911 WRPS Calls Data Final Project_Konsur

The Final Project the description of the dataset, the main 911 Waterloo Regional Police Service (WRPS) data sources in (*.csv) format and represents with more than 170806 insidents with 23 feature listed below. All properties of incidents are continuous variables, and Final_Priority (Severity) is an ordinal, dependent variable http://www.wrps.on.ca/sites/default/files/WRPSOccurrenceData_Year_2014_October_15.csv (http://www.wrps.on.ca/sites/default/files/WRPSOccurrenceData_Year_2014_October_15.csv)

The data contains the following fields:

- Occurrence Number
- Geographic Location [long, lat]
- Nearest Intersection Location
- Patrol Division
- Patrol Zone
- Municipality
- Reported [Date and Time]
- Initial Call Type (REMOVED)
- Initial Call Type Description
- Final Call Type
- Final Call Type Description
- Initial Priority (Removed)
- Final Priority [1-9]
- Disposition (Removed)
- Dispatch [Date and Time]
- Arrival [Date and Time]
- Cleared [Date and Time]
- Call Dispatch Delay = Dispath - Reported
- Call Travel Time = Arrival - Dispatch
- Call On-Scene Time = Cleared - Arrived
- Call Response Time = Arrival - Reported
- Call Service Time = Cleared - Dispatch
- Total Unit Service Time = ?????

Note: -- installing nn on my computer (from conda prompt): conda update scikit-learn followed by: pip install scikit-neuralnetwork

Data and Setup

Import numpy and pandas

In [187]:

```
%matplotlib inline
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
sns.set_style('whitegrid')
```

In [188]:

```
from multiprocessing import Process, freeze_support
from pylab import rcParams
from scipy import stats
from sklearn import tree
from sklearn import datasets, linear_model, preprocessing
from sklearn import cross_validation
from sklearn.cross_validation import train_test_split, cross_val_score
from sklearn.ensemble import RandomForestClassifier, GradientBoostingClassifier, ExtraTreesClassifier
from sklearn.grid_search import GridSearchCV
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import roc_curve, roc_auc_score
from sklearn.naive_bayes import GaussianNB
from sklearn.svm import SVC
from sklearn import svm
from sklearn.neural_network import MLPClassifier
```

Read in the csv file as a dataframe called df

In [189]:

```
path='C:\\Users\\cck023.DS\\OneDrive\\MSCA\\data\\WRPSOccurrenceData_Year_2015_November3_2016.csv'
```

```
In [190]: df=pd.read_csv(path)
          df.head(3)
```

Out[190]:

	Occurrence Number	Geographic Location	Nearest Intersection Location	Patrol Division	Patrol Zone	Municipality	Reportec Date and Time
0	WA15168339	537724.704700 ,4816634.248000	KING ST N / NORTHFIELD DR E / NORTHFIELD DR W	WN	WN6	NaN	2015-08-08 12:00:00
1	WA15274061	552814.080200 ,4804681.021100	MONTROSE ST N / RAILWAY ST	WS	WS6	CAM	2015-12-24 12:15:17
2	WA15240889	543979.878500 ,4805604.983000	BEASLEY DR / HOMER WATSON BLVD	WC	WC7	KIT	2015-11-09 13:19:15

3 rows × 23 columns

Check the info() of the df

In [191]:

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 280141 entries, 0 to 280140
Data columns (total 23 columns):
Occurrence Number                 280141 non-null object
Geographic Location               275947 non-null object
Nearest Intersection Location     275947 non-null object
Patrol Division                   279233 non-null object
Patrol Zone                       275594 non-null object
Municipality                      185449 non-null object
Reported Date and Time            280141 non-null object
Initial Call Type                 186435 non-null float64
Initial Call Type Description     186435 non-null object
Final Call Type                   280138 non-null float64
Final Call Type Description       280138 non-null object
Initial Priority                  186435 non-null float64
Final Priority                    280139 non-null float64
Disposition                       186452 non-null object
 Dispatch Date and Time           186468 non-null object
Arrival Date and Time             176577 non-null object
Cleared Date and Time             186417 non-null object
Call Dispatch Delay               186468 non-null float64
Call Travel Time                  176574 non-null float64
Call On-Scene Time                176537 non-null float64
Call Response Time                176577 non-null float64
Call Service Time                 186413 non-null float64
Total Unit Service Time           186455 non-null float64
dtypes: float64(10), object(13)
memory usage: 49.2+ MB
```

Check the head of df

In [192]:

```
df1=df.dropna()
```

In [193]:

```
df1.shape
```

Out[193]:

```
(170806, 23)
```

In [194]:
```
df1.reset_index(drop=True)
df1.head(5)
```

Out[194]:

	Occurrence Number	Geographic Location	Nearest Intersection Location	Patrol Division	Patrol Zone	Municipality	Reported Date and Time
1	WA15274061	552814.080200 ,4804681.021100	MONTROSE ST N / RAILWAY ST	WS	WS6	CAM	2015-12-24 12:15:17
2	WA15240889	543979.878500 ,4805604.983000	BEASLEY DR / HOMER WATSON BLVD	WC	WC7	KIT	2015-11-09 13:19:15
3	WA15171651	556059.710500 ,4802351.015300	COULSON ST / ELMWOOD AVE	WS	WS4	CAM	2015-08-13 07:38:07
4	WA15200283	541176.033600 ,4810854.312200	CHARLES ST W / ONTARIO ST S	WC	WC1	KIT	2015-09-18 14:30:35
6	WA15162132	538320.095900 ,4814442.414200	COLUMBIA ST E / COLUMBIA ST W / KING ST N	W3	324	WAT	2015-07-31 07:01:43

5 rows × 23 columns

In [195]:
```
df1.shape
```

Out[195]:
```
(170806, 23)
```

In [196]:
```
df1 = df1.drop('Disposition', 1)
df1 = df1.drop('Initial Priority', 1)
```

In [197]:
```
df1 = df1.drop('Initial Call Type', 1)
```

In [198]:
```
df1 = df1.drop('Initial Call Type Description',1)
```

In [199]:
```
df1.shape
```

Out[199]:
```
(170806, 19)
```

In [200]:
```
df1.head(5)
```

Out[200]:

	Occurrence Number	Geographic Location	Nearest Intersection Location	Patrol Division	Patrol Zone	Municipality	Reported Date and Time
1	WA15274061	552814.080200 ,4804681.021100	MONTROSE ST N / RAILWAY ST	WS	WS6	CAM	2015-12-24 12:15:17
2	WA15240889	543979.878500 ,4805604.983000	BEASLEY DR / HOMER WATSON BLVD	WC	WC7	KIT	2015-11-09 13:19:15
3	WA15171651	556059.710500 ,4802351.015300	COULSON ST / ELMWOOD AVE	WS	WS4	CAM	2015-08-13 07:38:07
4	WA15200283	541176.033600 ,4810854.312200	CHARLES ST W / ONTARIO ST S	WC	WC1	KIT	2015-09-18 14:30:35
6	WA15162132	538320.095900 ,4814442.414200	COLUMBIA ST E / COLUMBIA ST W / KING ST N	W3	324	WAT	2015-07-31 07:01:43

In [201]:
```
df1.columns = [c.replace(' ', '_') for c in df1.columns]
```

In [202]:

```
df1.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 170806 entries, 1 to 280140
Data columns (total 19 columns):
Occurrence_Number                 170806 non-null object
Geographic_Location               170806 non-null object
Nearest_Intersection_Location     170806 non-null object
Patrol_Division                   170806 non-null object
Patrol_Zone                       170806 non-null object
Municipality                      170806 non-null object
Reported_Date_and_Time            170806 non-null object
Final_Call_Type                   170806 non-null float64
Final_Call_Type_Description       170806 non-null object
Final_Priority                    170806 non-null float64
_Dispatch_Date_and_Time           170806 non-null object
Arrival_Date_and_Time             170806 non-null object
Cleared_Date_and_Time             170806 non-null object
Call_Dispatch_Delay               170806 non-null float64
Call_Travel_Time                  170806 non-null float64
Call_On-Scene_Time                170806 non-null float64
Call_Response_Time                170806 non-null float64
Call_Service_Time                 170806 non-null float64
Total_Unit_Service_Time           170806 non-null float64
dtypes: float64(8), object(11)
memory usage: 26.1+ MB
```

In [203]:

```
df1['Reason'] = df1['Final_Call_Type_Description'].apply(lambda Final_Call_Type_Description: Final_Call_Type_Description.split('-')[1])
```

```
In [204]: df1['Reason'].value_counts()
```

Out[204]:

VEHICLE STOP	41624
COMPASSIONATE TO LOCATE	12589
BYLAW COMPLAINT	8460
THEFT UNDER $5000	6132
SELECTIVE TRAFFIC ENFORCEMENT PROGRAM (STEP)	5957
DOMESTIC DISPUTE	5610
ADMINISTRATIVE/ROUTINE DETAIL	5599
PROACTIVE INITIATIVE/PROJECT	5583
UNWANTED PERSON	5525
MVC PROP. DAMAGE	4874
DRIVING COMPLAINT	4591
PERSON STOP	4067
ALARM	3465
INJURED/SICK PERSON	3457
DISPUTE	3425
DOMESTIC OTHER	2691
ARREST	2470
SUSPICIOUS PERSON	2350
PROP. (LOST AND FOUND)	2294
DISTURBANCE	2289
MENTALLY ILL	2155
BREAK & ENTER	2098
MISSING PERSON	2034
MVC PERSONAL INJURY	1683
FRAUD	1633
DRUGS	1606
ASSIST OTHER SERVICE	1591
PROPERTY DAMAGE	1586
ATTEMPT SUICIDE	1475
PAID DUTY	1329
	...
SEX OFFENCE	341
CHILD CUSTODY AND ACCESS	318
WORKPLACE ACCIDENT	233
ROBBERY	220
GRAFFITI	183
VEHICLE / PLATE SEIZURE	149
ALERT	140
SEARCH WARRANT	138
CRIMINAL HARASSMENT/STALKING	137
COUNTERFEIT MONEY	121
THEFT OVER $5000	96
INDECENT ACT	95
ADMINISTRATIVE NOTICE (9	93
ELDER ABUSE	68
PROSTITUTION	62
PORNOGRAPHY	53
SUSPECT APPREHENSION PURSUIT	50
PROWLER	41
PUBLIC MISCHIEF	36
EXTORTION	20
TECHNOLOGY/INTERNET CRIME	17
BOMB THREAT	14
MVC FATALITY	12
LABOUR DISPUTE	12
ABDUCTION	6
GAMING & BETTING	6

