accuracy_score(y_test, y_predict)

    # Compute confusion matrix
    cnf_matrix = confusion_matrix(y_test, y_predict)
    np.set_printoptions(precision=2)

    # Plot non-normalized confusion matrix
    plt.figure()
    plot_confusion_matrix(cnf_matrix, classes=class_names,
                          title='Confusion matrix, without normalization')

    plt.show()

print("Average accuracy: ", total_acc/count)
```

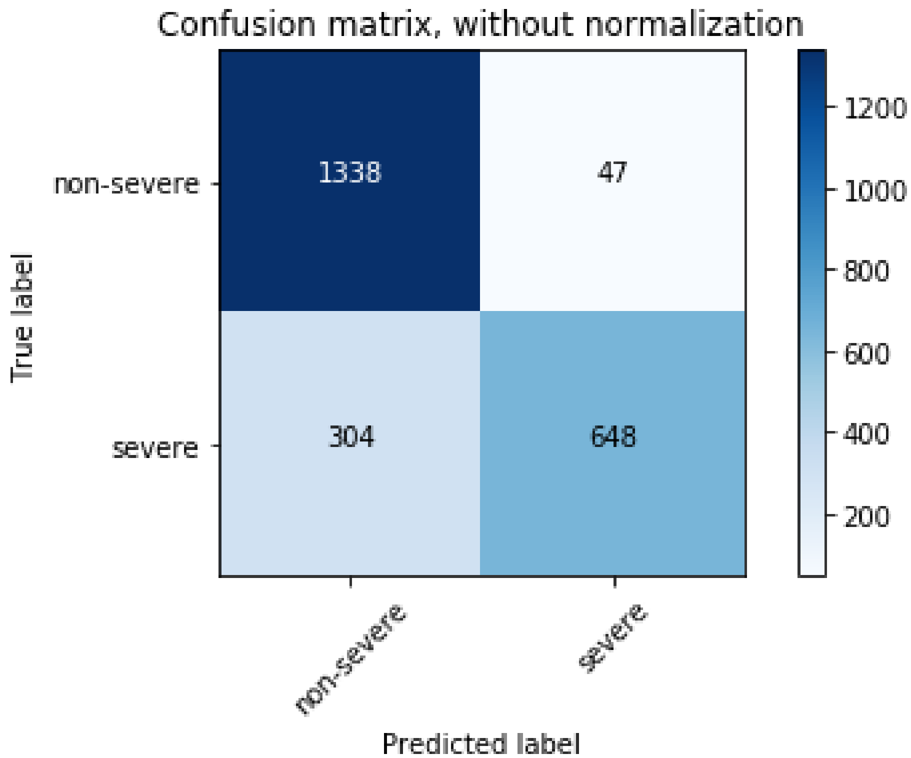
```
Confusion matrix, without normalization
[[1306   80]
 [ 359  593]]
```



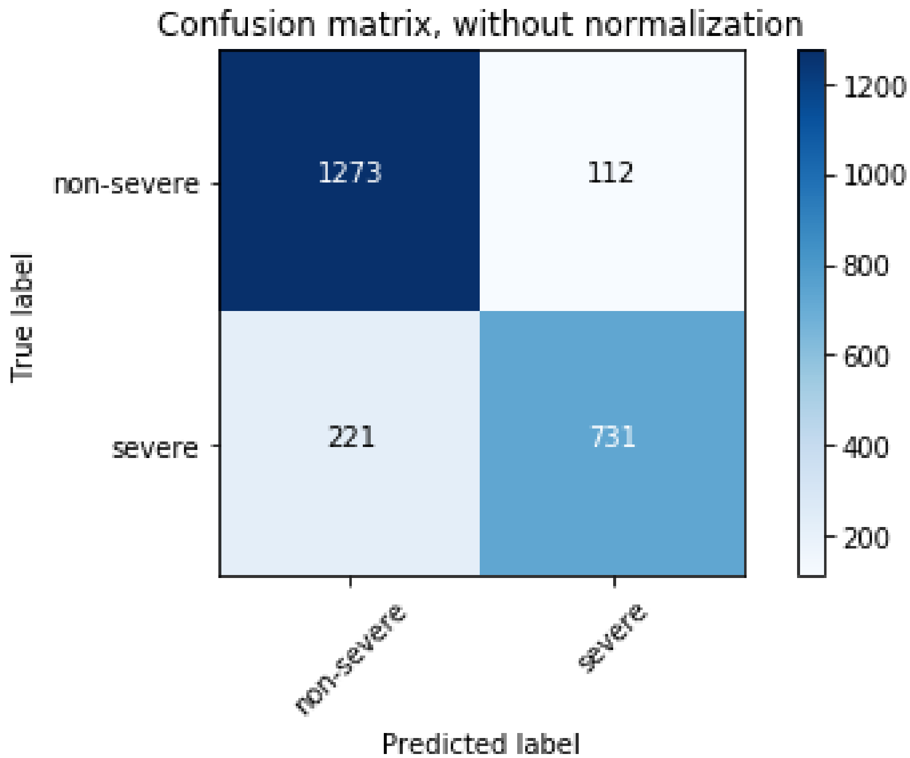

