Imports

```
In [1]: import pandas as pd
        import numpy as np
        import seaborn as sns
        from collections import defaultdict
        import matplotlib.pyplot as plt
```

Read in Data

```
In [2]: df = pd.read_csv("final_data_file_with_encoding.csv")
        df.head()
```

Out[2]:

	id	anchor	target	context	score	anchor_len	target_len	section	classes	context_desc	...	spacy_total	spacy_
0	37d61fd2272659b1	44	46	A47	0.50	1	2	36	47	10103	...	0.000000	
1	7b9652b17b68b7a4	44	257	A47	0.75	1	2	36	47	10103	...	0.388094	
2	36d72442aefd8232	44	276	A47	0.25	1	2	36	47	10103	...	0.085102	
3	5296b0c19e1ce60e	44	8048	A47	0.50	1	2	36	47	10103	...	0.427271	
4	54c1e3b9184cb5b6	44	9734	A47	0.00	1	2	36	47	10103	...	0.415349	

5 rows × 40 columns

Fill in Null values

```
In [3]: df.fillna(0,inplace=True)
```

Correlation Check Among features only

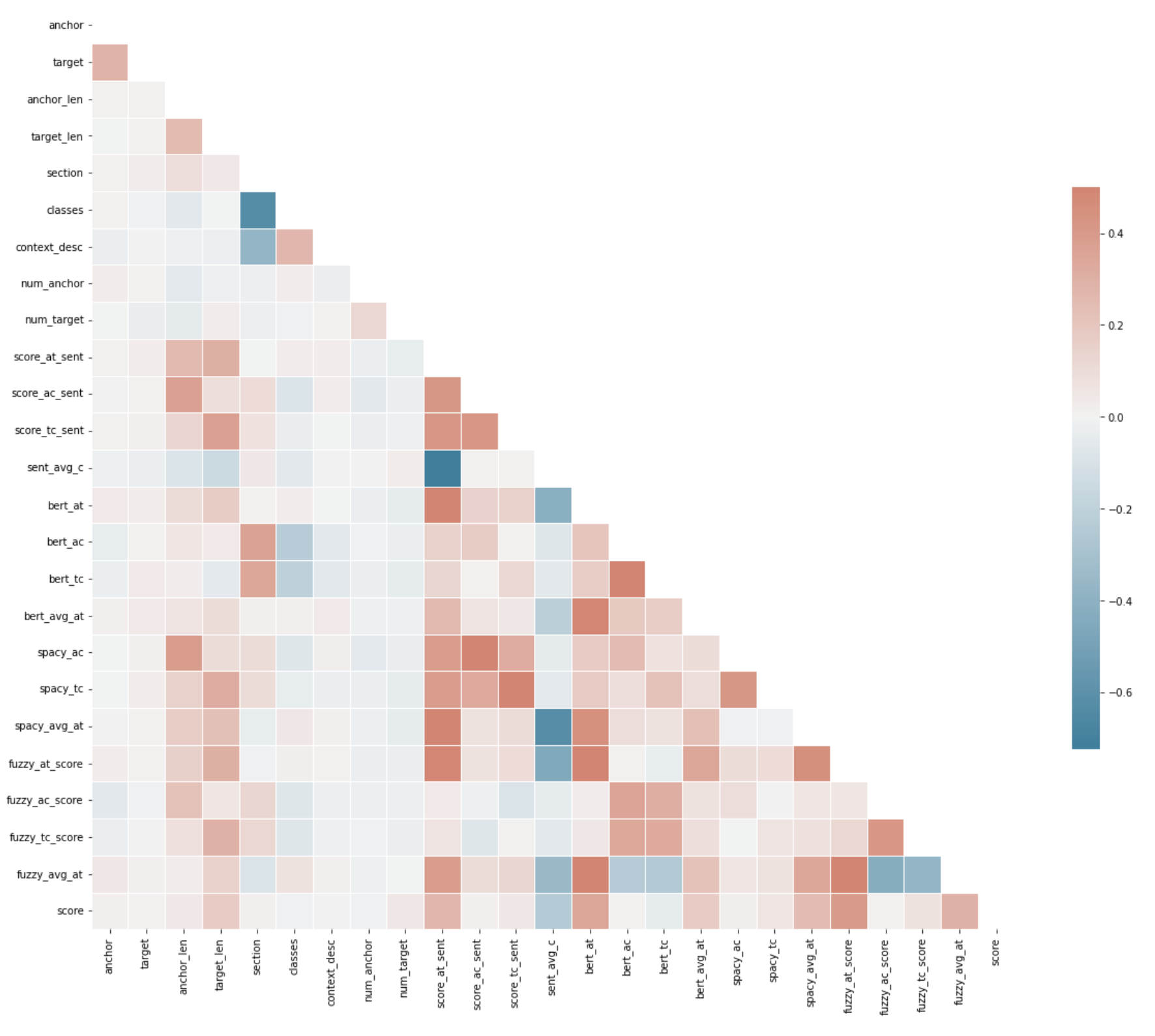
```
In [4]: features = df.drop('score',axis=1)
        # Create correlation matrix
        corr_matrix = features.corr().abs()
        # Select upper triangle of correlation matrix
        upper = corr_matrix.where(np.triu(np.ones(corr_matrix.shape), k=1).astype(np.bool))

        # Find features with correlation greater than 0.95
        to_drop = [column for column in upper.columns if any(upper[column] > 0.8)]

        # Drop features
        features.drop(to_drop, axis=1, inplace=True)
```

```
/var/folders/13/5qrysg6938s14gxnpjdn6b540000gn/T/ipykernel_12737/3226852571.py:5: DeprecationWarning: `np.bool` is a deprecated alias for the builtin `bool`. To silence this warning, use `bool` by itself. Doing this will no
t modify any behavior and is safe. If you specifically wanted the numpy scalar type, use `np.bool_` here.
Deprecated in NumPy 1.20; for more details and guidance: https://numpy.org/devdocs/release/1.20.0-notes.html#de
precations
  upper = corr_matrix.where(np.triu(np.ones(corr_matrix.shape), k=1).astype(np.bool))
```

```
In [5]: df_2 = features
        df_2['score'] = df['score']
```

```
In [6]: correlation_matrix = df_2.corr(method='spearman')
        mask = np.triu(np.ones_like(correlation_matrix, dtype=bool))
        f, ax = plt.subplots(figsize=(20, 20))
        cmap = sns.diverging_palette(230, 20, as_cmap=True)
        sns.heatmap(correlation_matrix, mask=mask, cmap=cmap, vmax=.5, center=0, square=True, linewidths=.5, cbar_kws={
```