```
HOMICIDE                                            6
FILED 9                                             5
HUMAN TRAFFICKING                                   4
UNKNOWN CALL REQUIRING POLICE ASSISTANCE            1
Name: Reason, dtype: int64
```

What are the top 5 Patrol Zones for 911 calls?

In [205]:
```
df1['Patrol_Zone'].value_counts().head(5)
```

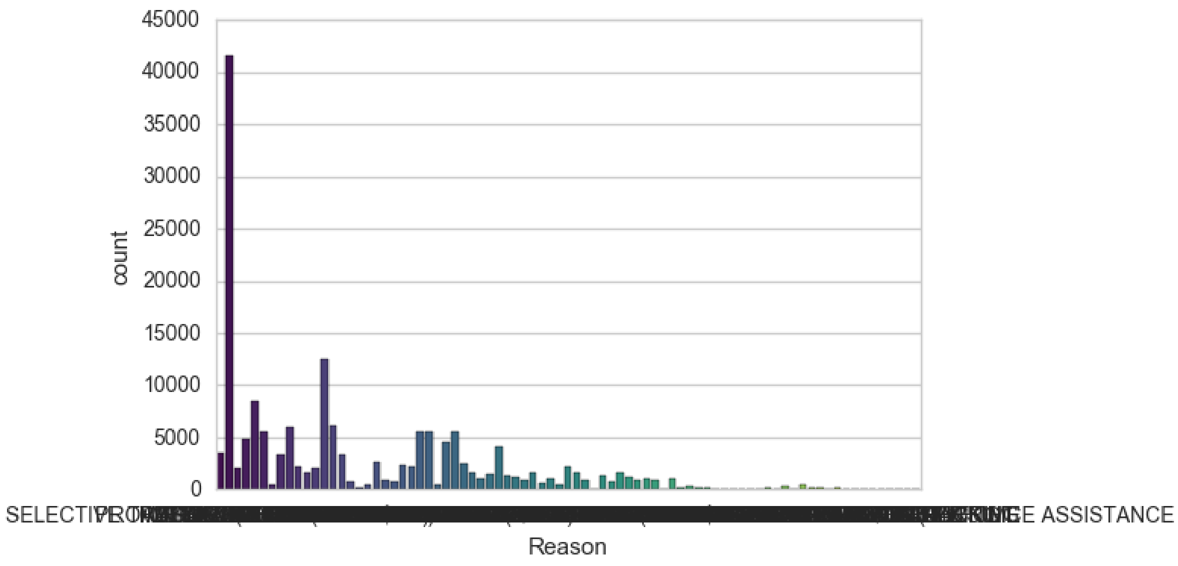
Out[205]:
```
WS4    10229
WN6     9935
WC2     9508
WC5     9341
WS2     9315
Name: Patrol_Zone, dtype: int64
```

In [206]:
```
df1['Patrol_Division'].value_counts().head(5)
```

Out[206]:
```
WN    62662
WC    59070
WS    47492
WR      275
W2      232
Name: Patrol_Division, dtype: int64
```

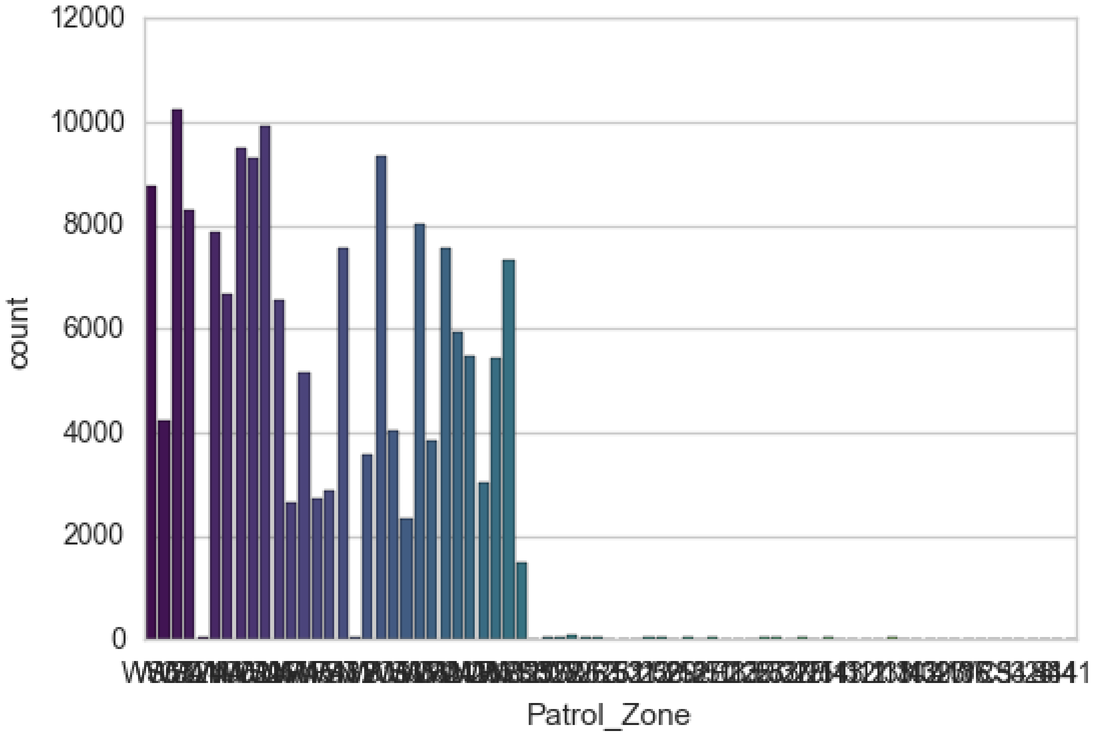
In [207]:
```
sns.countplot(x='Reason',data=df1,palette='viridis')
```

Out[207]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x2caadbbf9e8>
```



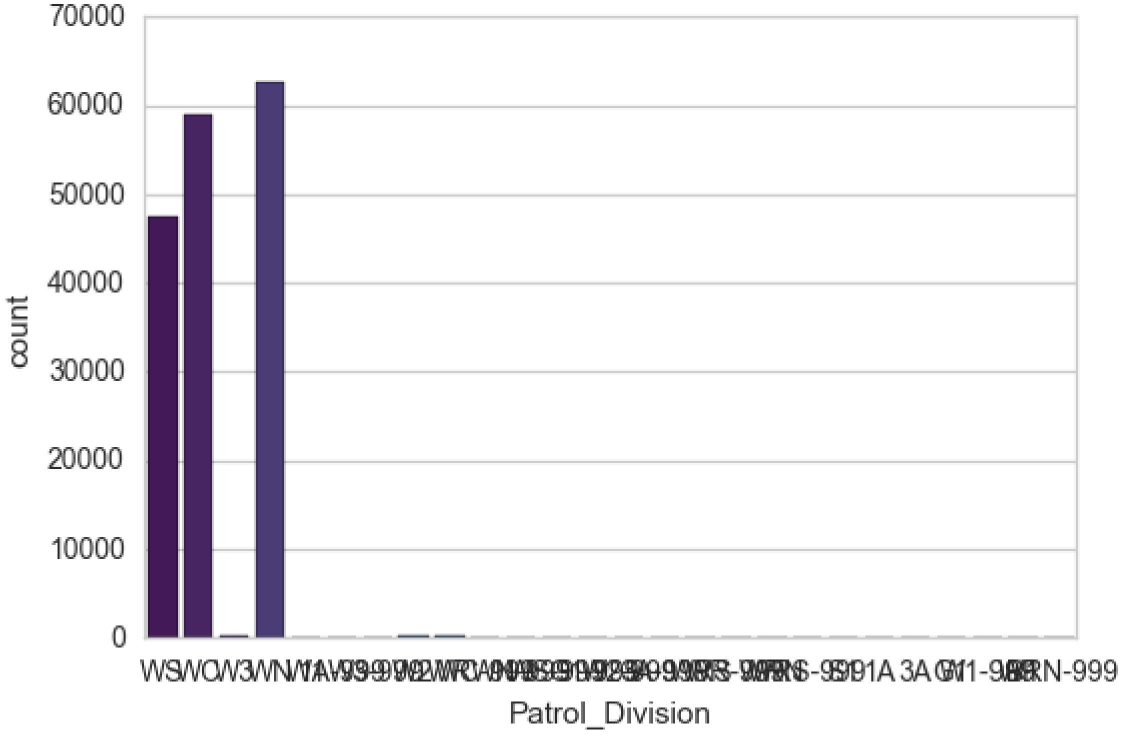
```
In [208]: sns.countplot(x='Patrol_Zone',data=df1,palette='viridis')
```

```
Out[208]: <matplotlib.axes._subplots.AxesSubplot at 0x2caaf339a58>
```



```
In [209]: sns.countplot(x='Patrol_Division',data=df1,palette='viridis')
```

```
Out[209]: <matplotlib.axes._subplots.AxesSubplot at 0x2caa533f940>
```



Y: Recoding target variable: If 'Final Priority' >= 7, then 1, else 0.

```
In [210]: df1.shape

Out[210]: (170806, 20)
```

```
In [211]: df1.columns

Out[211]: Index(['Occurrence_Number', 'Geographic_Location',
                 'Nearest_Intersection_Location', 'Patrol_Division', 'Patrol_Zone',
                 'Municipality', 'Reported_Date_and_Time', 'Final_Call_Type',
                 'Final_Call_Type_Description', 'Final_Priority',
                 '_Dispatch_Date_and_Time', 'Arrival_Date_and_Time',
                 'Cleared_Date_and_Time', 'Call_Dispatch_Delay', 'Call_Travel_Time',
                 'Call_On-Scene_Time', 'Call_Response_Time', 'Call_Service_Time',
                 'Total_Unit_Service_Time', 'Reason'],
                dtype='object')
```

```
In [212]: Y = df1.Final_Priority.values
```

```
In [213]: df1 = df1.drop('Final_Priority', axis=1)
          X = df1.as_matrix()
          X_cols = df1.columns[0:11]
          Y = np.asarray([1 if i>=7 else 0 for i in Y])
```

```
In [214]: X.shape

Out[214]: (170806, 19)
```

```
In [215]: Y.shape

Out[215]: (170806,)
```

```
In [216]: X[:,12:17]

Out[216]: array([[13772.0, 330.0, 278.0, 14102.0, 608.0],
                 [5.0, 1.0, 993.0, 6.0, 994.0],
                 [19.0, 270.0, 1072.0, 289.0, 1342.0],
                 ...,
                 [19403.0, 433.0, 1188.0, 19836.0, 1621.0],
                 [227.0, 717.0, 3633.0, 944.0, 4350.0],
                 [36.0, 7.0, 7564.0, 43.0, 7571.0]], dtype=object)
```

```
In [217]: X2=X[:,12:17]
```

In [218]:

```
df1.head(5)
```

Out[218]:

	Occurrence_Number	Geographic_Location	Nearest_Intersection_Location	Patrol_D
1	WA15274061	552814.080200 ,4804681.021100	MONTROSE ST N / RAILWAY ST	WS
2	WA15240889	543979.878500 ,4805604.983000	BEASLEY DR / HOMER WATSON BLVD	WC
3	WA15171651	556059.710500 ,4802351.015300	COULSON ST / ELMWOOD AVE	WS
4	WA15200283	541176.033600 ,4810854.312200	CHARLES ST W / ONTARIO ST S	WC
6	WA15162132	538320.095900 ,4814442.414200	COLUMBIA ST E / COLUMBIA ST W / KING ST N	W3

In [219]:

```
#Creating train and test set.
np.random.seed(2)
X_train, X_test, Y_train, Y_test = train_test_split(X2[1:1000,:], Y[1:1000], t
rain_size=0.7)
```

I'll standardize the features so that they are centered around 0 with a standard deviation of 1.