```
Confusion matrix, without normalization
[[1251  135]
 [ 327  625]]
```



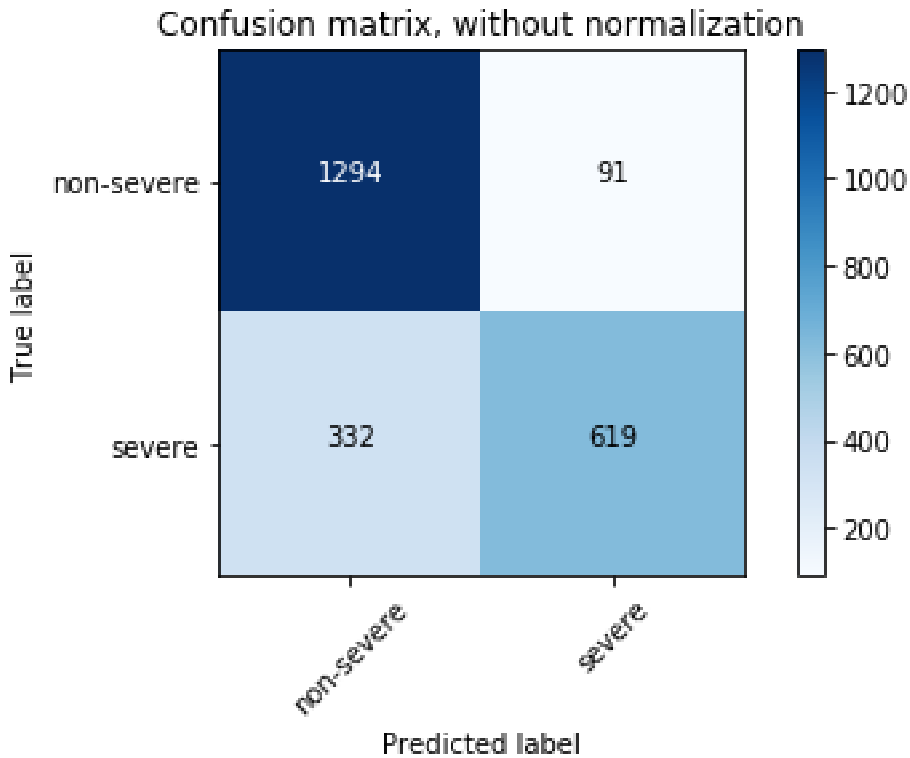

```
Confusion matrix, without normalization
[[1338   47]
 [ 304  648]]
```




```
Confusion matrix, without normalization
[[1273  112]
 [ 221  731]]
```




```
Confusion matrix, without normalization
[[1294   91]
 [ 332  619]]
```




```
Average accuracy:  0.828173238626
```

1.7 Feature extraction using gensim

```
In [ ]: def clean_str(string):
            """
            Tokenization/string cleaning for all datasets except for SST.
            Original taken from https://github.com/yoonkim/CNN_sentence/blob/master/process_data
            """
            string = re.sub(r"[^A-Za-z0-9(),!?\'\`]", " ", string)
            string = re.sub(r"\'s", " \'s", string)
            string = re.sub(r"\'ve", " \'ve", string)
            string = re.sub(r"n\'t", " n\'t", string)
            string = re.sub(r"\'re", " \'re", string)
            string = re.sub(r"\'d", " \'d", string)
            string = re.sub(r"\'ll", " \'ll", string)
            string = re.sub(r",", " , ", string)
            string = re.sub(r"!", " ! ", string)
            string = re.sub(r"\(", " \( ", string)
            string = re.sub(r"\)", " \) ", string)
            string = re.sub(r"\?", " \? ", string)
```

```
    string = re.sub(r"\s{2,}", " ", string)
    return string.strip().lower()
```

```
In [ ]: class MeanEmbeddingVectorizer(object):
            def __init__(self, word2vec):
                self.word2vec = word2vec
                # if a text is empty we should return a vector of zeros
                # with the same dimensionality as all the other vectors

            def fit(self, X, y):
                return self

            def transform(self, X):
                """
                This method sums all wordvecs of all words in a sentences
                and divides the resulting vector by the len of word count in the sentence
                """
                return np.array([np.sum([self.word2vec[w] for w in words if w in self.word2vec]
                                        [np.zeros(100)], axis=0) / len(words) for words in X ])
```

```
In [ ]: sentences = [clean_str(s).split(" ") for s in summaries]
        severities = [df1.values[id][1] for id in range(len(df1.values))]

        model = models.Word2Vec(sentences, size=100, workers=-1, iter=1000)
        words = list(model.wv.vocab)
        model.wv.save_word2vec_format('model.bin')
        # model = models.Word2Vec.load('model.bin')
```

```
In [ ]: w2v = dict(zip(model.wv.index2word, model.wv.syn0))
        mev = MeanEmbeddingVectorizer(w2v)
        vec_weights = mev.transform(sentences)
```

```
In [ ]: X_train, X_test, Y_train, Y_test = train_test_split(vec_weights, severities, test_size=0
```

```
In [ ]: X_train.shape
```

1.7.1 Linear SVM

```
In [ ]: lsvm = LinearSVC()
        lsvm.fit(X_train, Y_train)

        scores = cross_val_score(lsvm, X_test, Y_test, cv=5, n_jobs=-1)

        print(lsvm)
        print("Accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std() * 2))
```

```
In [ ]: Y_expect = Y_test
        Y_predict = lsvm.predict(X_test)
        print("Accuracy: %4.2f" % (accuracy_score(Y_expect, Y_predict)))
```

```
print(confusion_matrix(Y_expect, Y_predict))
print(recall_score(Y_expect, Y_predict, average=None))
print(precision_score(Y_expect, Y_predict,average=None))
```

1.7.2 Logistic Regression

```
In [ ]: lr = LogisticRegression(dual=False)
        lr.fit(X_train, Y_train)

        scores = cross_val_score(lr, X_test, Y_test, cv=5, n_jobs=-1)

        print(lr)
        print("Accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std() * 2))
```

```
In [ ]: Y_expect = Y_test
        Y_predict = lr.predict(X_test)
        print("Accuracy: %4.2f" % (accuracy_score(Y_expect, Y_predict)))
        print(confusion_matrix(Y_expect, Y_predict))
        print(recall_score(Y_expect, Y_predict, average=None))
        print(precision_score(Y_expect, Y_predict,average=None))
```

```
In [ ]: le = preprocessing.LabelEncoder()
        y = le.fit_transform(Y_train)

        pca = PCA(n_components=2)
        X_r = pca.fit(X_train).transform(X_train)
        plt.figure()
        colors = ['red', 'yellow']
        lw = 2
        target_names = np.array(["non-severe", "severe"])
        for color, i, target_name in zip(colors, [0, 1], target_names):
            plt.scatter(X_r[y == i, 0], X_r[y == i, 1], color=color, alpha=.8, lw=lw, label=targ
        plt.legend(loc='best', shadow=False, scatterpoints=1)
        plt.title('PCA of features')

        plt.show()
```

1.8 Iteratively checking every classes

```
In [ ]: def check_iteratively(class1, class2):
            df4 = df.copy()
        #     df4 = pd.read_csv('summaryListResolved.csv', error_bad_lines=False, quotechar="'",
            df4 = df4.loc[(df4['severity'] == class1) | (df4['severity'] == class2)]
            print(class1.upper() + ' + ' + class2.upper())
            print("**************************")
            print(df4.groupby(['severity']).size())

            summaries = [df4.values[id][0] for id in range(len(df4.values))]
            severities = [df4.values[id][1] for id in range(len(df4.values))]
```