Out[6]: <AxesSubplot:>



Get the features that have a positive correlation with score

```
In [7]: indecies_pos = np.where(correlation_matrix['score'] > 0)
        improved_features_pos = correlation_matrix.iloc[indecies_pos].drop('score')
        improved_features_pos['score']
```

```
Out[7]: anchor            0.012513
        target            0.005400
        anchor_len        0.043443
        target_len        0.179157
        section           0.012529
        num_target        0.047326
        score_at_sent     0.267441
        score_ac_sent     0.012725
        score_tc_sent     0.046938
        bert_at           0.353972
        bert_ac           0.008446
        bert_avg_at       0.177569
        spacy_ac          0.017530
        spacy_tc          0.054077
        spacy_avg_at      0.246161
        fuzzy_at_score    0.403842
        fuzzy_ac_score    0.010377
        fuzzy_tc_score    0.069892
        fuzzy_avg_at      0.294686
        Name: score, dtype: float64
```

Features to be used in model

```
In [8]: feats = list(improved_features_pos.index)
```

Model Evaluation

```
In [9]: x = df[feats].values
        y = df['score'].values
```

Random Forest

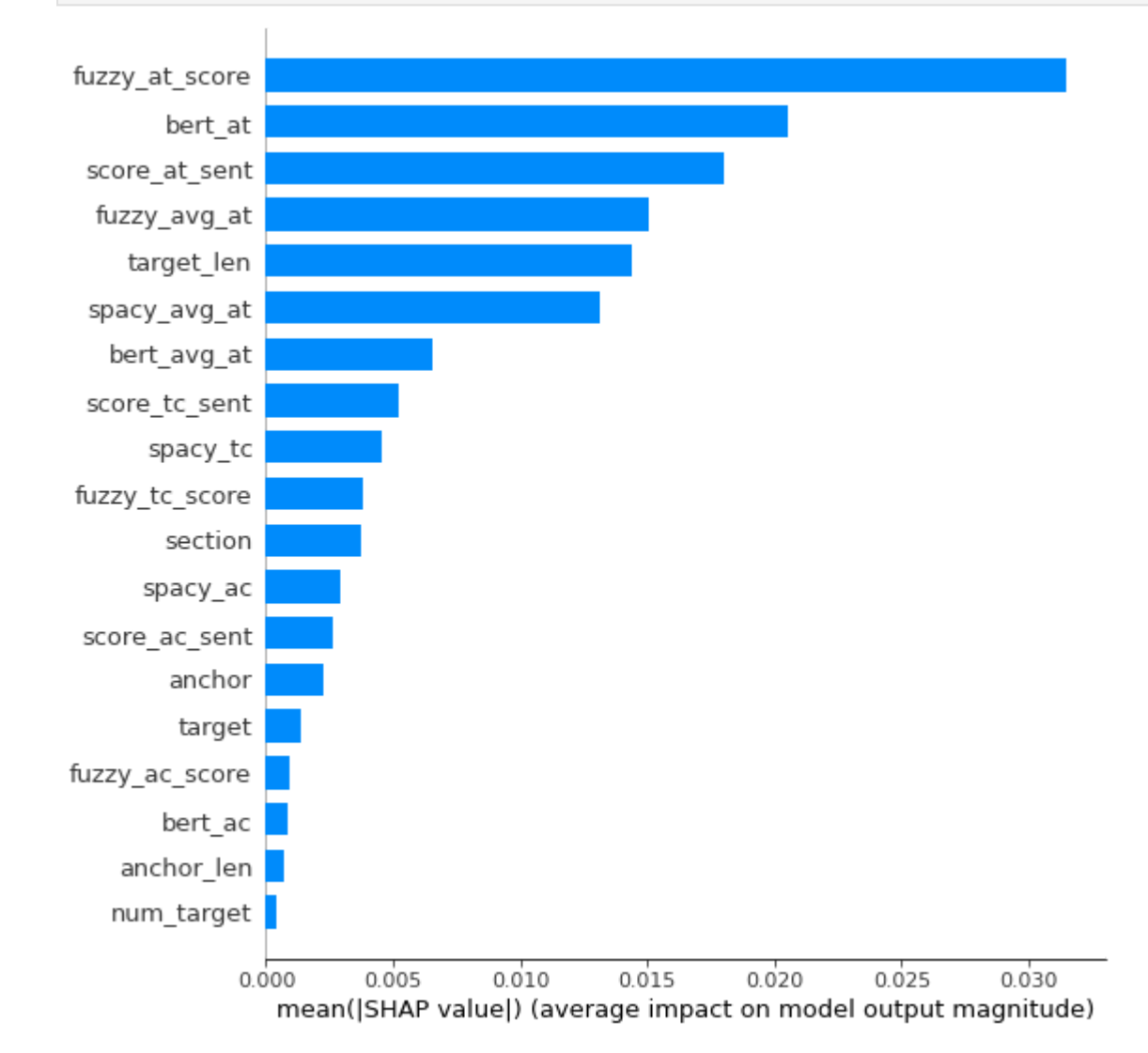
```
In [10]: from sklearn.model_selection import KFold
         kf = KFold(n_splits=5,shuffle=True,random_state=141)
         kf.get_n_splits(x)
         print(kf)
         mse_arr = []
         mape_arr = []
         rmse_arr = []
         mae_arr = []
         for train_index, test_index in kf.split(x):
             print("TRAIN:", train_index, "TEST:", test_index)
             x_train, x_test = x[train_index], x[test_index]
             y_train, y_test = y[train_index], y[test_index]
             from sklearn.ensemble import RandomForestRegressor
             clf = RandomForestRegressor(random_state=141,n_estimators = 1000,
                                         min_samples_split= 10,
                                         min_samples_leaf= 2,
                                         max_features= 'sqrt',
                                         max_depth= 10,