In [220]:

```
std_scale = preprocessing.StandardScaler().fit(X_train)
X_train = std_scale.transform(X_train)
X_test = std_scale.transform(X_test)
```

```
C:\Users\cck023.DS\AppData\Local\Continuum\Anaconda3\lib\site-packages\sklear
n\utils\validation.py:429: DataConversionWarning: Data with input dtype objec
t was converted to float64 by StandardScaler.
  warnings.warn(msg, _DataConversionWarning)
```

Quick test of multiple models with cross validation

In [221]:

```
clf1 = LogisticRegression()
clf2 = RandomForestClassifier()
clf3 = GaussianNB()
clf4 = ExtraTreesClassifier()
```

```
In [222]: for clf, label in zip([clf1, clf2, clf3, clf4],
           ['Logistic Regression', 'Random Forest', 'Naive Bayes','Extra Trees']):
           scores = cross_validation.cross_val_score(clf, X_train, Y_train, cv=10, scori
          ng='accuracy')
           print("Accuracy: %0.2f (+/- %0.2f) [%s]" % (scores.mean(), scores.std(), labe
          l))
```

```
Accuracy: 0.87 (+/- 0.03) [Logistic Regression]
Accuracy: 0.92 (+/- 0.03) [Random Forest]
Accuracy: 0.54 (+/- 0.06) [Naive Bayes]
Accuracy: 0.89 (+/- 0.03) [Extra Trees]
```

```
In [223]: clf6 = GradientBoostingClassifier()
          clf7 = tree.DecisionTreeClassifier()
```

```
In [224]: for clf, label in zip([clf6, clf7],
           ['Gradient Boosting', 'Decision Tree']):
           scores = cross_validation.cross_val_score(clf, X_train, Y_train, cv=10, scori
          ng='accuracy')
           print("Accuracy: %0.2f (+/- %0.2f) [%s]" % (scores.mean(), scores.std()*2, la
          bel))
```

```
Accuracy: 0.92 (+/- 0.07) [Gradient Boosting]
Accuracy: 0.90 (+/- 0.06) [Decision Tree]
```

```
In [225]: clf5 = SVC()
          clf5
```

```
Out[225]: SVC(C=1.0, cache_size=200, class_weight=None, coef0=0.0,
            decision_function_shape=None, degree=3, gamma='auto', kernel='rbf',
            max_iter=-1, probability=False, random_state=None, shrinking=True,
            tol=0.001, verbose=False)
```

```
In [226]: for clf, label in zip([clf5],
           ['SVM']):
           scores = cross_validation.cross_val_score(clf, X_train, Y_train, cv=2, scorin
          g='accuracy')
           print("Accuracy: %0.2f (+/- %0.2f) [%s]" % (scores.mean(), scores.std(), labe
          l))
```

```
Accuracy: 0.80 (+/- 0.01) [SVM]
```

Gradient Boosting, Random Forest and Extra trees performs the best, while naive bayes performs the worst. I will drop Logistic Regression and Naive Bayes and will analyze the following models: Decision Tree, Random Forest, Gradient Boosting, SVM, and Extra Trees. Decision Tree

DecisionTree Classifier with default parameters

```
In [227]: dt = tree.DecisionTreeClassifier(criterion="gini", min_samples_split=10)
          dt.fit(X_train, Y_train)
          dt_test_preds = dt.predict_proba(X_test)[:, 1]
```

```
In [228]: dt_preds = dt.predict(X_test)
          print (pd.crosstab(index=Y_test, columns=dt_preds, rownames=["Actual"], colnam
          es=["Pred"]))

          Pred      0   1
          Actual
          0       175  16
          1        14  95
```

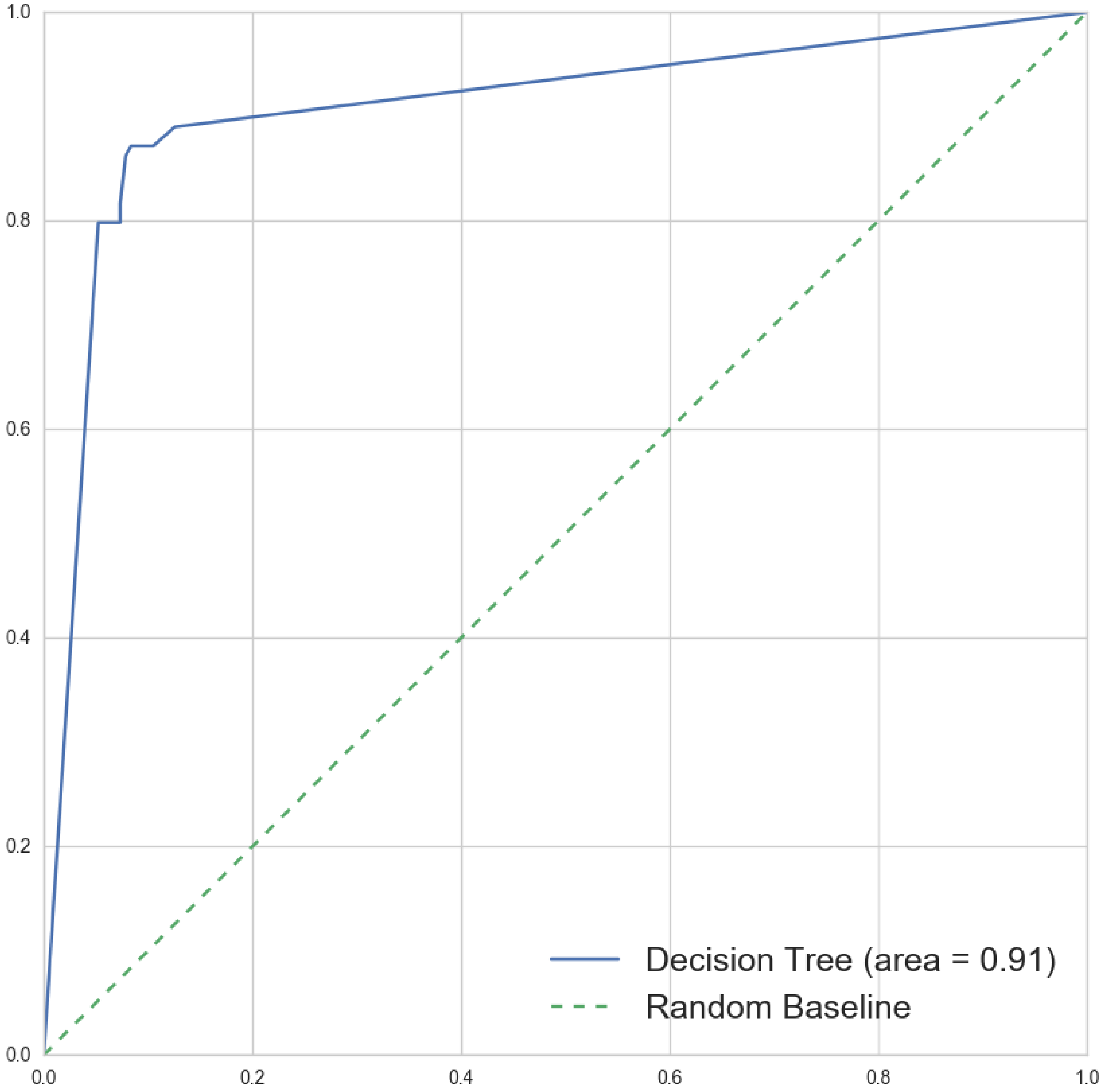
```
In [229]: dt_roc = roc_auc_score(Y_test, dt_test_preds)
          dt_roc

Out[229]: 0.90945770690234884
```

```
In [230]: fpr_decision_tree, tpr_decision_tree, thresholds_decision_tree = roc_curve(Y_t
          est, dt_test_preds)
```

In [231]:

```
fpr_rand = tpr_rand = np.linspace(0, 1, 10)
rcParams['figure.figsize'] = 10, 10
plt.plot(fpr_decision_tree, tpr_decision_tree, label='Decision Tree (area = %0.2f)' % dt_roc)
plt.plot(fpr_rand, tpr_rand, linestyle='--', label='Random Baseline')
plt.legend(loc='lower right', prop={'size':18})
plt.show()
```



Random Forest Random Forest Classifier with default parameters

In [232]:

```
rf = RandomForestClassifier()
rf.fit(X_train, Y_train)
rf_test_preds = rf.predict_proba(X_test)[:, 1]
```

```
In [233]: rf_preds = rf.predict(X_test)
          print (pd.crosstab(index=Y_test, columns=rf_preds, rownames=["Actual"], colnam
          es=["Pred"]))
```

```
Pred      0    1
Actual
0       177   14
1         9  100
```

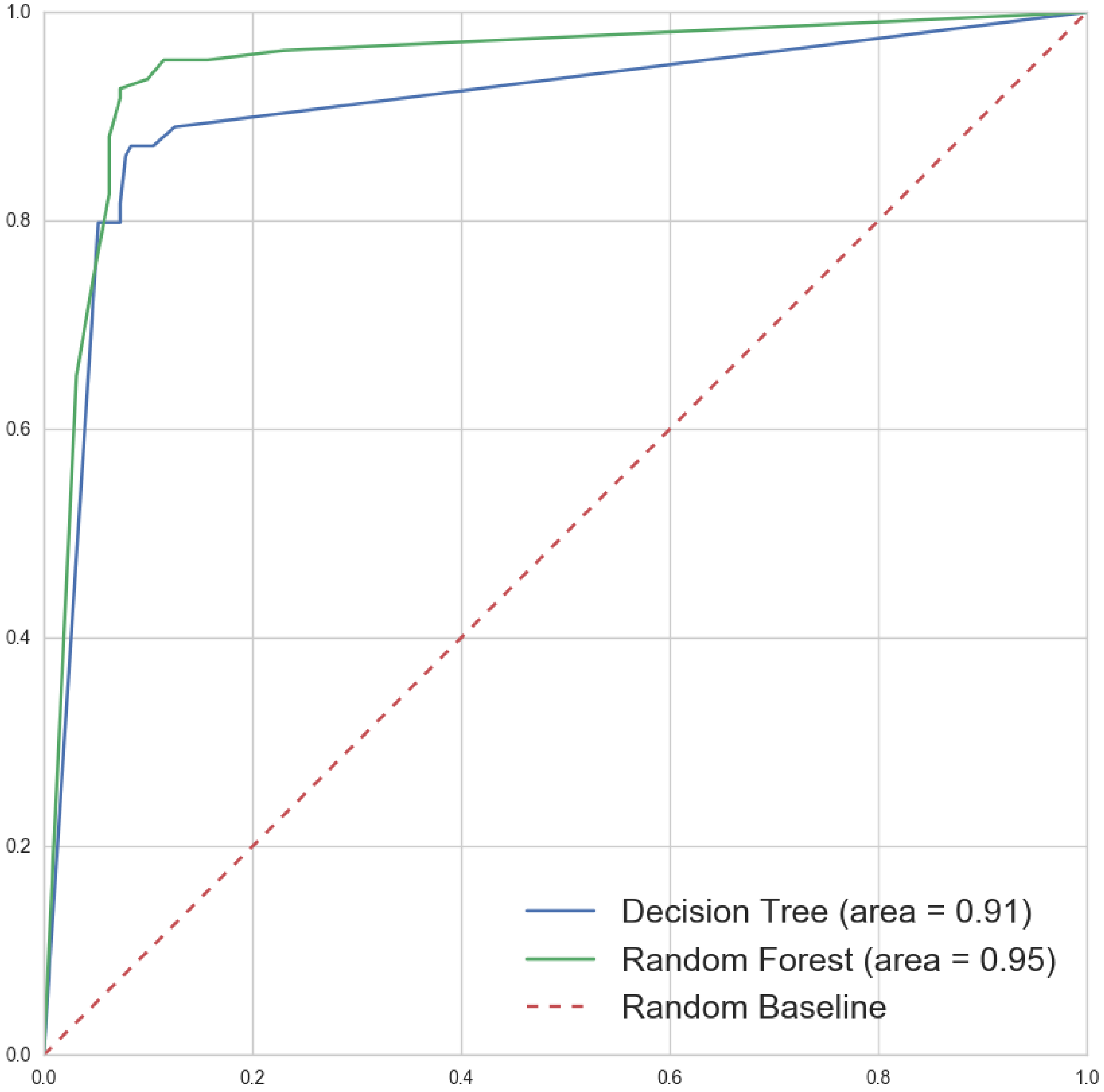
```
In [234]: rf_roc = roc_auc_score(Y_test, rf_test_preds)
          roc_auc_score(Y_test, rf_test_preds)
```

```
Out[234]: 0.9478841442912724З
```

```
In [235]: fpr_rf, tpr_rf, thresholds_rf = roc_curve(Y_test, rf_test_preds)
```