```
        vectorizer = TfidfVectorizer(analyzer='word',tokenizer=word_tokenize, stop_words='en
        tvec_weights = vectorizer.fit_transform(summaries)
        X = tvec_weights.todense()
        Y = np.asarray(severities)
        X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.1)

        lsvm = LinearSVC(dual=False, max_iter=10000)
        lsvm.fit(X_train, Y_train)

        scores = cross_val_score(lsvm, X_test, Y_test, cv=5, n_jobs=-1)

        print(lsvm)
        print("Accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std() * 2))
        print(scores)
        Y_expect = Y_test
        Y_predict = lsvm.predict(X_test)
        print("Accuracy: %4.2f" % (accuracy_score(Y_expect, Y_predict)))
        print(confusion_matrix(Y_expect, Y_predict))
        print("recall_score: ", recall_score(Y_expect, Y_predict, average=None))
        print("precision_score: "precision_score(Y_expect, Y_predict,average=None))
```

```
In [ ]: check_iteratively('enhancement', 'trivial')
        check_iteratively('trivial', 'minor')
        check_iteratively('minor', 'normal')
        check_iteratively('normal', 'major')
        check_iteratively('major', 'critical')
        check_iteratively('critical', 'blocker')
```

```
In [ ]: check_iteratively('enhancement', 'trivial')
        check_iteratively('trivial', 'minor')
        check_iteratively('minor', 'normal')
        check_iteratively('normal', 'major')
        check_iteratively('major', 'critical')
        check_iteratively('critical', 'blocker')
```

1.9 Using word vectors as features

```
In [57]: from sentiment import *
```

```
In [58]: df5 = verified.copy()
         summaries = [df5.values[id][0] for id in range(len(df5.values))]
         severities = [df5.values[id][1] for id in range(len(df5.values))]

         summary_arr = summaries
         summary_arr = convert_tolower(summary_arr)
         summary_arr = remove_punctuation(summary_arr)
         tokenized = tokenize_sentences(summary_arr)
```

```
# documents = remove_stopwords(summary_arr, tokenized)
# stemmed = stem_words(summary_arr, documents)
```

In [59]:
```
stemmed = tokenized
```

In [60]:
```
class MeanEmbeddingVectorizer(object):
    def __init__(self, word2vec):
        self.word2vec = word2vec
        # if a text is empty we should return a vector of zeros
        # with the same dimensionality as all the other vectors

    def fit(self, X, y):
        return self

    def transform(self, X):
        """
        This method sums all wordvecs of all words in a sentences
        and divides the resulting vector by the len of word count in the sentence
        """
        return np.array([np.sum([self.word2vec[w] for w in words if w in self.word2vec]
                                 [np.zeros(100)], axis=0) / len(words) for words in X ])
```

In [62]:
```
sentences = stemmed

model = models.Word2Vec(sentences, size=100, workers=-1, iter=1000)
words = list(model.wv.vocab)
model.wv.save_word2vec_format('model.bin')
# model = models.Word2Vec.load('model.bin')

w2v = dict(zip(model.wv.index2word, model.wv.syn0))
mev = MeanEmbeddingVectorizer(w2v)


X_train, X_test, Y_train, Y_test = train_test_split(vec_weights, severities, test_size=
```

In [63]:
```
vec_weights
```

Out[63]:
```
array([[ -1.88e-04,  -1.65e-05,  -8.55e-04, ...,  -5.69e-04,  -6.03e-04,
          1.20e-03],
       [ -1.91e-05,  -7.02e-05,   1.57e-04, ...,   6.53e-04,   8.13e-04,
         -5.07e-04],
       [ -3.15e-04,   9.49e-04,   7.78e-04, ...,   6.82e-04,   9.34e-04,
          5.19e-04],
       ...,
       [  1.39e-03,  -9.60e-05,  -1.21e-03, ...,   7.07e-04,   1.49e-03,
          5.80e-05],
       [  2.03e-04,  -8.10e-04,   1.84e-04, ...,  -2.93e-04,  -2.00e-04,
         -7.95e-04],
       [ -9.65e-04,   1.41e-03,  -7.03e-04, ...,  -1.53e-03,   1.16e-04,
          2.13e-04]])
```

```
In [64]: lsvm = LinearSVC(max_iter=5000)
         lsvm.fit(X_train, Y_train)

         scores = cross_val_score(lsvm, X_test, Y_test, cv=5, n_jobs=-1)

         print(lsvm)
         print("Accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std() * 2))