                                         bootstrap= True)
             clf.fit(x_train,y_train)
             from sklearn.metrics import r2_score, mean_absolute_error, mean_squared_error
             y_pred = clf.predict(x_test)
             #y_pred = [x_round(i) for i in y_pred]
             mse = mean_squared_error(y_test, y_pred)
             mape = r2_score(y_test,y_pred)
             rmse = mean_squared_error(y_test, y_pred,squared=False)
             mae = mean_absolute_error(y_test,y_pred)
             print("Mean Square Error: {} \nRoot Mean Squared Error: {} \nMean Absolute Error: {} \nR-Squared: {} ".form
             mse_arr.append(mse)
             mape_arr.append(mape)
             rmse_arr.append(rmse)
             mae_arr.append(mae)
```

```
KFold(n_splits=5, random_state=141, shuffle=True)
TRAIN: [    0     2     3 ... 36470 36471 36472] TEST: [    1     4     9 ... 36449 36453 36457]
Mean Square Error: 0.04332968134597487
Root Mean Squared Error: 0.2081578279718898
Mean Absolute Error: 0.15871597383981748
R-Squared: 0.3469226373696688
TRAIN: [    1     2     3 ... 36470 36471 36472] TEST: [    0     6    10 ... 36455 36456 36467]
Mean Square Error: 0.0434745273703186
Root Mean Squared Error: 0.20850546124818553
Mean Absolute Error: 0.15964243865029965
R-Squared: 0.35877208883904155
TRAIN: [    0     1     2 ... 36468 36471 36472] TEST: [    5    12    23 ... 36464 36469 36470]
Mean Square Error: 0.04374850360668626
Root Mean Squared Error: 0.20916142953873273
Mean Absolute Error: 0.16070461523204702
R-Squared: 0.33720499704293905
TRAIN: [    0     1     3 ... 36469 36470 36472] TEST: [    2     7     8 ... 36465 36466 36471]
Mean Square Error: 0.04400460535992982
Root Mean Squared Error: 0.20977274694280432
Mean Absolute Error: 0.16211050193945112
R-Squared: 0.3274363132542043
TRAIN: [    0     1     2 ... 36469 36470 36471] TEST: [    3    24    27 ... 36462 36468 36472]
Mean Square Error: 0.04400211729791756
Root Mean Squared Error: 0.20976681648420362
Mean Absolute Error: 0.16204540453058333
R-Squared: 0.3535814887278925
```