In [236]:

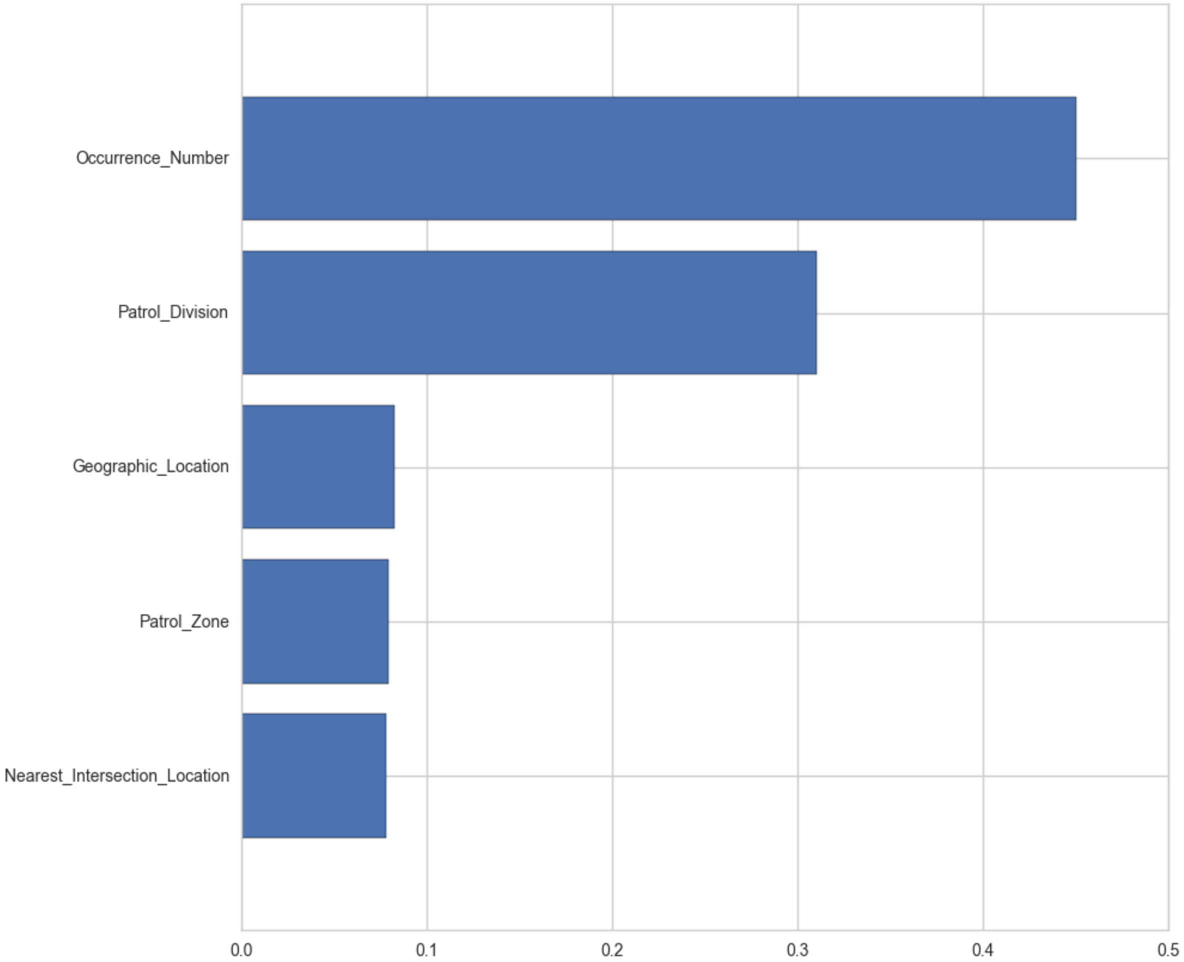
```
plt.plot(fpr_decision_tree, tpr_decision_tree, label='Decision Tree (area = %0.2f)' % dt_roc)
plt.plot(fpr_rf, tpr_rf, label='Random Forest (area = %0.2f)' % rf_roc)
plt.plot(fpr_rand, tpr_rand, linestyle='--', label='Random Baseline')
plt.legend(loc='lower right',prop={'size':18})
plt.show()
```



*Random Forest Classifier feature importance

In [237]:

```
rf_importances = rf.feature_importances_
sorted_indices = np.argsort(rf_importances)
y_pos = range(len(rf_importances))
plt.barh(y_pos, rf_importances[sorted_indices], align='center')
plt.yticks(y_pos, X_cols[sorted_indices])
plt.show()
```



In [238]:

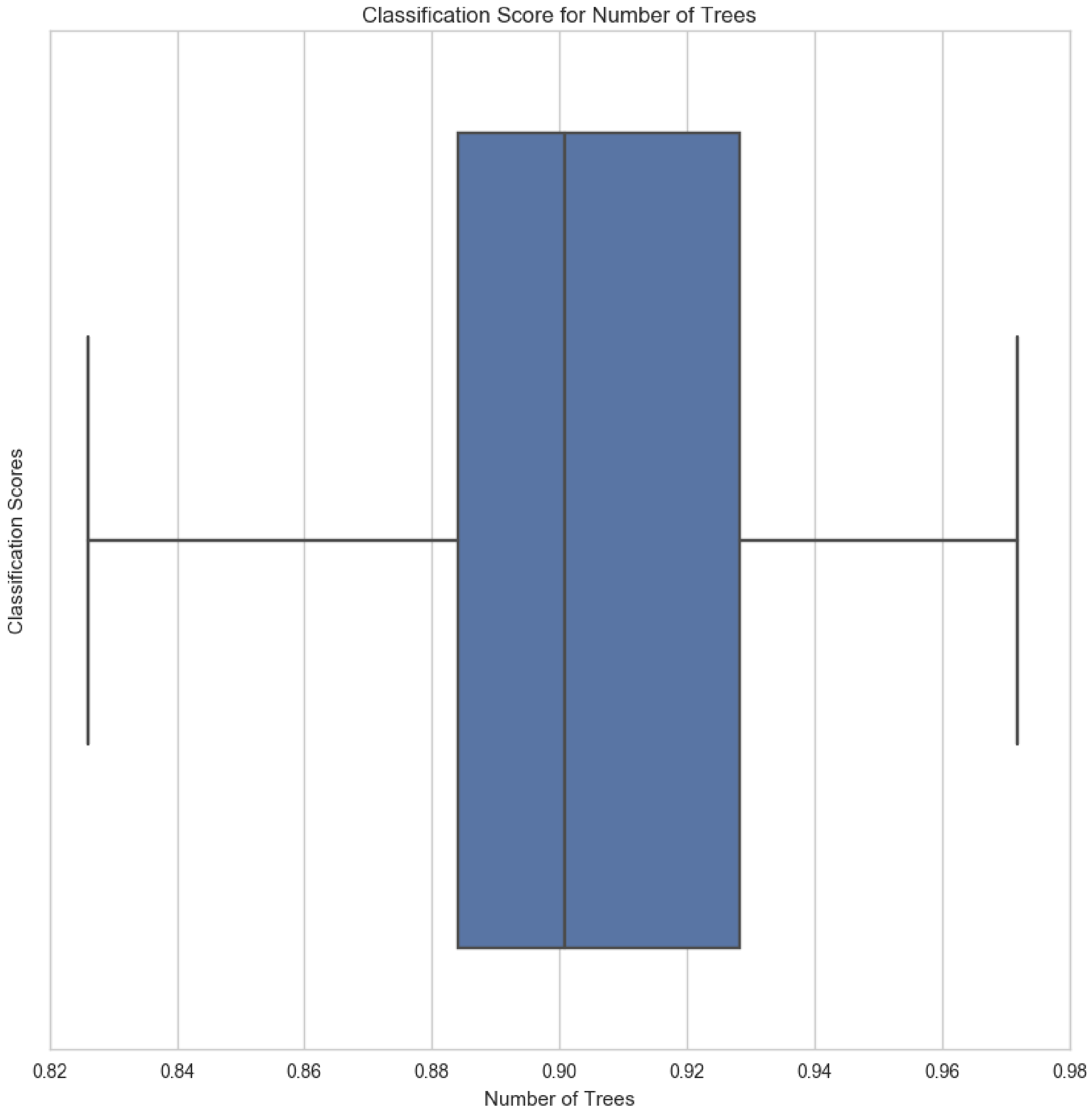
```
scores = []
```

In [239]:

```
for val in range(1,10):
 rf = RandomForestClassifier(n_estimators = val)
 validated = cross_val_score(rf, X_train, Y_train, cv=10)
 scores.append(validated)
```

In [240]:

```
sns.boxplot(scores)
plt.xlabel('Number of Trees')
plt.ylabel('Classification Scores')
plt.title('Classification Score for Number of Trees')
plt.show()
```



The classification score increases as the number of trees increase but it stadystate at 10.