         Y_expect = Y_test
         Y_predict = lsvm.predict(X_test)
         print("Accuracy: %4.2f" % (accuracy_score(Y_expect, Y_predict)))
         print(confusion_matrix(Y_expect, Y_predict))
         print(recall_score(Y_expect, Y_predict, average=None))
         print(precision_score(Y_expect, Y_predict,average=None))
```

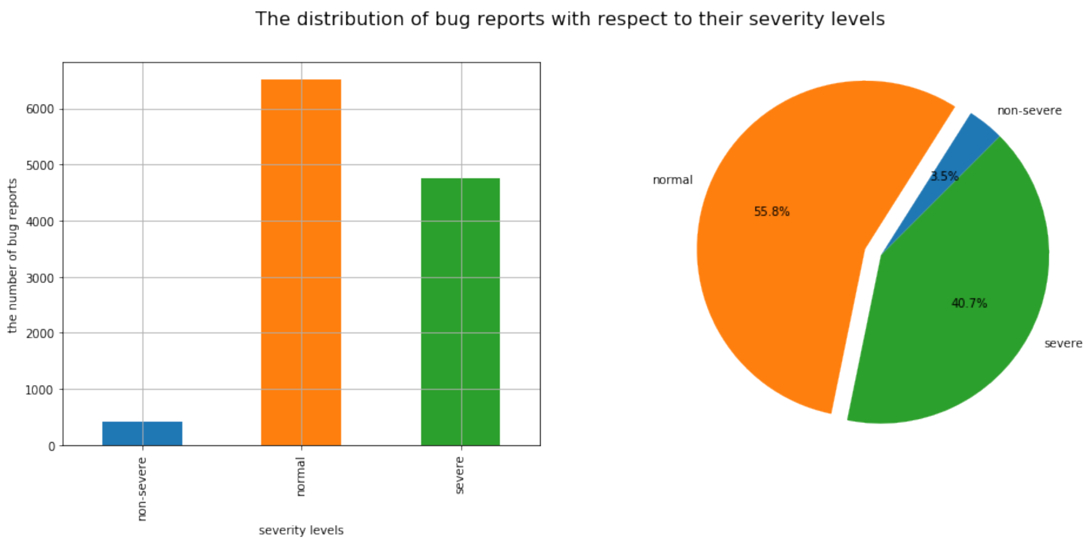
```
LinearSVC(C=1.0, class_weight=None, dual=True, fit_intercept=True,
     intercept_scaling=1, loss='squared_hinge', max_iter=5000,
     multi_class='ovr', penalty='l2', random_state=None, tol=0.0001,
     verbose=0)
Accuracy: 0.54 (+/- 0.01)
Accuracy: 0.58
[[  0   1   0   0   0  22   0]
 [  0  48   0   0   0 324   0]
 [  0   0   0   0   0  17   0]
 [  0   0   0   0   0  91   0]
 [  0   0   0   0   0  20   0]
 [  0   3   0   0   0 633   0]
 [  0   0   0   0   0  10   0]]
[ 0.    0.13  0.    0.    0.    1.    0.  ]
[ 0.    0.92  0.    0.    0.    0.57  0.  ]
```

1.10 Sklearn Neural Networks

```
In [65]: df7 = verified.copy()

         df7.loc[df7.severity == 'blocker', 'severity'] = "severe"
         df7.loc[df7.severity == 'critical', 'severity'] = "severe"
         df7.loc[df7.severity == 'major', 'severity'] = "severe"

         df7.loc[df7.severity == 'normal', 'severity'] = "normal"

         df7.loc[df7.severity == 'minor', 'severity'] = "non-severe"
         df7.loc[df7.severity == 'enhancement', 'severity'] = "non-severe"
         df7.loc[df7.severity == 'trivial', 'severity'] = "non-severe"
```

```
In [66]: severity_count = df7.groupby(['severity']).size()  # returns a series object
         total = severity_count.sum()
```

```
severity_percentage = severity_count / total * 100
fig, axes = plt.subplots(nrows=1, ncols=2, figsize=(16, 6))
explode = ( 0,0.1, 0)

ax1 = severity_count.plot("bar", ax=axes[0])
ax1.set_ylabel("the number of bug reports")
ax1.set_xlabel("severity levels")
ax1.grid(True)

ax2 = severity_percentage.plot("pie", ax=axes[1], explode=explode, autopct='%1.1f%%', s
ax2.set_ylabel("")
ax2.axis("equal")

plt.suptitle('The distribution of bug reports with respect to their severity levels', f
plt.show()
```



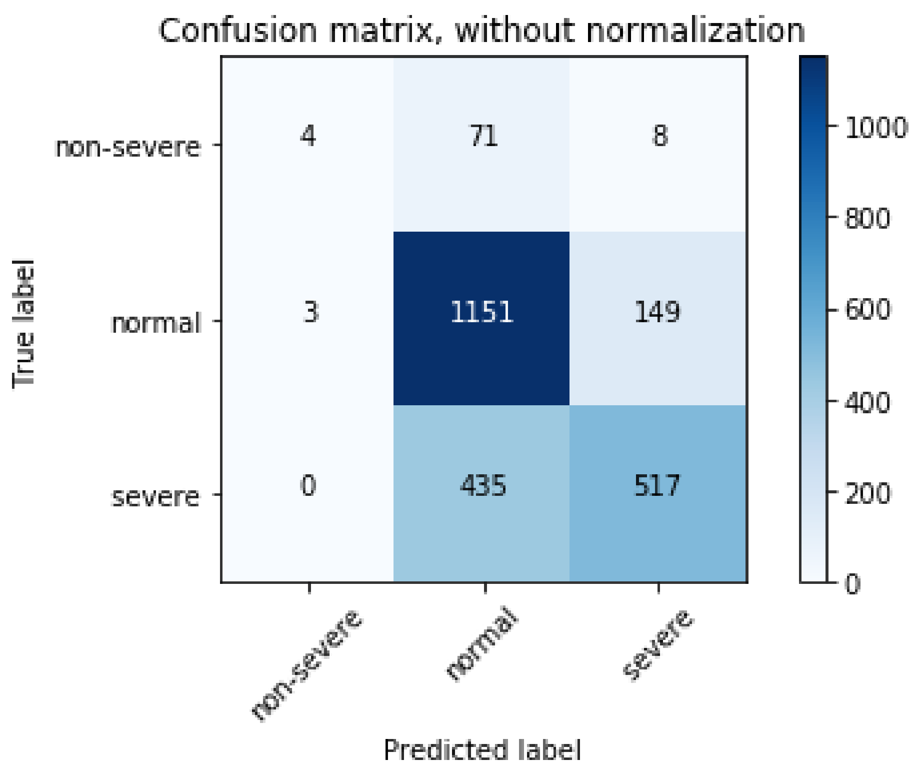

```
In [67]: summaries = [df7.values[id][0] for id in range(len(df7.values))]
         severities = [df7.values[id][1] for id in range(len(df7.values))]

In [68]: nn = MLPClassifier(hidden_layer_sizes=(100,), activation='tanh', solver='lbfgs',random_
                            verbose=True, early_stopping=False, max_iter=1000)

In [69]: class_names = ["non-severe", "normal", " severe"]