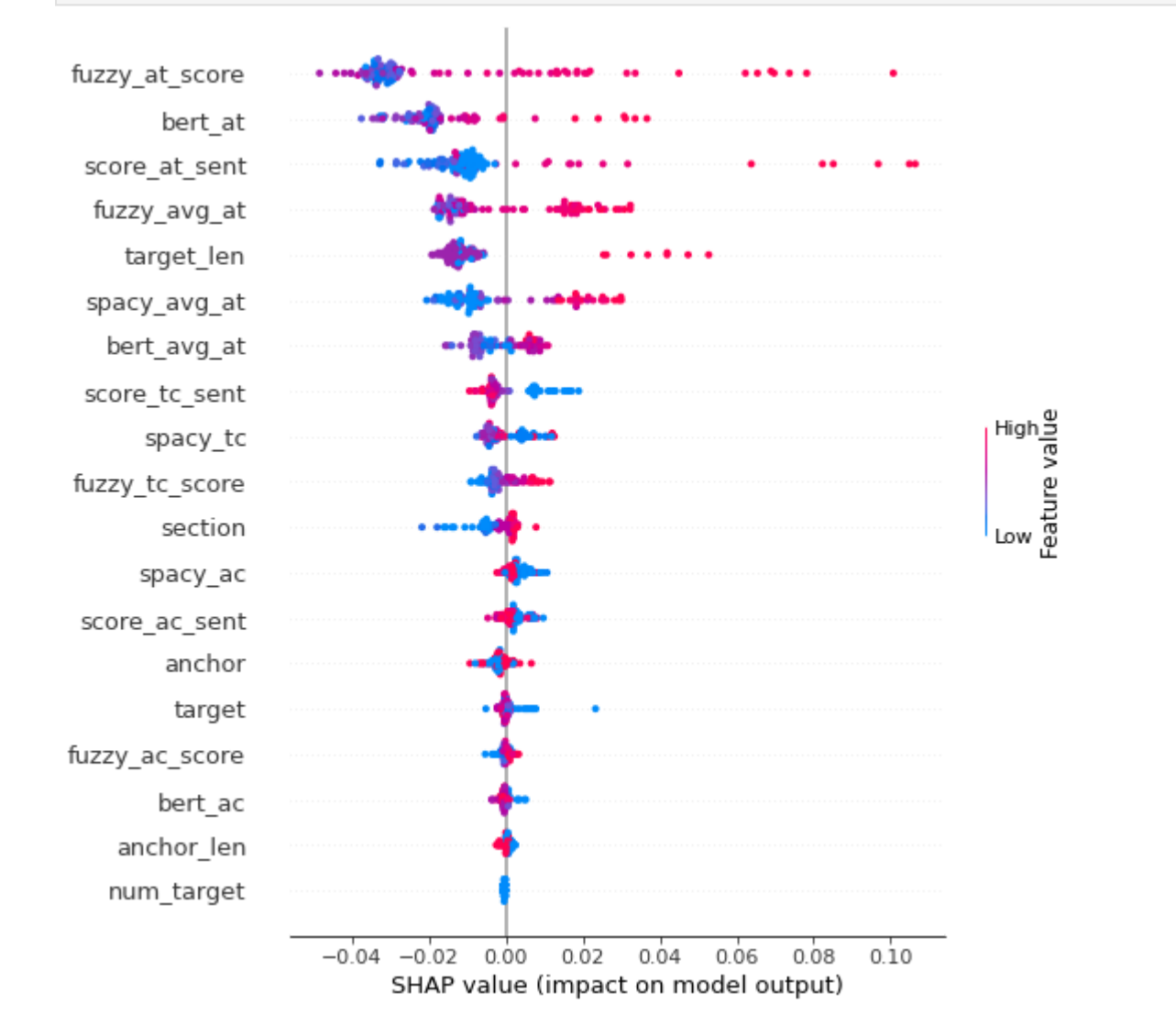
```
In [11]: print("Mean Square Error: {} \nRoot Mean Squared Error: {} \nMean Absolute Error: {} \nR-Squared: {} ".format(n
```

```
Mean Square Error: 0.04371188699616542
Root Mean Squared Error: 0.2090728564371632
Mean Absolute Error: 0.16064378683843972
R-Squared: 0.34478350504674926
```

```
In [12]: import shap
         shap_values = shap.TreeExplainer(clf).shap_values(x_train[:100])
         shap.summary_plot(shap_values, x_train[:100], plot_type="bar",feature_names=feats)
```