In [241]:

```
param_grid = {"n_estimators": [5,19,26],
 "max_depth": [3,4,5,6,7,None],
 "max_features": ['auto',None],
 "min_samples_split": [1,3,5,10],
 "min_samples_leaf": [1,3,5,10]}
```

In [242]:

```
rf_ml = RandomForestClassifier()
```

In [243]:

```
#grid_search = GridSearchCV(rf_ml, param_grid=param_grid, cv=5)
#grid_search.fit(X_train, Y_train)
#print (grid_search.best_params_)
#{'max_features': 'auto', 'min_samples_split': 1, 'n_estimators': 19, 'max_dep
th': None,
#'min_samples_leaf': 1}
```

In [244]:

```
rf_custom = RandomForestClassifier(n_estimators=19, max_depth=None, max_featur
es='auto',
 min_samples_split=2, min_samples_leaf=2)
rf_custom.fit(X_train,Y_train)
```

Out[244]:

```
RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
            max_depth=None, max_features='auto', max_leaf_nodes=None,
            min_impurity_split=1e-07, min_samples_leaf=2,
            min_samples_split=2, min_weight_fraction_leaf=0.0,
            n_estimators=19, n_jobs=1, oob_score=False, random_state=None,
            verbose=0, warm_start=False)
```

In [245]:

```
RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
 max_depth=None, max_features='auto', max_leaf_nodes=None,
min_samples_leaf=1, min_samples_split=1,
min_weight_fraction_leaf=0.0, n_estimators=19, n_jobs=1,
oob_score=False, random_state=None, verbose=0,
warm_start=False)
```

Out[245]:

```
RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
            max_depth=None, max_features='auto', max_leaf_nodes=None,
            min_impurity_split=1e-07, min_samples_leaf=1,
            min_samples_split=1, min_weight_fraction_leaf=0.0,
            n_estimators=19, n_jobs=1, oob_score=False, random_state=None,
            verbose=0, warm_start=False)
```

In [246]:

```
rf_custom_preds = rf_custom.predict(X_test)
print (pd.crosstab(Y_test, rf_custom_preds, rownames=["Actual"], colnames=["Pr
ed"]))
```

```
Pred      0    1
Actual
0       177   14
1         8  101
```

In [247]:

```
rf_custom_test_preds = rf_custom.predict_proba(X_test)[:, 1]
rf_custom_roc = roc_auc_score(Y_test, rf_custom_test_preds)
roc_auc_score(Y_test, rf_custom_test_preds)
```

Out[247]:

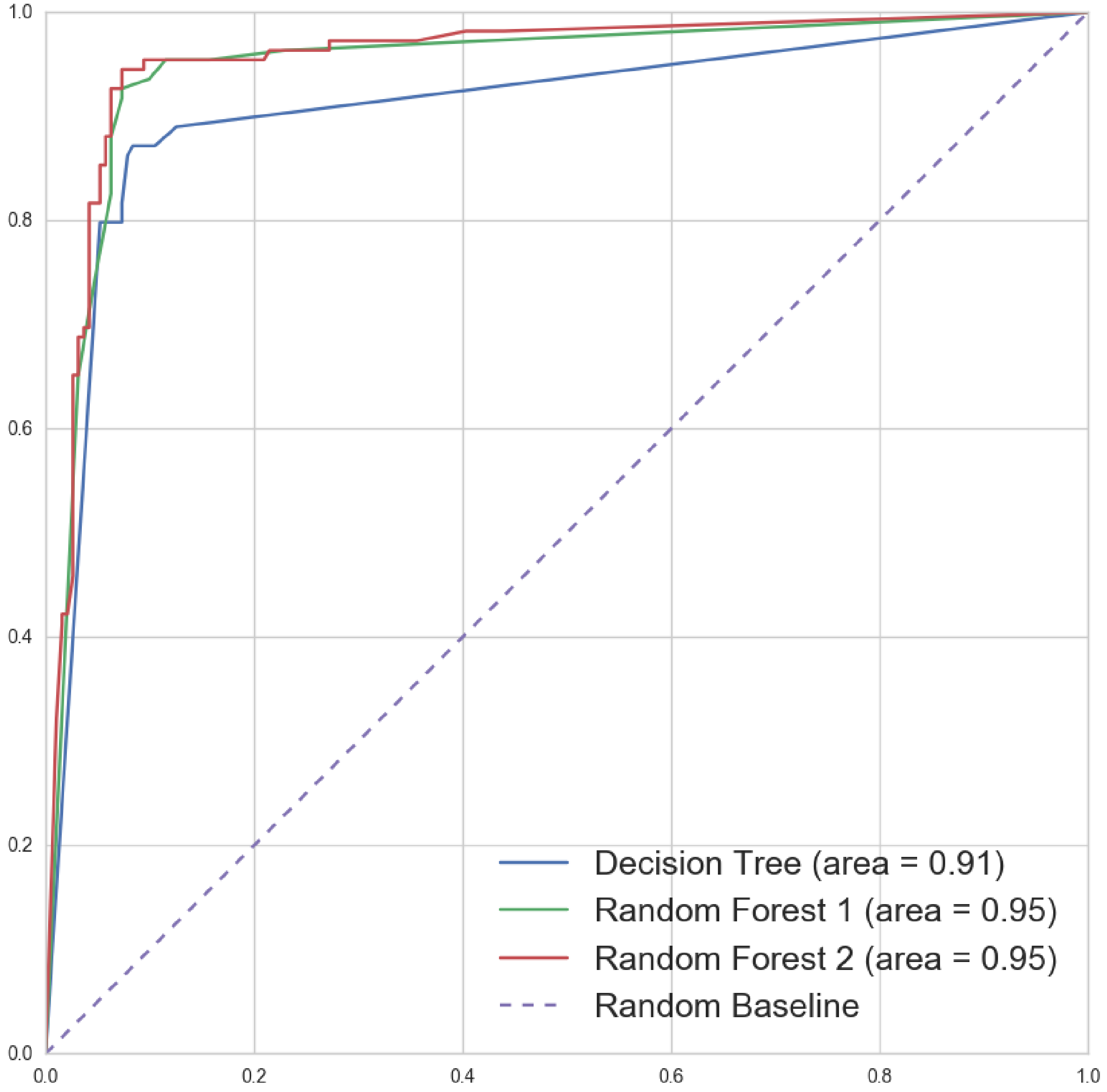
```
0.9548489360680148
```

In [248]:

```
fpr_rf_custom, tpr_rf_custom, thresholds_rf_custom = roc_curve(Y_test, rf_cust
om_test_preds)
```

In [249]:

```
plt.plot(fpr_decision_tree, tpr_decision_tree, label='Decision Tree (area = %0.2f)' % dt_roc)
plt.plot(fpr_rf, tpr_rf, label='Random Forest 1 (area = %0.2f)' % rf_roc)
plt.plot(fpr_rf_custom, tpr_rf_custom, label='Random Forest 2 (area = %0.2f)' % rf_custom_roc)
plt.plot(fpr_rand, tpr_rand, linestyle='--', label='Random Baseline')
plt.legend(loc='lower right', prop={'size':18})
plt.show()
```



Gradient Boosting Classifier

In [250]:

```
gbc = GradientBoostingClassifier(learning_rate=0.1, n_estimators=500, max_depth=5)
```

In [251]:

```
gbc.fit(X_train, Y_train)
gbc_test_preds = gbc.predict_proba(X_test)[:, 1]
```

In [252]:

```
gbc_test_preds = gbc.predict_proba(X_test)[:, 1]
gbc_preds = gbc.predict(X_test)
```

In [253]:

```
print (pd.crosstab(index=Y_test, columns=gbc_preds, rownames=['True'], colname
s=['Predicted']))
```

```
Predicted    0   1
True              
0          176  15
1           15  94
```

In [254]:

```
gbc_roc = roc_auc_score(Y_test, gbc_test_preds)
roc_auc_score(Y_test, gbc_test_preds)
```

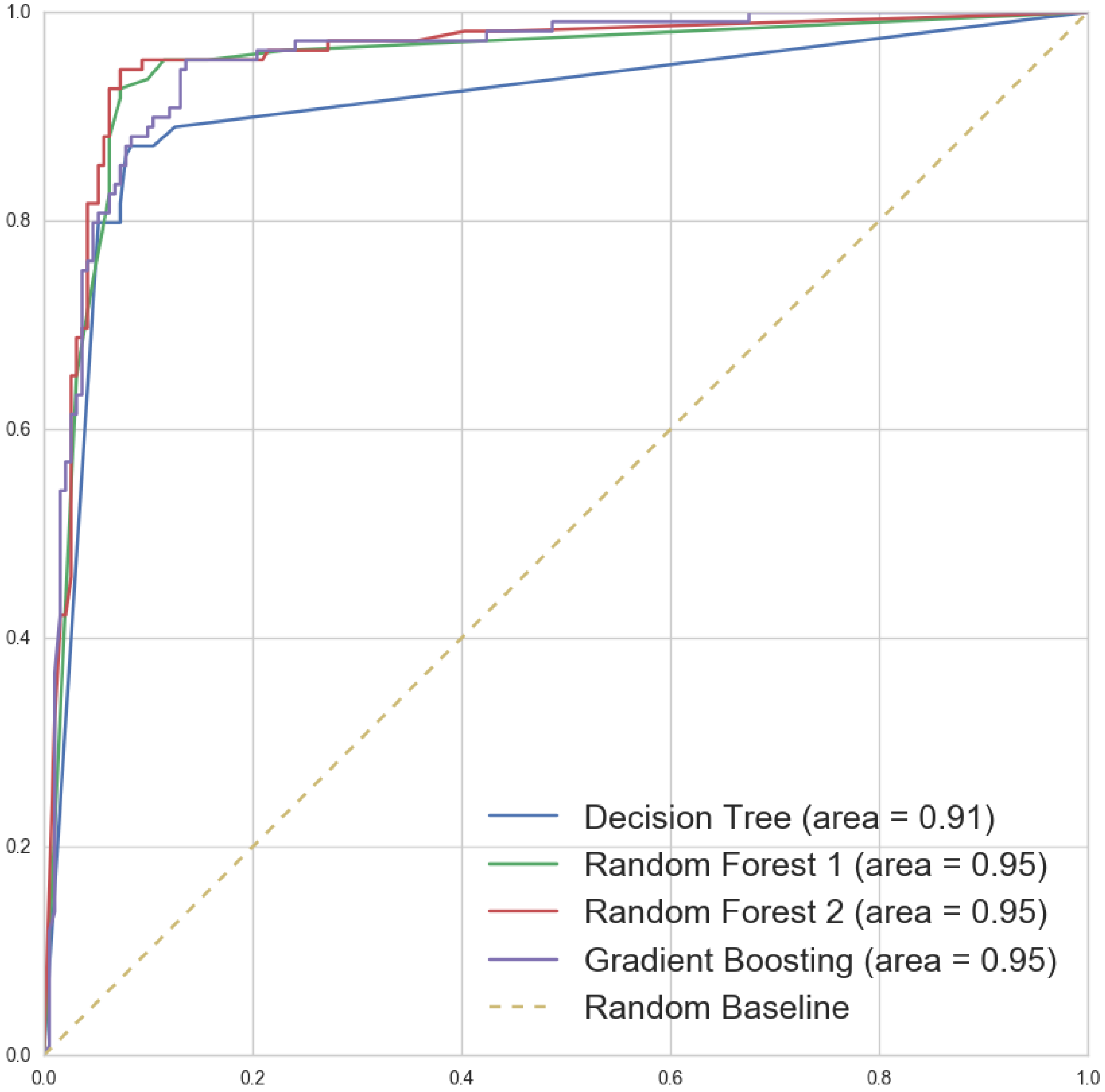
Out[254]:

```
0.95194293674047747
```

In [255]:

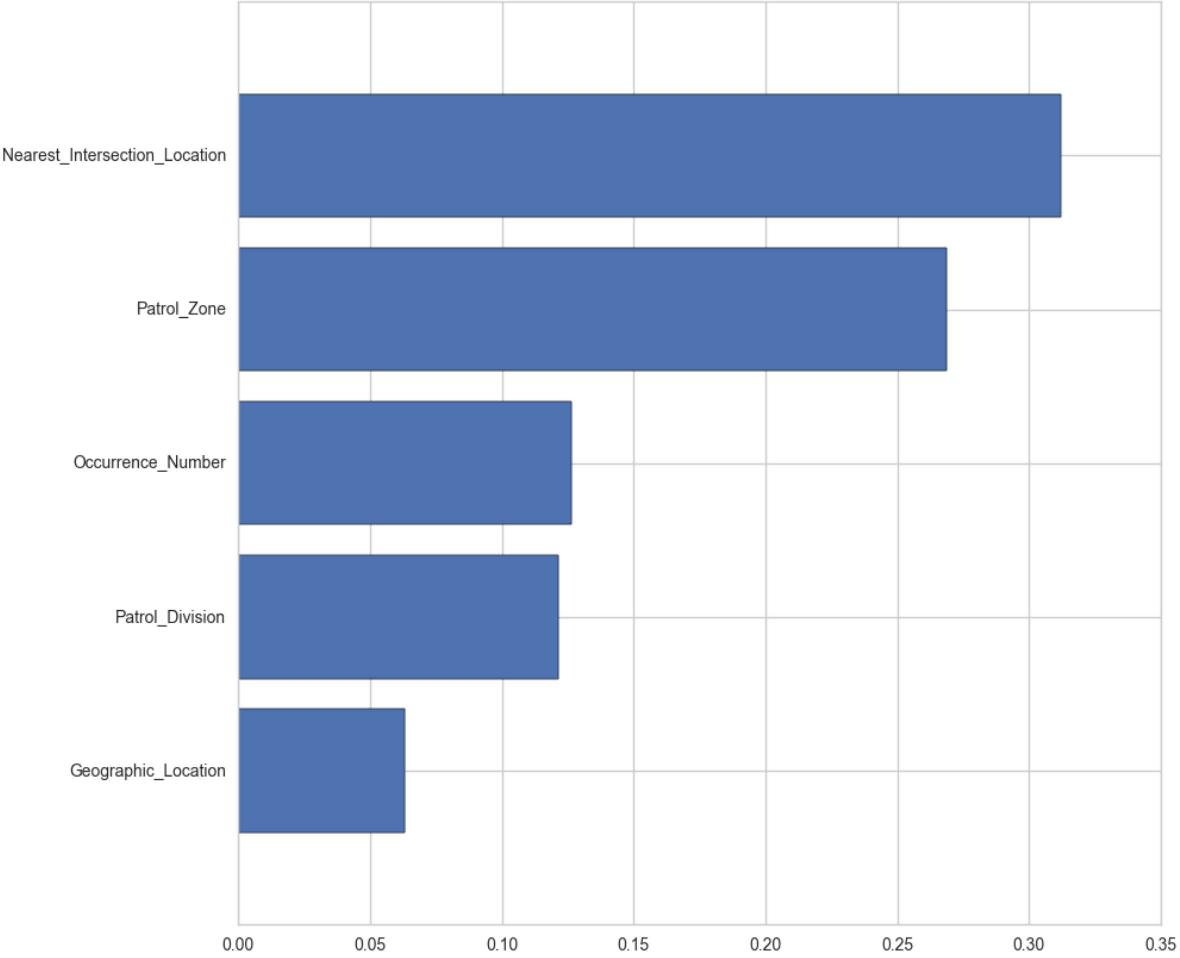
```
fpr_gbc, tpr_gbc, thresholds_gbc = roc_curve(Y_test, gbc_test_preds)
```

In [256]:
```
plt.plot(fpr_decision_tree, tpr_decision_tree, label='Decision Tree (area = %
0.2f)' % dt_roc)
plt.plot(fpr_rf, tpr_rf, label='Random Forest 1 (area = %0.2f)' % rf_roc)
plt.plot(fpr_rf_custom, tpr_rf_custom, label='Random Forest 2 (area = %0.2f)'
% rf_custom_roc)
plt.plot(fpr_gbc, tpr_gbc, label='Gradient Boosting (area = %0.2f)' % gbc_roc)
plt.plot(fpr_rand, tpr_rand, linestyle='--', label='Random Baseline')
plt.legend(loc='lower right', prop={'size':18})
plt.show()
```



In [257]:

```
gbc_importances = gbc.feature_importances_
sorted_indices = np.argsort(gbc_importances)
y_pos = range(len(gbc_importances))
plt.barh(y_pos, gbc_importances[sorted_indices], align='center')
plt.barh(y_pos, gbc_importances[sorted_indices], align='center')
plt.yticks(y_pos, X_cols[sorted_indices])
plt.show()
```



Support Vector Machine (SVM)

In [258]:

```
clf = SVC(C=1.0, probability=True)
clf
```

Out[258]:

```
SVC(C=1.0, cache_size=200, class_weight=None, coef0=0.0,
  decision_function_shape=None, degree=3, gamma='auto', kernel='rbf',
  max_iter=-1, probability=True, random_state=None, shrinking=True,
  tol=0.001, verbose=False)
```

In [259]:

```
X_train.shape
```

Out[259]:

```
(699, 5)
```

```
In [260]: Y_train.shape
```

```
Out[260]: (699,)
```

```
In [261]: SVC(C=1.0, cache_size=200, class_weight=None, coef0=0.0, degree=3, kernel='rb
          f', max_iter=-1,
              probability=True, random_state=None,
          shrinking=True, tol=0.001, verbose=False)
```

```
Out[261]: SVC(C=1.0, cache_size=200, class_weight=None, coef0=0.0,
            decision_function_shape=None, degree=3, gamma='auto', kernel='rbf',
            max_iter=-1, probability=True, random_state=None, shrinking=True,
            tol=0.001, verbose=False)
```

```
In [262]: clf.fit(X_train, Y_train)
```

```
Out[262]: SVC(C=1.0, cache_size=200, class_weight=None, coef0=0.0,
            decision_function_shape=None, degree=3, gamma='auto', kernel='rbf',
            max_iter=-1, probability=True, random_state=None, shrinking=True,
            tol=0.001, verbose=False)
```

```
In [263]: svm_test_preds = clf.predict_proba(X_test)[:, 1]
          svm_preds = clf.predict(X_test)
```

```
In [264]: print (pd.crosstab(index=Y_test, columns=svm_preds, rownames=['True'], colname
          s=['Predicted']))
```

```
          Predicted    0   1
          True
          0          160  31
          1           11  98
```

```
In [265]: svm_roc = roc_auc_score(Y_test, svm_test_preds)
          roc_auc_score(Y_test, svm_test_preds)
```

```
Out[265]: 0.93839761756088191
```

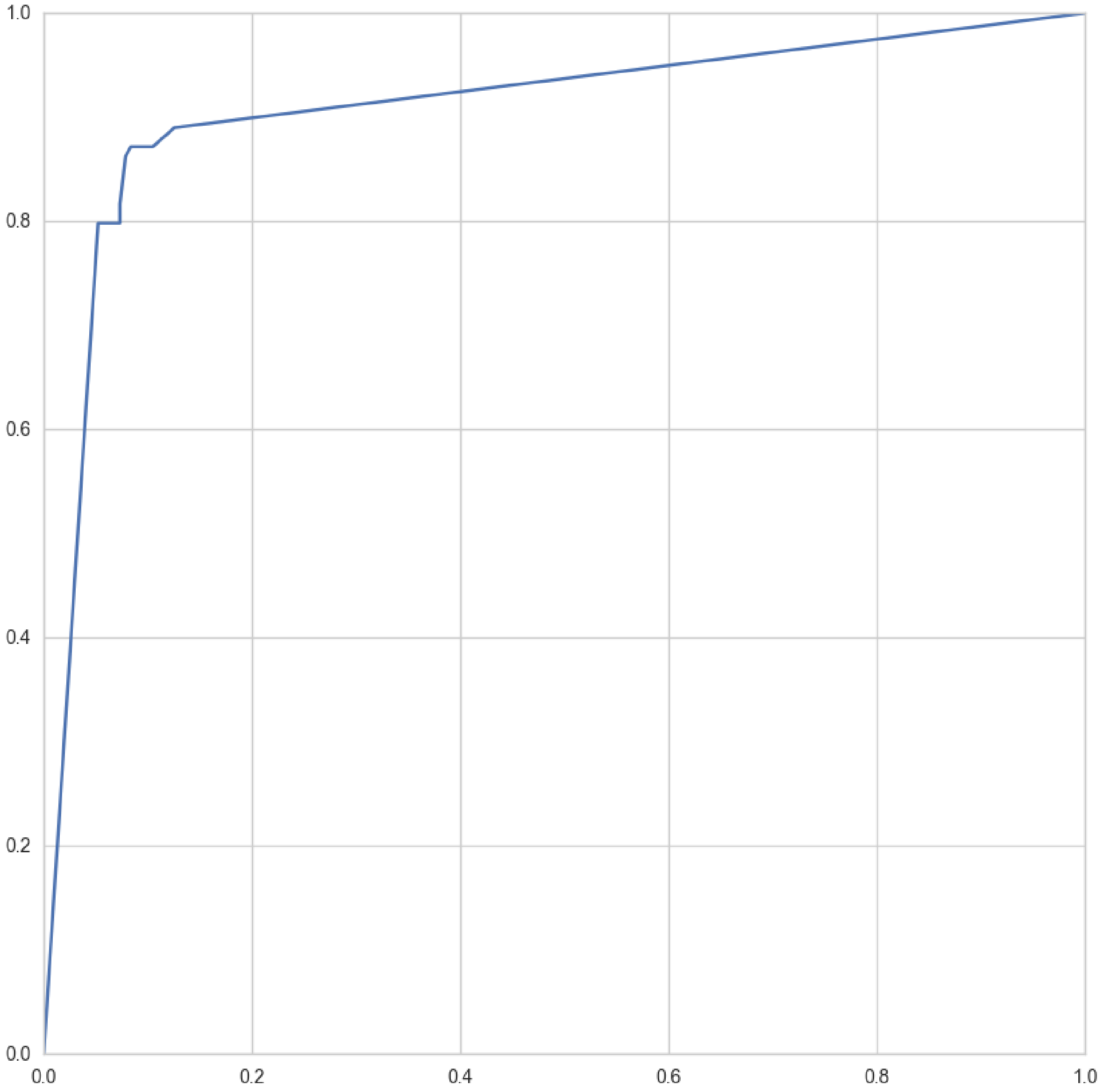
```
In [266]: fpr_svm, tpr_smv, thresholds_smv = roc_curve(Y_test, svm_test_preds)
```