In [70]: def plot_confusion_matrix(cm, classes,
                                   normalize=False,
                                   title='Confusion matrix',
                                   cmap=plt.cm.Blues):
             """
             This function prints and plots the confusion matrix.
```

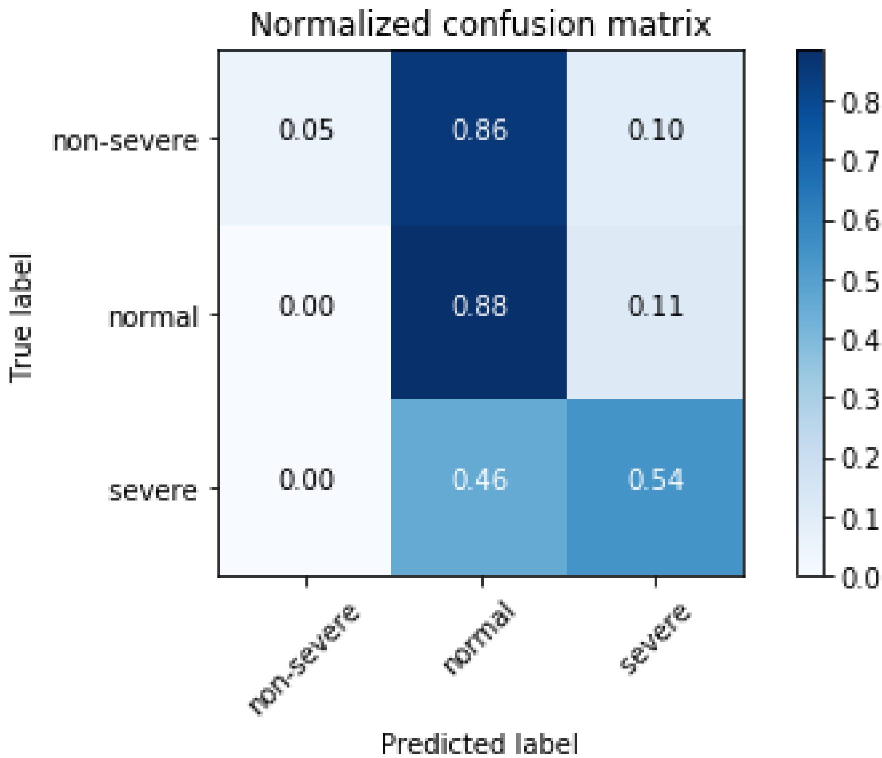
```
    Normalization can be applied by setting `normalize=True`.
    """
    if normalize:
        cm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]
        print("Normalized confusion matrix")
    else:
        print('Confusion matrix, without normalization')

    print(cm)

    plt.imshow(cm, interpolation='nearest', cmap=cmap)
    plt.title(title)
    plt.colorbar()
    tick_marks = np.arange(len(classes))
    plt.xticks(tick_marks, classes, rotation=45)
    plt.yticks(tick_marks, classes)

    fmt = '.2f' if normalize else 'd'
    thresh = cm.max() / 2.
    for i, j in itertools.product(range(cm.shape[0]), range(cm.shape[1])):
        plt.text(j, i, format(cm[i, j], fmt),
                 horizontalalignment="center",
                 color="white" if cm[i, j] > thresh else "black")

    plt.tight_layout()
    plt.ylabel('True label')
    plt.xlabel('Predicted label')
```

```
In [71]: skf = StratifiedKFold(n_splits=5)
         count=0
         total_acc = 0
         M = vec_weights
         y = severities
         y = np.asarray(y)
         for train_index, test_index in skf.split(M,y):
             count +=1
             x_train, x_test = M[train_index], M[test_index]
             y_train, y_test = y[train_index], y[test_index]
             nn.fit(x_train, y_train)
             y_predict = nn.predict(x_test)
             total_acc += accuracy_score(y_test, y_predict)

             # Compute confusion matrix
             cnf_matrix = confusion_matrix(y_test, y_predict)
             np.set_printoptions(precision=2)

             # Plot non-normalized confusion matrix
             plt.figure()
```

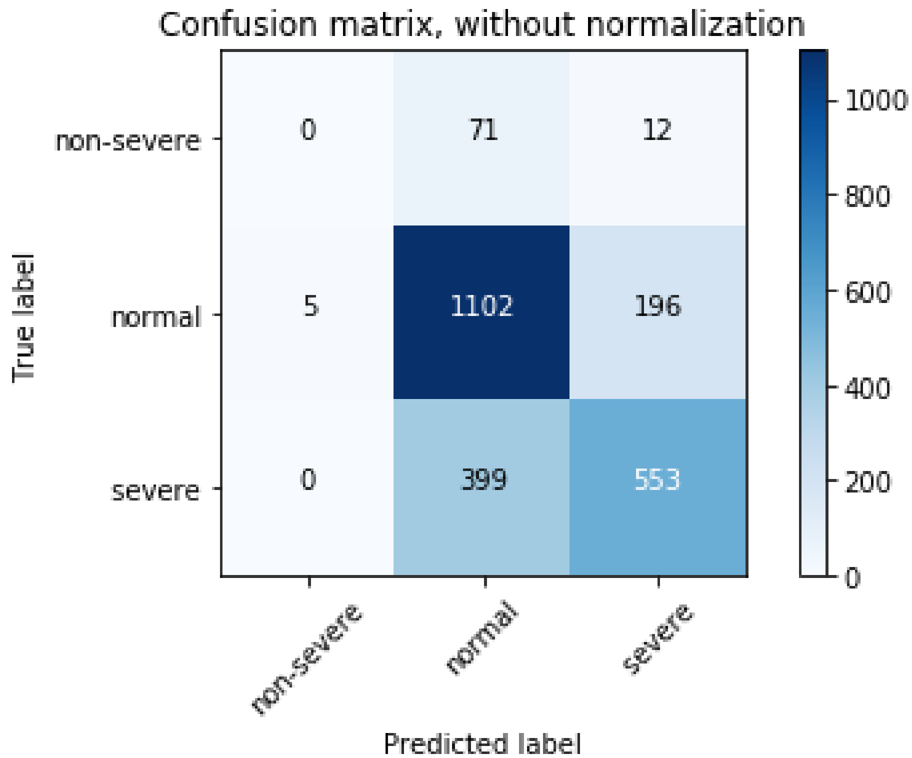
```
        plot_confusion_matrix(cnf_matrix, classes=class_names,
                              title='Confusion matrix, without normalization')