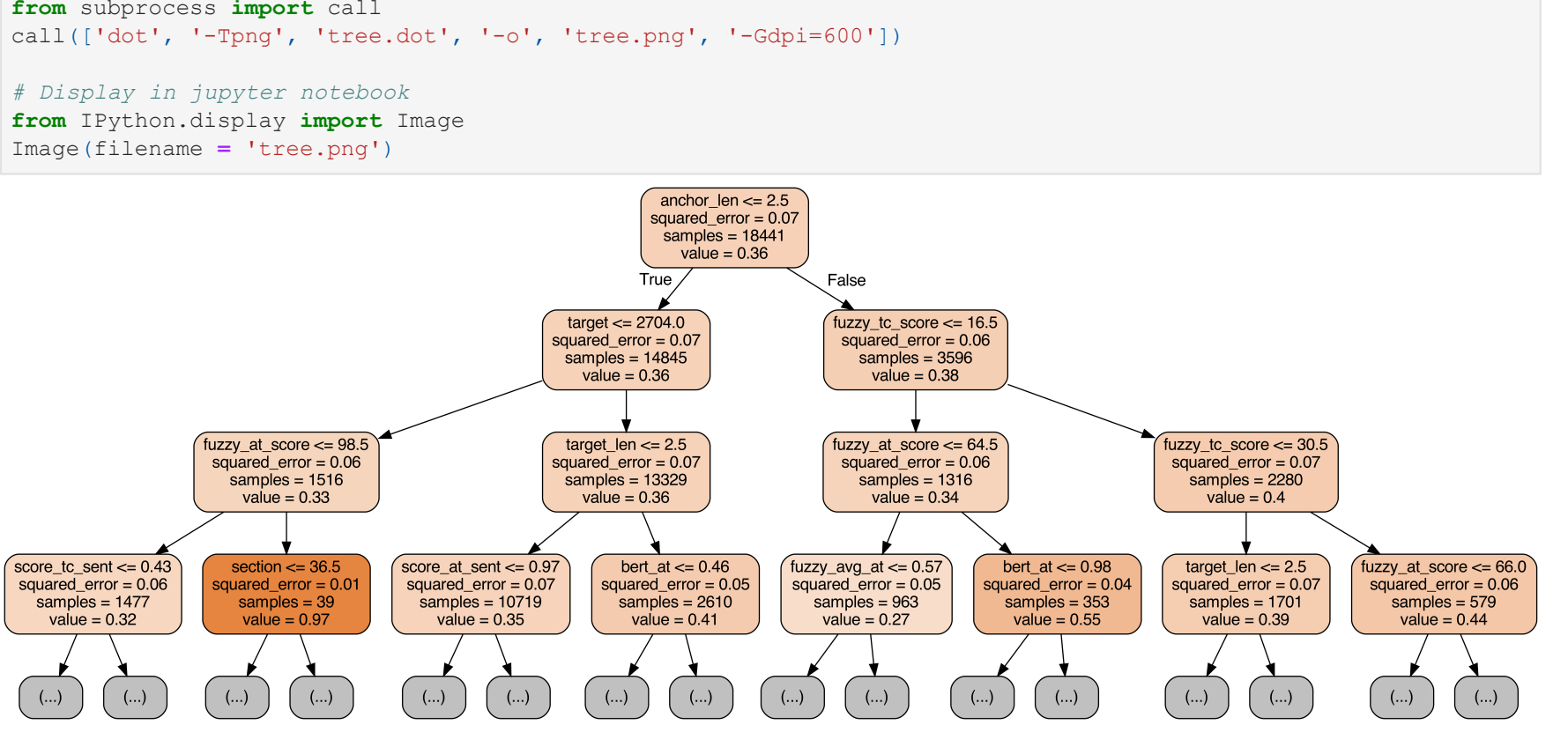



```
In [13]: shap.summary_plot(shap_values, x_train[:100],feature_names=feats)
```




```
In [14]: from sklearn.tree import export_graphviz
         # Export as dot file
         export_graphviz(clf.estimators_[1], out_file='tree.dot',
                         feature_names = feats,
                         max_depth = 3,
                         rounded = True, proportion = False,
                         precision = 2, filled = True)

         # Convert to png using system command (requires Graphviz)
         from subprocess import call
         call(['dot', '-Tpng', 'tree.dot', '-o', 'tree.png', '-Gdpi=600'])

         # Display in jupyter notebook
         from IPython.display import Image
         Image(filename = 'tree.png')
```