In [267]:

```
plt.plot(fpr_decision_tree, tpr_decision_tree, label='Decision Tree (area = %
0.2f)' % dt_roc)
```

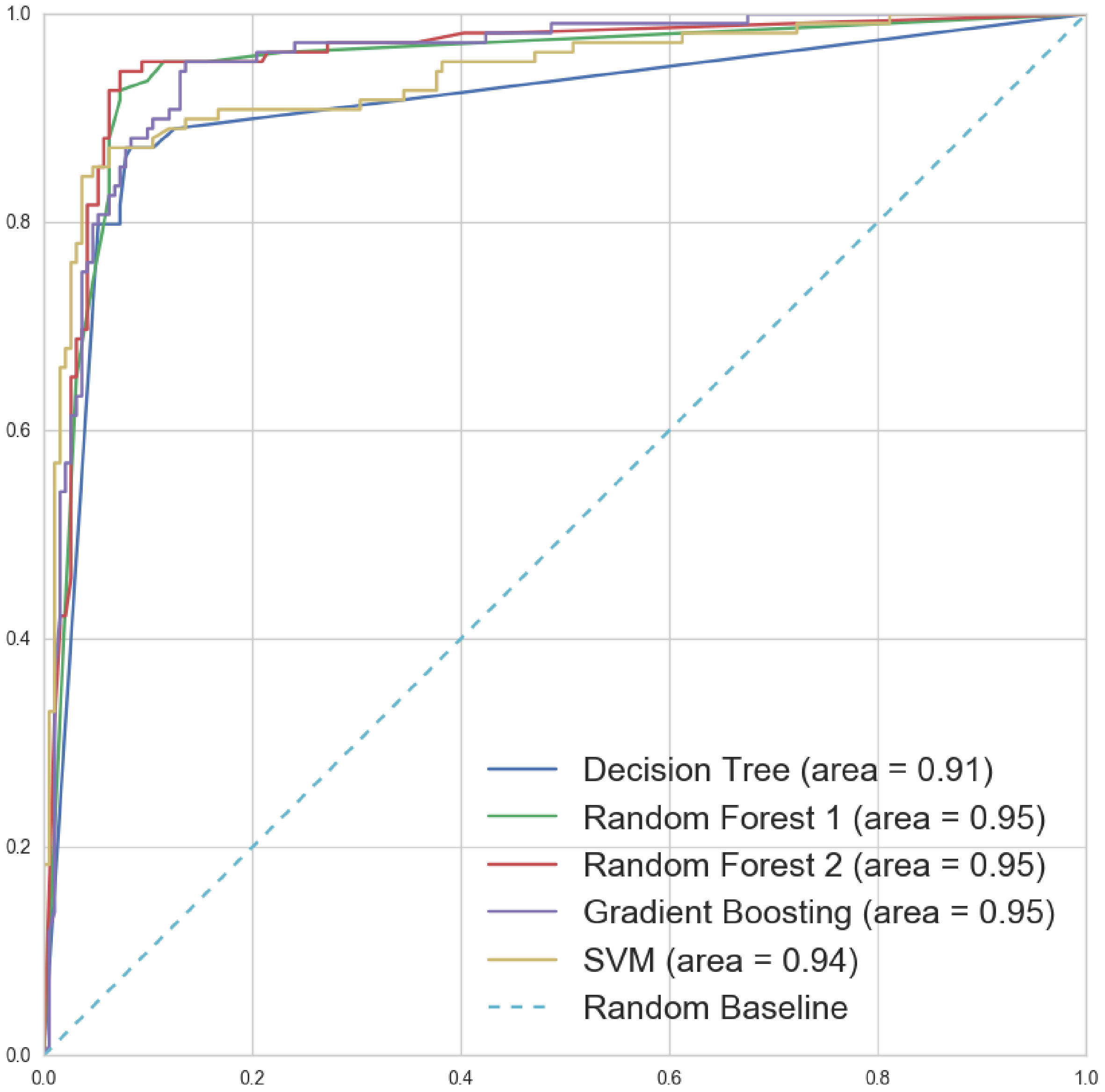
Out[267]:

```
[<matplotlib.lines.Line2D at 0x2cab884beb8>]
```



In [268]:

```
plt.plot(fpr_decision_tree, tpr_decision_tree, label='Decision Tree (area = %
0.2f)' % dt_roc)
plt.plot(fpr_rf, tpr_rf, label='Random Forest 1 (area = %0.2f)' % rf_roc)
plt.plot(fpr_rf_custom, tpr_rf_custom, label='Random Forest 2 (area = %0.2f)'
% rf_custom_roc)
plt.plot(fpr_gbc, tpr_gbc, label='Gradient Boosting (area = %0.2f)' % gbc_roc)
plt.plot(fpr_svm, tpr_smv, label='SVM (area = %0.2f)' % svm_roc)
plt.plot(fpr_rand, tpr_rand, linestyle='--', label='Random Baseline')
plt.legend(loc='lower right', prop={'size':18})
plt.show()
```



Which feature is most important?

Extra Tree Clasifier

In [269]:

```
et = ExtraTreesClassifier(n_estimators=500)
```

In [270]:

```
et.fit(X_train, Y_train)
et_test_preds = et.predict_proba(X_test)[:, 1]
et_preds = et.predict(X_test)
```

In [271]:

```
print (pd.crosstab(index=Y_test, columns=et_preds, rownames=['True'],
colnames=['Predicted']))
```

```
Predicted    0   1
True
0          177  14
1           14  95
```

In [272]:

```
fpr_et, tpr_et, thresholds_et = roc_curve(Y_test, et_test_preds)
```

In [273]:

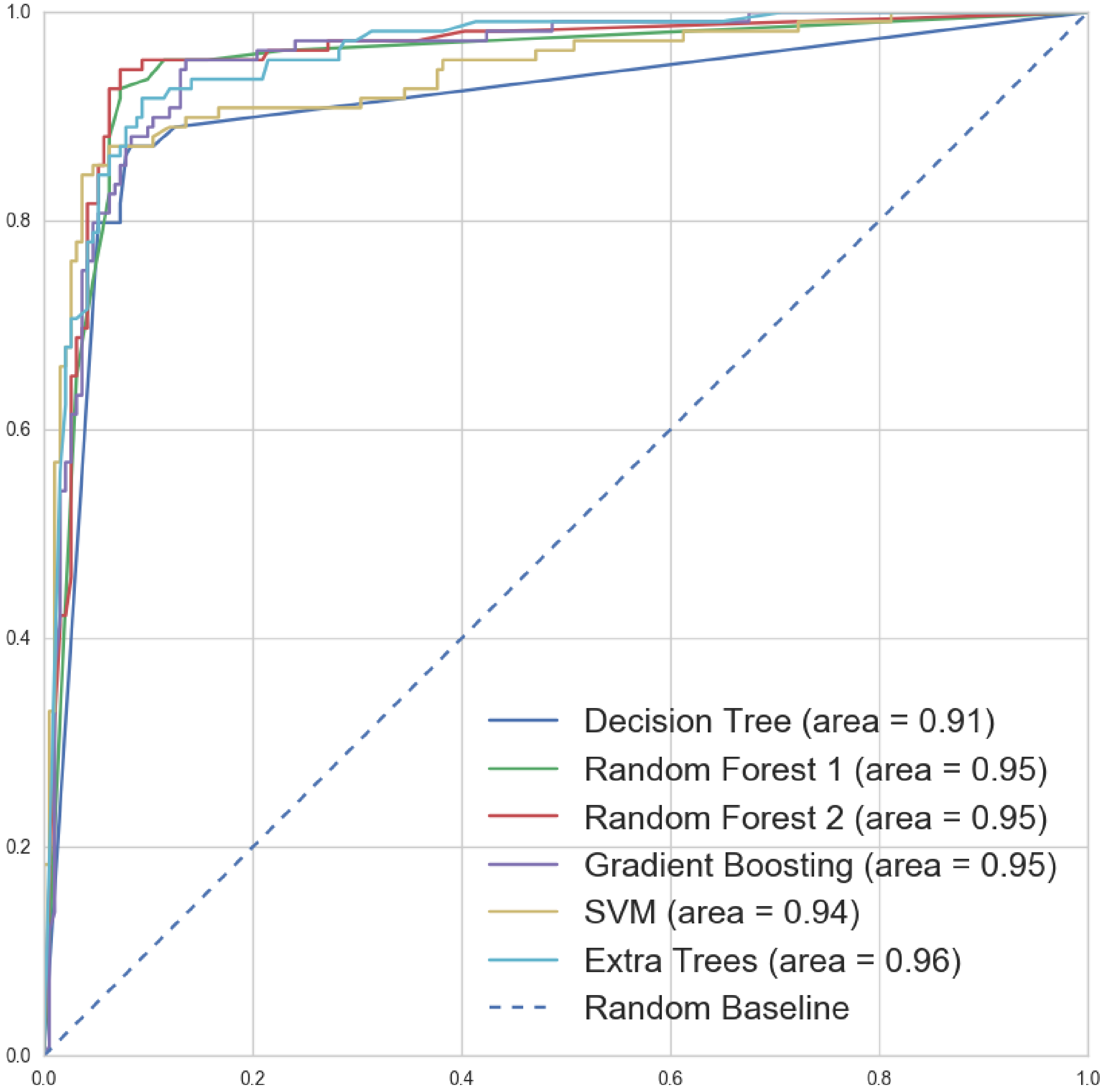
```
et_roc = roc_auc_score(Y_test, et_test_preds)
roc_auc_score(Y_test, et_test_preds)
```

Out[273]:

```
0.9562418944233632‌7
```

In [274]:

```
plt.plot(fpr_decision_tree, tpr_decision_tree, label='Decision Tree (area = %
0.2f)' % dt_roc)
plt.plot(fpr_rf, tpr_rf, label='Random Forest 1 (area = %0.2f)' % rf_roc)
plt.plot(fpr_rf_custom, tpr_rf_custom, label='Random Forest 2 (area = %0.2f)'
% rf_custom_roc)
plt.plot(fpr_gbc, tpr_gbc, label='Gradient Boosting (area = %0.2f)' % gbc_roc)
plt.plot(fpr_svm, tpr_smv, label='SVM (area = %0.2f)' % svm_roc)
plt.plot(fpr_et, tpr_et, label='Extra Trees (area = %0.2f)' % et_roc)
plt.plot(fpr_rand, tpr_rand, linestyle='--', label='Random Baseline')
plt.legend(loc='lower right', prop={'size':18})
plt.show()
```