        # Plot normalized confusion matrix
        plt.figure()
        plot_confusion_matrix(cnf_matrix, classes=class_names, normalize=True,
                              title='Normalized confusion matrix')

        plt.show()

    print("Average accuracy: ", total_acc/count)
```

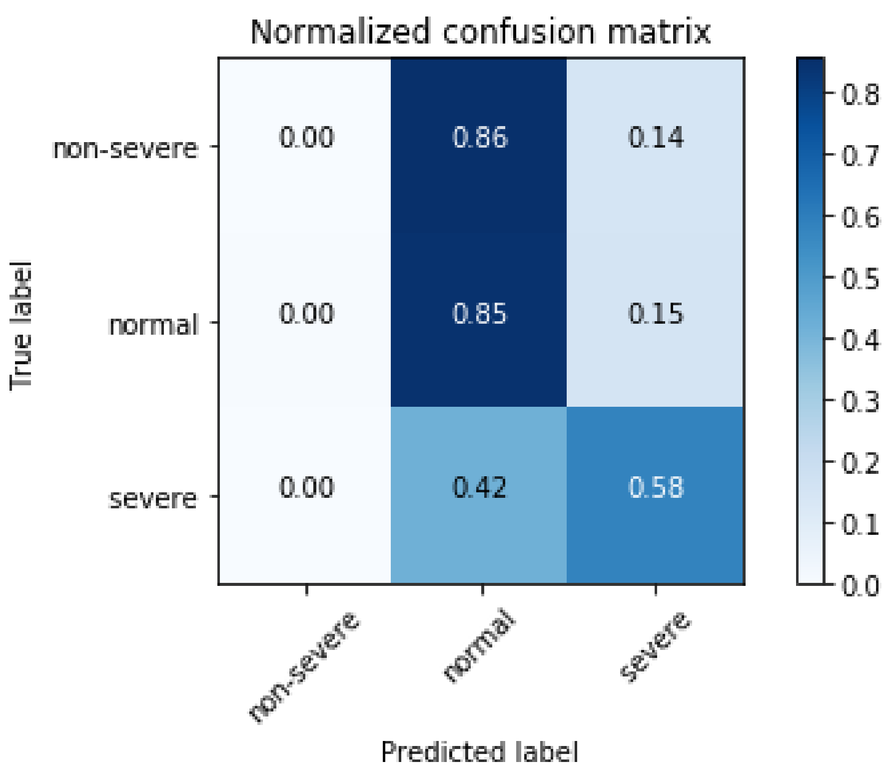
```
Confusion matrix, without normalization
[[   4   71    8]
 [   3 1151  149]
 [   0  435  517]]
Normalized confusion matrix
[[ 0.05  0.86  0.1 ]
 [ 0.    0.88  0.11]
 [ 0.    0.46  0.54]]
```



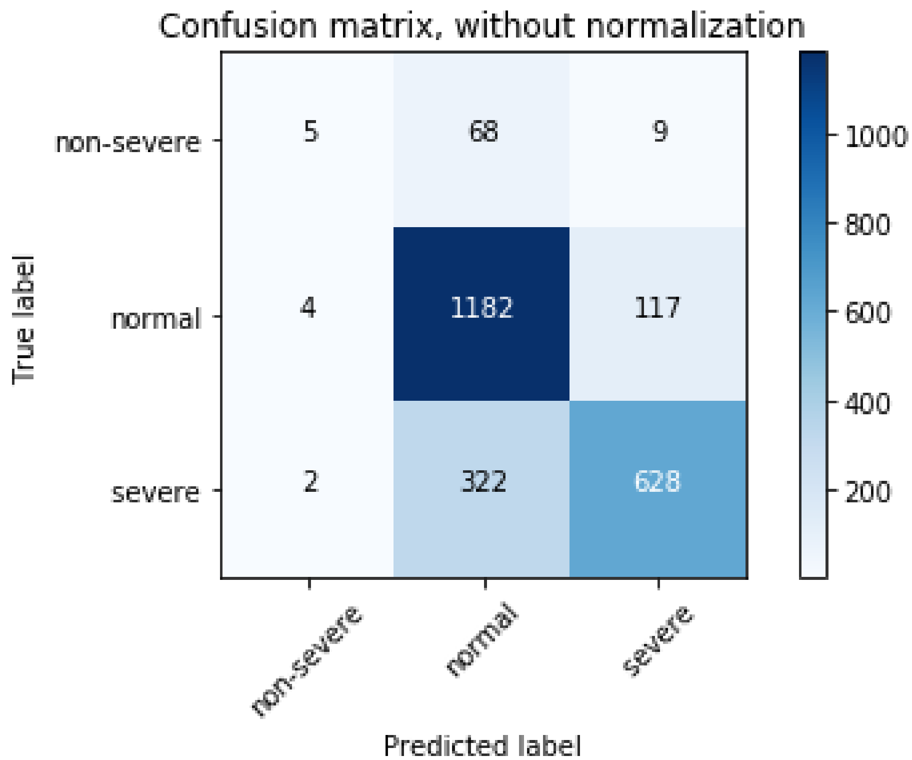


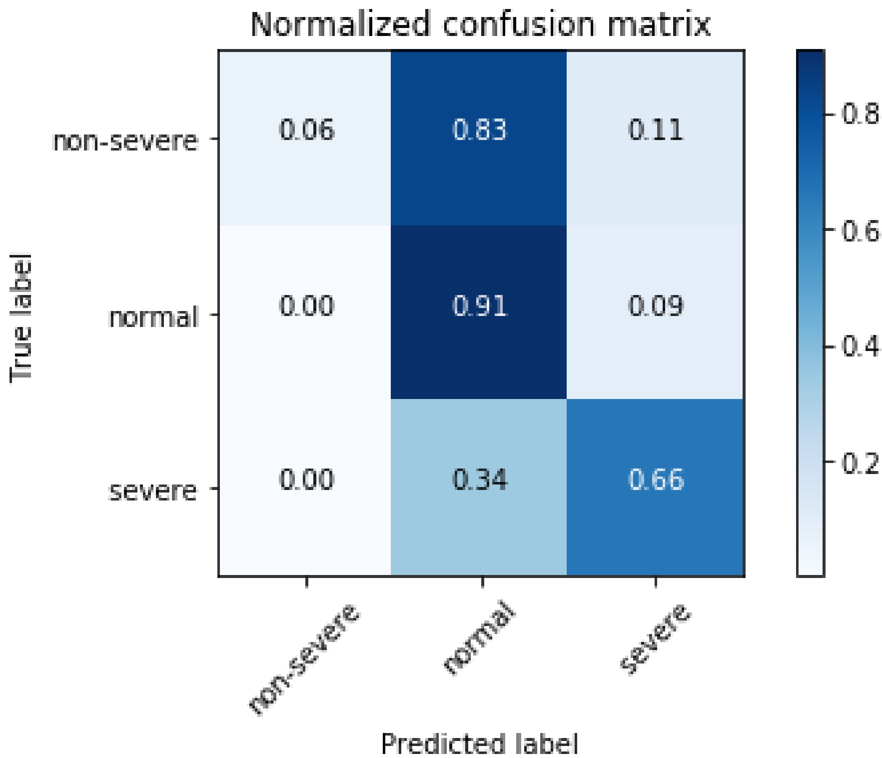