Out[14]:



CatBoostRegressor

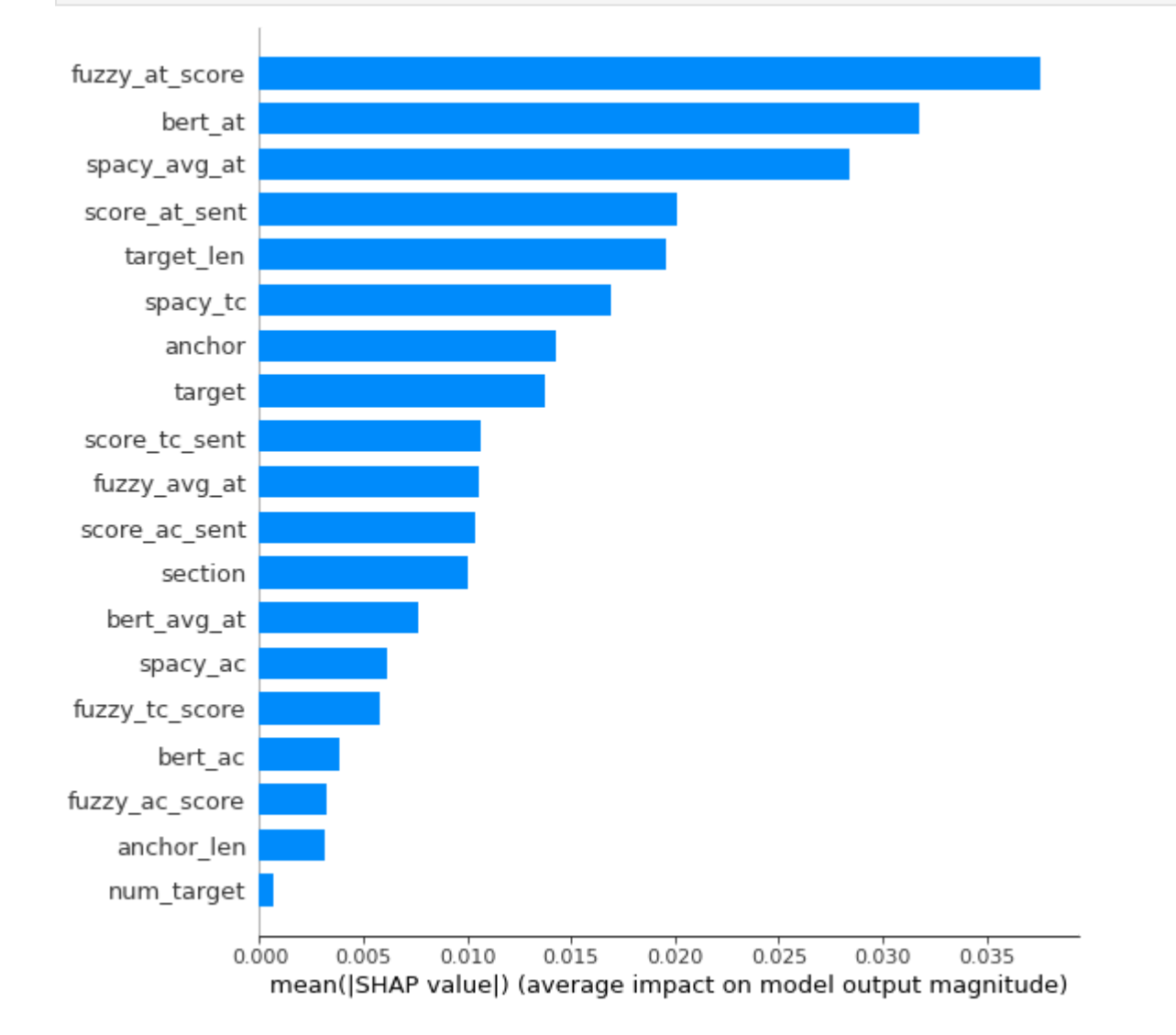
```
In [15]: from sklearn.model_selection import KFold
         kf = KFold(n_splits=5,shuffle=True,random_state=141)
         kf.get_n_splits(x)
         print(kf)
         mse_arr = []
         mape_arr = []
         rmse_arr = []
         mae_arr = []
         for train_index, test_index in kf.split(x):
             print("TRAIN:", train_index, "TEST:", test_index)
             x_train, x_test = x[train_index], x[test_index]
             y_train, y_test = y[train_index], y[test_index]
             from catboost import CatBoostRegressor
             cat_base = CatBoostRegressor(
                 eval_metric='MAE'
             )
             cbf = cat_base.fit(x_train, y_train, silent=True)
             from sklearn.metrics import r2_score, mean_absolute_error, mean_squared_error
             y_pred = cbf.predict(x_test)
             mse = mean_squared_error(y_test, y_pred)
             mape = r2_score(y_test,y_pred)
             rmse = mean_squared_error(y_test, y_pred,squared=False)
             mae = mean_absolute_error(y_test,y_pred)
             mse_arr.append(mse)
             mape_arr.append(mape)
             rmse_arr.append(rmse)
             mae_arr.append(mae)
             print("Mean Square Error: {} \nRoot Mean Squared Error: {} \nMean Absolute Error: {} \nR-Squared: {} ".form