In [275]:

```
#neural network clasificer
clfnn = MLPClassifier(solver='lbfgs', alpha=1e-5, hidden_layer_sizes=(5, 2), r
andom_state=1)
clfnn.fit(X_train, Y_train)
MLPClassifier(activation='relu', alpha=1e-05, batch_size='auto',
       beta_1=0.9, beta_2=0.999, early_stopping=False,
       epsilon=1e-08, hidden_layer_sizes=(5, 2), learning_rate='constant',
       learning_rate_init=0.001, max_iter=200, momentum=0.9,
       nesterovs_momentum=True, power_t=0.5, random_state=1, shuffle=True,
       solver='lbfgs', tol=0.0001, validation_fraction=0.1, verbose=False,
       warm_start=False)
nn_test_preds = clfnn.predict_proba(X_test)[:, 1]
nn_preds = clfnn.predict(X_test)
print (pd.crosstab(index=Y_test, columns=nn_preds, rownames=['True'],
colnames=['Predicted']))
```

```
Predicted    0   1
True
0          180  11
1           11  98
```

In [276]:

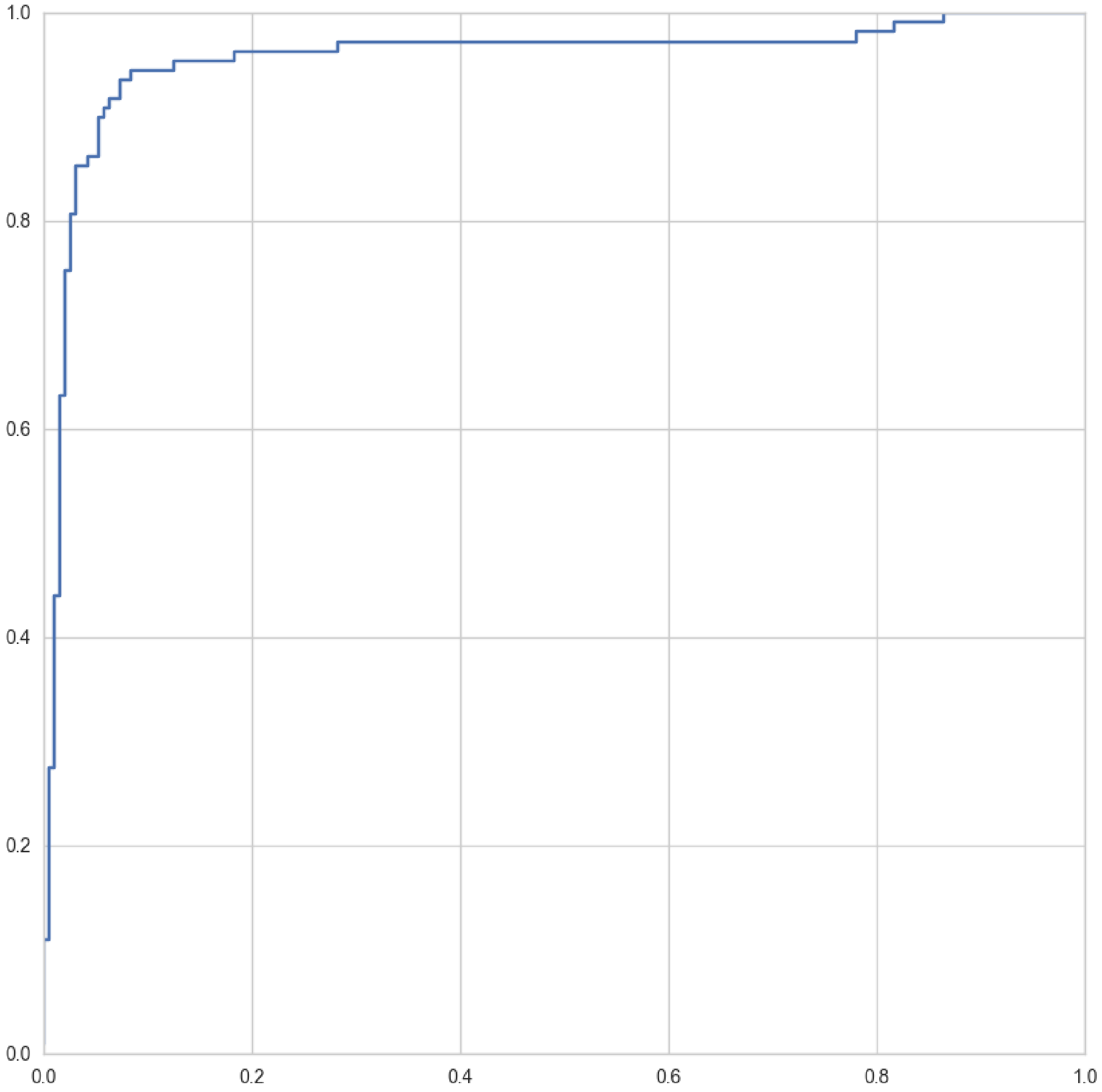
```
nn_roc = roc_auc_score(Y_test, nn_test_preds)
roc_auc_score(Y_test, nn_test_preds)
```

Out[276]:

```
0.9554733656755848З
```

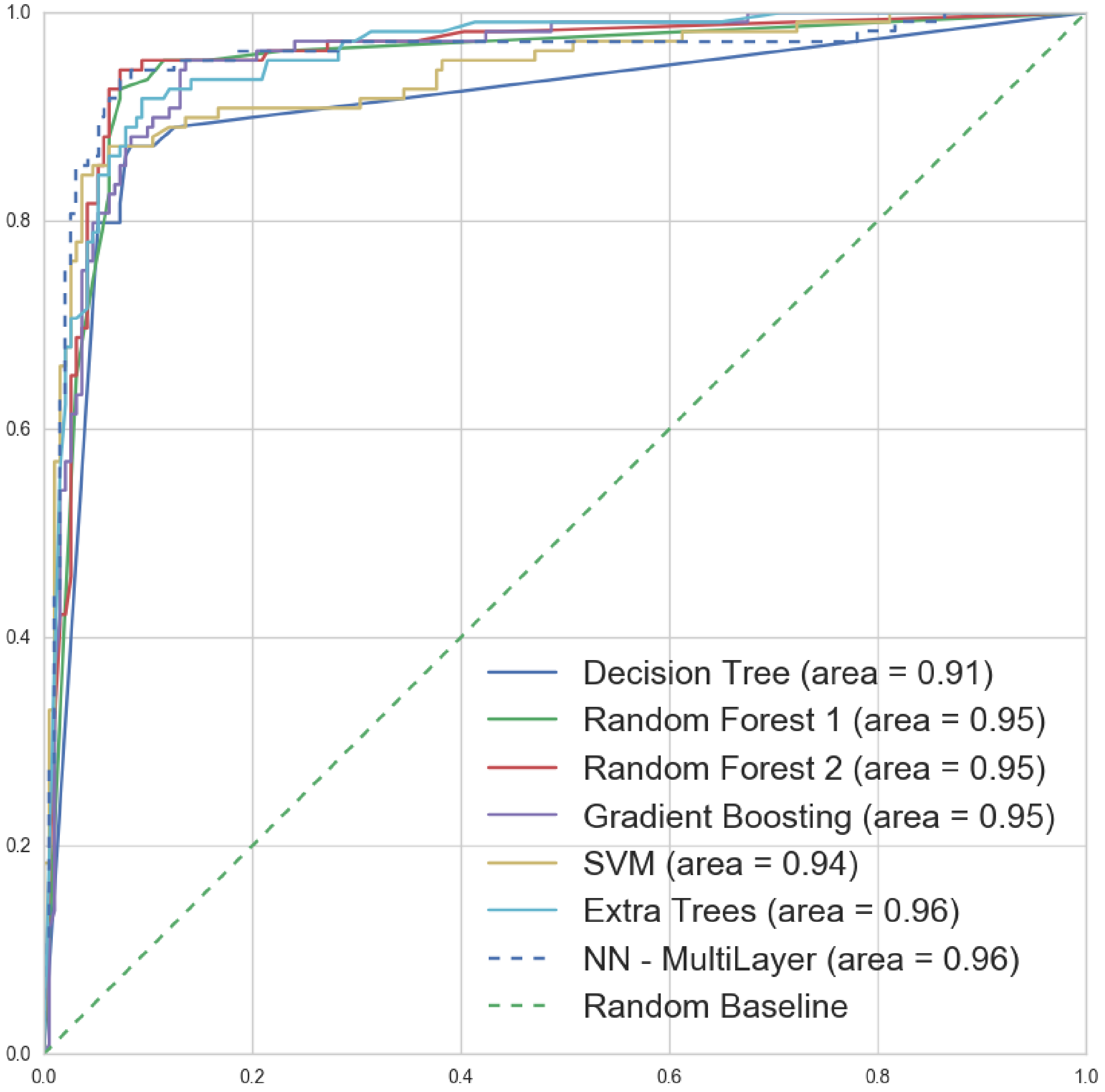
```
In [277]: fpr_nn, tpr_nn, thresholds_nn = roc_curve(Y_test, nn_test_preds)
          plt.plot(fpr_nn, tpr_nn, label='NN (area = %0.2f)' % nn_roc)
```

```
Out[277]: [<matplotlib.lines.Line2D at 0x2cab58de1d0>]
```



In [278]:

```
plt.plot(fpr_decision_tree, tpr_decision_tree, label='Decision Tree (area = %
0.2f)' % dt_roc)
plt.plot(fpr_rf, tpr_rf, label='Random Forest 1 (area = %0.2f)' % rf_roc)
plt.plot(fpr_rf_custom, tpr_rf_custom, label='Random Forest 2 (area = %0.2f)'
% rf_custom_roc)
plt.plot(fpr_gbc, tpr_gbc, label='Gradient Boosting (area = %0.2f)' % gbc_roc)
plt.plot(fpr_svm, tpr_smv, label='SVM (area = %0.2f)' % svm_roc)
plt.plot(fpr_et, tpr_et, label='Extra Trees (area = %0.2f)' % et_roc)
plt.plot(fpr_nn, tpr_nn, linestyle='--', label='NN - MultiLayer (area = %0.2f)
 nn_roc)
plt.plot(fpr_rand, tpr_rand, linestyle='--', label='Random Baseline')
plt.legend(loc='lower right', prop={'size':18})
plt.show()
```



Model ROC Summary

```
In [279]: print("ROC: %0.3f (Decision Tree)" % (dt_roc))
          print("ROC: %0.3f (Random Forest - Default Parameters)" % (rf_roc))
          print("ROC: %0.3f (Random Forest - Custom Parameters)" % (rf_custom_roc))
          print("ROC: %0.3f (Gradient Boosting)" % (gbc_roc))
          print("ROC: %0.3f (SVM)" % (svm_roc))
          print("ROC: %0.3f (Extra Trees)" % (et_roc))
          print("ROC: %0.3f (NN MultiLayer)" % (nn_roc))
```

```
ROC: 0.909 (Decision Tree)
ROC: 0.948 (Random Forest - Default Parameters)
ROC: 0.955 (Random Forest - Custom Parameters)
ROC: 0.952 (Gradient Boosting)
ROC: 0.938 (SVM)
ROC: 0.956 (Extra Trees)
ROC: 0.955 (NN MultiLayer)
```

Based on the above ROC, The Extra Trees followed by MultiLayer Neural Network are the preferred model to predict the Severity of incients