```
Confusion matrix, without normalization
[[   0   71   12]
 [   5 1102  196]
 [   0  399  553]]
Normalized confusion matrix
[[ 0.    0.86  0.14]
 [ 0.    0.85  0.15]
 [ 0.    0.42  0.58]]
```


Confusion matrix, without normalization
True label
Predicted label
non-severe
normal
severe
0
71
12
5
1102
196
0
399
553
1000
800
600
400
200
0

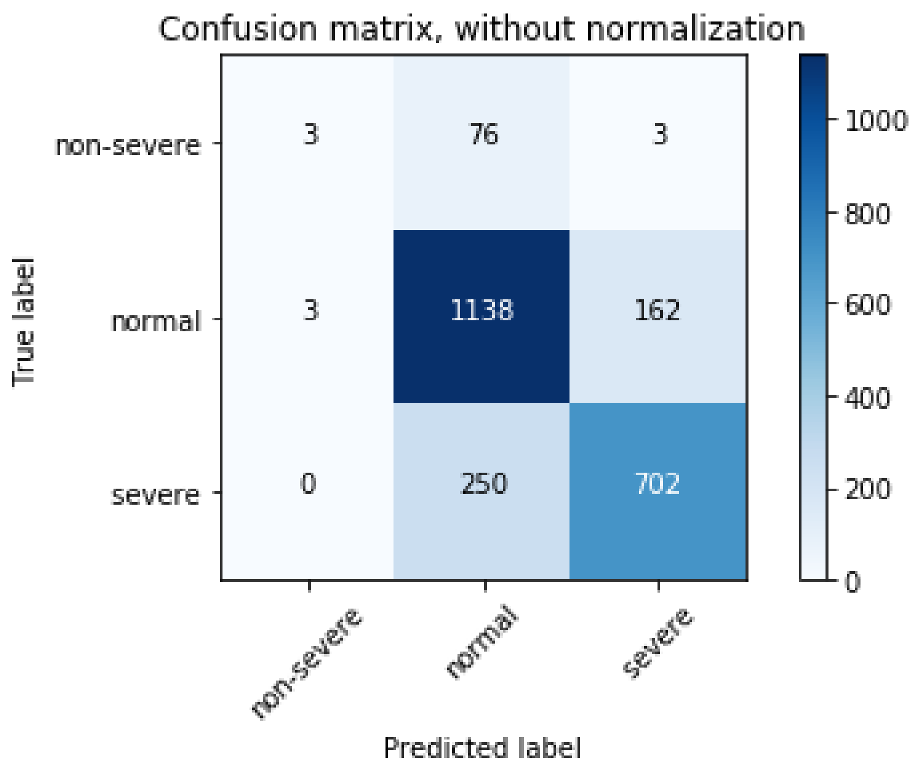

Normalized confusion matrix
True label
Predicted label
non-severe
normal
severe
0.00
0.86
0.14
0.00
0.85
0.15
0.00
0.42
0.58
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

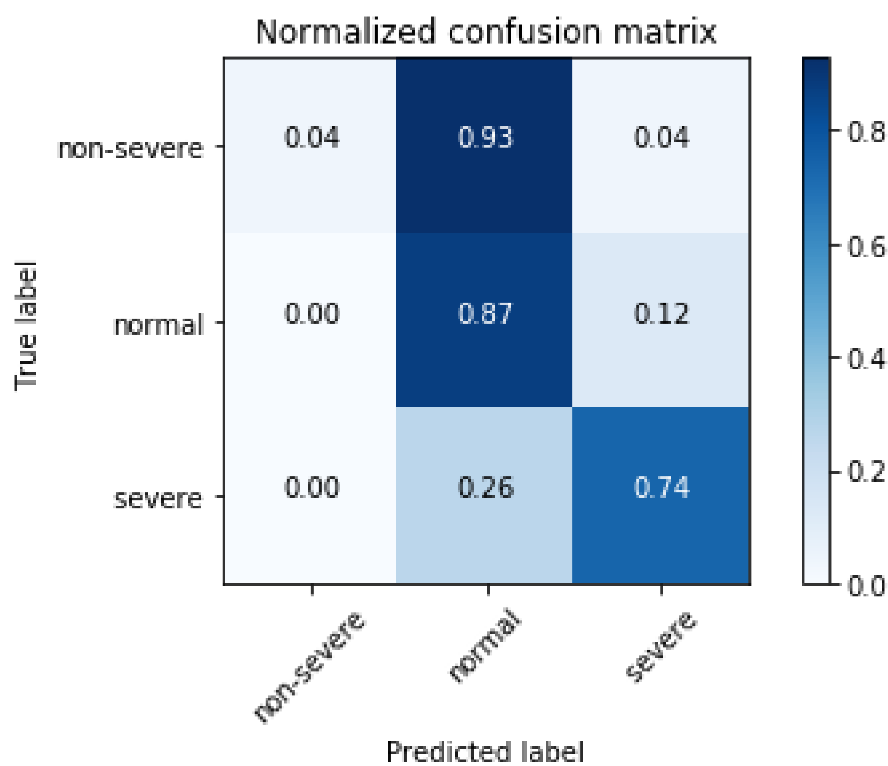
```
Confusion matrix, without normalization
[[   5   68    9]
 [   4 1182  117]
 [   2  322  628]]
Normalized confusion matrix
[[ 0.06  0.83  0.11]
 [ 0.    0.91  0.09]
 [ 0.    0.34  0.66]]
```