```

```
KFold(n_splits=5, random_state=141, shuffle=True)
TRAIN: [    0     2     3 ... 36470 36471 36472] TEST: [    1     4     9 ... 36449 36453 36457]
Mean Square Error: 0.041165460430935025
Root Mean Squared Error: 0.20289273134081226
Mean Absolute Error: 0.15712721196240012
R-Squared: 0.3795423946223937
TRAIN: [    1     2     3 ... 36470 36471 36472] TEST: [    0     6    10 ... 36455 36456 36467]
Mean Square Error: 0.04127107711710196
Root Mean Squared Error: 0.2031528417647707
Mean Absolute Error: 0.15739139636708716
R-Squared: 0.39127189708725796
TRAIN: [    0     1     2 ... 36468 36471 36472] TEST: [    5    12    23 ... 36464 36469 36470]
Mean Square Error: 0.04107577752520238
Root Mean Squared Error: 0.202671600194 0143
Mean Absolute Error: 0.1565620470823163
R-Squared: 0.3776971132306519
TRAIN: [    0     1     3 ... 36469 36470 36472] TEST: [    2     7     8 ... 36465 36466 36471]
Mean Square Error: 0.041558885898949884
Root Mean Squared Error: 0.20385996639593043
Mean Absolute Error: 0.1592277430000668
R-Squared: 0.36481653934573155
TRAIN: [    0     1     2 ... 36469 36470 36471] TEST: [    3    24    27 ... 36462 36468 36472]
Mean Square Error: 0.041070978197104126
Root Mean Squared Error: 0.2026597596887555
Mean Absolute Error: 0.1580952808716972
R-Squared: 0.39664174787521667
```