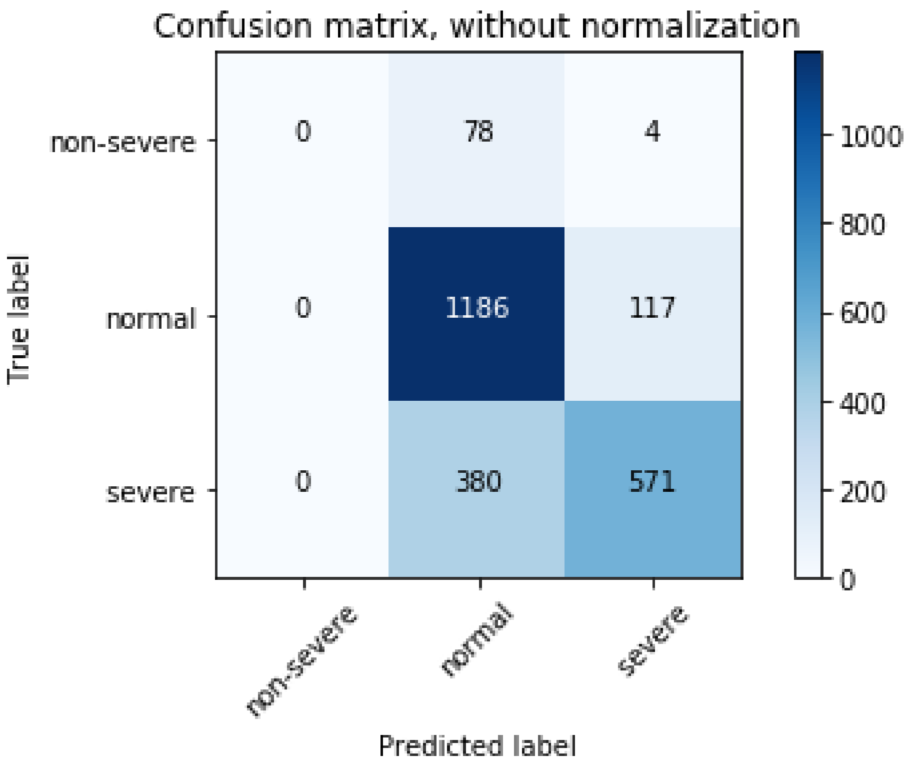


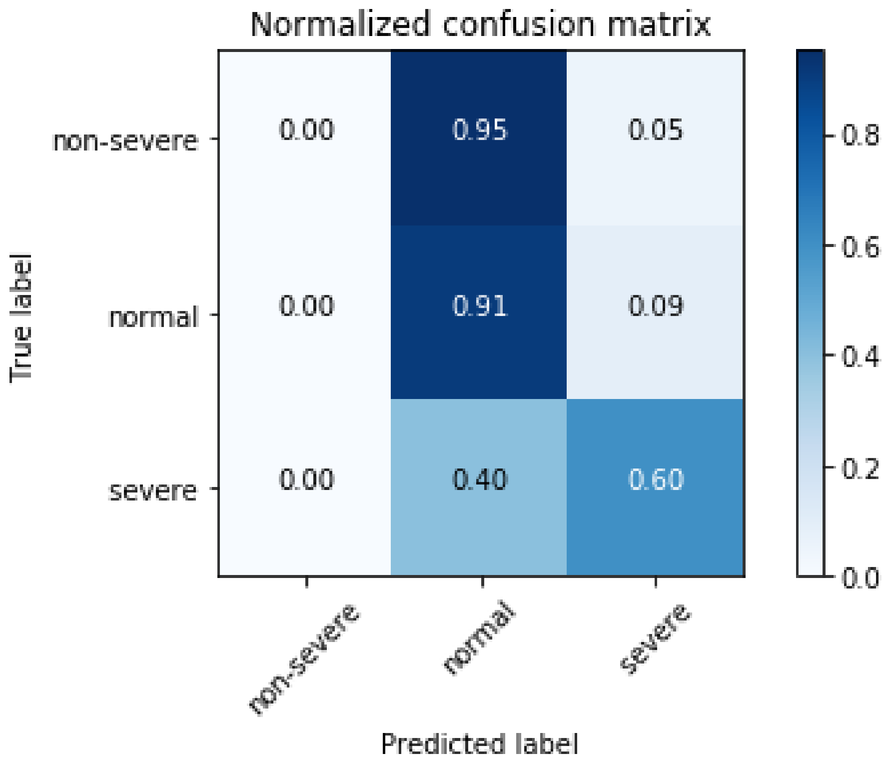

```
Confusion matrix, without normalization
[[   3   76    3]
 [   3 1138  162]
 [   0  250  702]]
Normalized confusion matrix
[[ 0.04  0.93  0.04]
 [ 0.    0.87  0.12]
 [ 0.    0.26  0.74]]
```


Confusion matrix, without normalization
True label
non-severe
normal
severe
3
76
3
3
1138
162
0
250
702
Predicted label
1000
800
600
400
200
0


Normalized confusion matrix
True label
non-severe
normal
severe
0.04
0.93
0.04
0.00
0.87
0.12
0.00
0.26
0.74
Predicted label
0.8
0.6
0.4
0.2
0.0

```
Confusion matrix, without normalization
[[   0   78    4]
 [   0 1186  117]
 [   0  380  571]]
Normalized confusion matrix
[[ 0.    0.95  0.05]
 [ 0.    0.91  0.09]
 [ 0.    0.4   0.6 ]]
```






```
Average accuracy:  0.748081226298
```