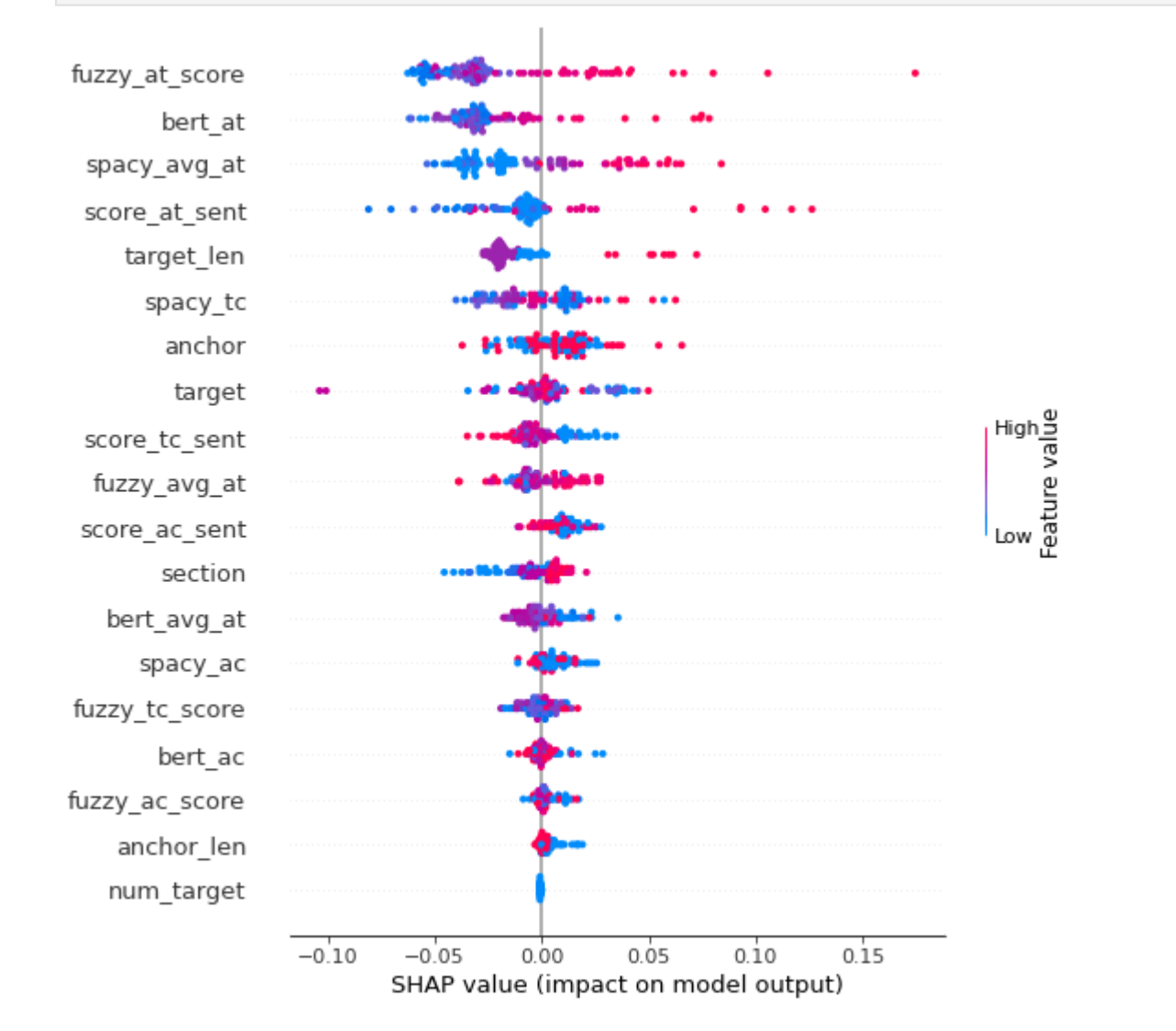
```
In [16]: print("Mean Square Error: {} \nRoot Mean Squared Error: {} \nMean Absolute Error: {} \nR-Squared: {} ".format(n
```

```
Mean Square Error: 0.04122843583385867
Root Mean Squared Error: 0.20304737987685667
Mean Absolute Error: 0.15768073585671355
R-Squared: 0.3819939384322503
```

```
In [17]: import shap
         shap_values = shap.TreeExplainer(cbf).shap_values(x_train[:100])
         shap.summary_plot(shap_values, x_train[:100], plot_type="bar",feature_names=feats)
```




```
In [18]: shap.summary_plot(shap_values, x_train[:100],feature_names=feats)
```




```
In [20]: import matplotlib.pyplot as plt
         import catboost
         from catboost import CatBoostRegressor, Pool
         pool = Pool(x_train, y_train,feature_names=feats)
```

```
In [21]: cbf.plot_tree(tree_idx=0,pool=pool)
```

Out[21]: