PR_curve_Timing_Dist

November 5, 2020

[18]:
```
# %% codecell
import pandas as pd
import pickle
import numpy as np
import matplotlib.pyplot as plt
from scipy.signal import find_peaks

from mil_functions import␣
 ↪get_dws_from,moving_average,inject_anomaly,next_step_splitter,plot_anomaly_detection

raw_samples = pickle.load(open("Data/raw_dws.pkl", "rb"))

avg_samples = pickle.load(open("Data/dw_normal_averaged.pkl", "rb"))



#these are anomalies added manually at a single point, however they are␣
 ↪unrealsitic since they go beyond a bit flip
#inject anomalies into raw samples (then take moving average)
anomaly_samples_avg = []
injection_settings = ((((np.arange(2000,4000),np.random.ranf(2000)*1))), ) * 60


for idx,samples in enumerate(raw_samples):
    anomaly_samples_avg.append(inject_anomaly(samples,*injection_settings[idx]))



raw_samples_norm = list(map(lambda samples: (samples - np.min(samples))/(np.
 ↪max(samples)- np.min(samples)+1), raw_samples))







import tensorflow
```

```
from tensorflow.compat.v1 import ConfigProto
from tensorflow.compat.v1 import InteractiveSession
config = ConfigProto()
config.gpu_options.allow_growth = True
session = InteractiveSession(config=config)

#choose model for unsupervised anomaly detection
model = pickle.load(open("Data/cnn_model_pred2.pkl", "rb"))
```

```
/home/aviraj/anaconda3/envs/tf-gpu/lib/python3.7/site-
packages/tensorflow/python/client/session.py:1735: UserWarning: An interactive
session is already active. This can cause out-of-memory errors in some cases.
You must explicitly call `InteractiveSession.close()` to release resources held
by the other session(s).
  warnings.warn('An interactive session is already active. This can '
```

[19]:
```
len(raw_samples)

select_idx = 0

for window in [1000]:
    anomaly_peaks = []

    for select_idx in range(60):

        # anomaly types, these are more realistic to an actual bitflip

        # random flips 1, 2, 3 bits
        single_bitflip = 2 ** np.arange(16)
        random_single_flips = np.array(list(map(lambda x:  np.bitwise_xor(x, np.
 ↪random.choice(single_bitflip)),raw_samples[select_idx])))
        random_double_flips = np.array(list(map(lambda x:  np.bitwise_xor(x, np.
 ↪random.choice(single_bitflip)),random_single_flips)))
        random_triple_flips = np.array(list(map(lambda x:  np.bitwise_xor(x, np.
 ↪random.choice(single_bitflip)),random_double_flips)))
        # flip lower
        single_bitflip = 2 ** np.arange(0,8)
        lower_flips = np.array(list(map(lambda x:  np.bitwise_xor(x, np.random.
 ↪choice(single_bitflip)),raw_samples[select_idx])))
        # flip higher bits
        single_bitflip = 2 ** np.arange(8,16)
        higher_bitflips = np.array(list(map(lambda x:  np.bitwise_xor(x, np.
 ↪random.choice(single_bitflip)),raw_samples[select_idx])))


        og_raw = moving_average(raw_samples[select_idx],window)
```

```
        random_single_flips = moving_average(random_single_flips,window)
        random_double_flips = moving_average(random_double_flips,window)
        random_triple_flips = moving_average(random_triple_flips,window)
        lower_flips = moving_average(lower_flips,window)
        higher_bitflips = moving_average(higher_bitflips, window)

        injection_locations = np.array([np.array_split(np.arange(15000),10)[::
↪2]]).flatten()

        baseline_locations = np.array(np.array_split(np.arange(15000),10)[1::
↪2]).flatten()

        random_single_flips.shape
        og_raw.shape
        # put original raw values into anomaly values

        np.put(random_single_flips, injection_locations,␣
↪og_raw[injection_locations])
        np.put(random_double_flips, injection_locations,␣
↪og_raw[injection_locations])
        np.put(random_triple_flips, injection_locations,␣
↪og_raw[injection_locations])
        np.put(lower_flips, injection_locations, og_raw[injection_locations])
        np.put(higher_bitflips, injection_locations,␣
↪og_raw[injection_locations])

        #normalize and movingg average all



        anomaly_samples_avg = [ moving_average(raw_samples[select_idx],window),
                                random_single_flips,
                                random_double_flips,
                                random_triple_flips,
                                lower_flips,
                                higher_bitflips]

        #normalizing after anomalies added
        anomaly_samples_avg = list(map(lambda samples: (samples - np.
↪min(samples))/(np.max(samples)- np.min(samples)+1), anomaly_samples_avg))
        # anomaly_samples_avg = list(map(lambda samples: (samples - np.
↪min(samples))/(np.max(samples)- np.min(samples)+1), anomaly_samples_avg))
```

```
        #norm
        # #normalize after adding anomaly
        raw_samples_norm = list(map(lambda samples: (samples - np.min(samples))/
↪(np.max(samples)- np.min(samples)+1), raw_samples))
        #
        #
        # #create sequences for prediction task
        anomaly_avg_sequences = []
        for sample in anomaly_samples_avg:
            sample_anomaly_avg_sequences, _ = next_step_splitter(sample[:-1],␣
↪width=100, prediction_size=2)
            sample_anomaly_avg_sequences = np.
↪expand_dims(sample_anomaly_avg_sequences,axis=2)
            anomaly_avg_sequences.append(sample_anomaly_avg_sequences)

        #
        # pickle.dump(anomaly_avg_sequences, open("Data/
↪dw_anomaly_averaged_sequences.pkl", "wb"))
        # anomaly_avg_sequences = pickle.load(open("Data/
↪dw_anomaly_averaged_sequences.pkl", "rb"))


        baseline = moving_average(raw_samples_norm[select_idx],window)
        # plt.plot(baseline)

        # predictions  = model.predict(anomaly_avg_sequences[select_idx])
        # plt.plot(abs(baseline[np.mod(np.arange(baseline.size),152)!=0] -␣
↪predictions.flatten()))

        titles = [ "Baseline",
                   "Random Single Flips",
                   "Random Double Flips",
                   "Random Triple Flips",
                   "Lower Flips",
                   "Higher Bitflips"]


        for i in range(1,4):
            try:
                baseline = moving_average(raw_samples_norm[select_idx],window)
                predictions  = model.predict(anomaly_avg_sequences[i])
                predictions = predictions.flatten()
                # plt.figure()
                # plt.title(f'Baseline')
                # plt.plot(baseline)
                # plt.xlabel("Packet Arrivals Over Time")
```

```
                # plt.ylabel("Raw Normalized Integer")
                # # plt.plot(predictions)
                # plt.figure()
                # plt.title(f'Next Value Prediction Error for {titles[i]}')
                #
                # plt.xlabel("Packet Arrivals Over Time")
                # plt.ylabel("Prediction Error")
                # plt.axhline(y=0.12, color='r', linestyle='-')
                next_val_err = abs(baseline[np.mod(np.arange(baseline.
↪size),152)!=0] - predictions.flatten())
                # plt.plot(next_val_err)

                anomaly_peaks.append(next_val_err)
                print(titles[i], np.average(next_val_err))
                # plt.figure()
            except:
                continue

pickle.dump(anomaly_peaks, open("Data/anomaly_peaks.pkl", "wb"))
```

```
Random Single Flips 0.4665068777643233
Random Double Flips 0.48978485887029355
Random Triple Flips 0.4942490009891994
Random Single Flips 0.08181596172884116
Random Double Flips 0.11942160120192609
Random Triple Flips 0.14725782526513448
Random Single Flips 0.08799263649797126
Random Double Flips 0.12433813953890044
Random Triple Flips 0.1550064583599566
Random Single Flips 0.27566317984920263
Random Double Flips 0.3233109402484936
Random Triple Flips 0.3423725074920597
Random Single Flips 0.14560289227492235
Random Double Flips 0.25357620587664087
Random Triple Flips 0.2839325398849133
Random Single Flips 0.23366919977900638
Random Double Flips 0.29775703180546664
Random Triple Flips 0.3342737737020461
Random Single Flips 0.06911463286829851
Random Double Flips 0.0999586256325621
Random Triple Flips 0.13735540202414537
Random Single Flips 0.18134810223683367
Random Double Flips 0.2590165772270357
Random Triple Flips 0.3091208995361969
Random Single Flips 0.1918054721610612
Random Double Flips 0.24849579215798437
Random Triple Flips 0.2980966933676963
```

```
Random Single Flips 0.5089595109047329
Random Double Flips 0.5057518621385417
Random Triple Flips 0.5143241066470144
Random Single Flips 0.4697811913108717
Random Double Flips 0.481981232419856
Random Triple Flips 0.49221852029182656
Random Single Flips 0.5728576064370787
Random Double Flips 0.5631376719331
Random Triple Flips 0.5590771101820134
Random Single Flips 0.48446583762212964
Random Double Flips 0.49664656496531145
Random Triple Flips 0.49663292114334034
Random Single Flips 0.4589213535540609
Random Double Flips 0.4920940259522783
Random Triple Flips 0.5064301415632921
Random Single Flips 0.5622296040499472
Random Double Flips 0.5674815824856063
Random Triple Flips 0.5593381690356639
Random Single Flips 0.4871302002531189
Random Double Flips 0.5019884786913937
Random Triple Flips 0.5121688990315132
Random Single Flips 0.4751098962359949
Random Double Flips 0.5062026900428404
Random Triple Flips 0.5139279151886578
Random Single Flips 0.5696809348306421
Random Double Flips 0.572924205538127
Random Triple Flips 0.5635952927745151
Random Single Flips 0.48468772330888965
Random Double Flips 0.5116493333270568
Random Triple Flips 0.5230978199120433
Random Single Flips 0.4620968517160523
Random Double Flips 0.4994737540410839
Random Triple Flips 0.513976269079753
Random Single Flips 0.5829569559037854
Random Double Flips 0.563949792106277
Random Triple Flips 0.5559874816248079
Random Single Flips 0.47775817258000264
Random Double Flips 0.5052910228947948
Random Triple Flips 0.5135800561731036
Random Single Flips 0.48544340306267275
Random Double Flips 0.5027378237302664
Random Triple Flips 0.5188491508712658
Random Single Flips 0.5804971956574562
Random Double Flips 0.5636827551096442
Random Triple Flips 0.5604873896470095
Random Single Flips 0.4868101890299756
Random Double Flips 0.4953297649162349
Random Triple Flips 0.4978732698629637
```

```
Random Single Flips 0.4719740522288185
Random Double Flips 0.4901547872036027
Random Triple Flips 0.49016607355677894
Random Single Flips 0.5642976679753824
Random Double Flips 0.5761940562243895
Random Triple Flips 0.5689419153370309
Random Single Flips 0.4710428006057091
Random Double Flips 0.4955917601601747
Random Triple Flips 0.5121570042145882
Random Single Flips 0.48597558226259885
Random Double Flips 0.5025774006021974
Random Triple Flips 0.49340765478736665
Random Single Flips 0.5653462502677926
Random Double Flips 0.5616535581273371
Random Triple Flips 0.5621038000316224
Random Single Flips 0.47943185867298976
Random Double Flips 0.49862676685711727
Random Triple Flips 0.5028029485973011
Random Single Flips 0.464504878211543
Random Double Flips 0.48473928337700495
Random Triple Flips 0.49725328857653367
Random Single Flips 0.5991013957298277
Random Double Flips 0.5744534794017703
Random Triple Flips 0.56818760324726
Random Single Flips 0.4844261894549776
Random Double Flips 0.5060400692899785
Random Triple Flips 0.5084284399049248
Random Single Flips 0.4034433812798374
Random Double Flips 0.42056266511894264
Random Triple Flips 0.4244056882640673
Random Single Flips 0.5754755817872697
Random Double Flips 0.5615209544397748
Random Triple Flips 0.5624949131653447
Random Single Flips 0.49778403406366534
Random Double Flips 0.5110234713366593
Random Triple Flips 0.5144087616276731
Random Single Flips 0.49873163241796714
Random Double Flips 0.46613258695061827
Random Triple Flips 0.46449738823998826
Random Single Flips 0.5781904993504546
Random Double Flips 0.5616661890533254
Random Triple Flips 0.5629335021030909
Random Single Flips 0.40578981009249304
Random Double Flips 0.42481609213634586
Random Triple Flips 0.4390881242977023
Random Single Flips 0.04253263962542837
Random Double Flips 0.06708318649247612
Random Triple Flips 0.08793851984327011
```

```
Random Single Flips 0.22600080563303146
Random Double Flips 0.2723724436352828
Random Triple Flips 0.3284397834953846
Random Single Flips 0.4160039199931609
Random Double Flips 0.41539886369759843
Random Triple Flips 0.4154887804225446
Random Single Flips 0.07591293260806417
Random Double Flips 0.11562410407376478
Random Triple Flips 0.1726440886558202
Random Single Flips 0.1730915341099691
Random Double Flips 0.20836313782905505
Random Triple Flips 0.2334504971977802
Random Single Flips 0.3203213403528648
Random Double Flips 0.41711822892796063
Random Triple Flips 0.45540994747127245
Random Single Flips 0.1337526995807418
Random Double Flips 0.21236552069415116
Random Triple Flips 0.2537596740034267
Random Single Flips 0.311267069865371
Random Double Flips 0.2645215979025952
Random Triple Flips 0.22676899255011743
Random Single Flips 0.4219005072827359
Random Double Flips 0.41302364737439273
Random Triple Flips 0.4000718769941311
Random Single Flips 0.08007956179924867
Random Double Flips 0.13342281574607615
Random Triple Flips 0.15953308140921954
Random Single Flips 0.2384725486490807
Random Double Flips 0.2955512452273908
Random Triple Flips 0.3359448652660769
Random Single Flips 0.35725720418586
Random Double Flips 0.3592931831638362
Random Triple Flips 0.38089033936327804
Random Single Flips 0.17902917203475247
Random Double Flips 0.18320599383090674
Random Triple Flips 0.19403081731671737
Random Single Flips 0.34312623147302923
Random Double Flips 0.32410048731243424
Random Triple Flips 0.3110133249951808
Random Single Flips 0.48550334011084323
Random Double Flips 0.4988022818362525
Random Triple Flips 0.5018188369683582
Random Single Flips 0.27688662216523585
Random Double Flips 0.3033020796535541
Random Triple Flips 0.33344337074075114
Random Single Flips 0.1959144080285254
Random Double Flips 0.20740912752849977
Random Triple Flips 0.21199137449323288
```

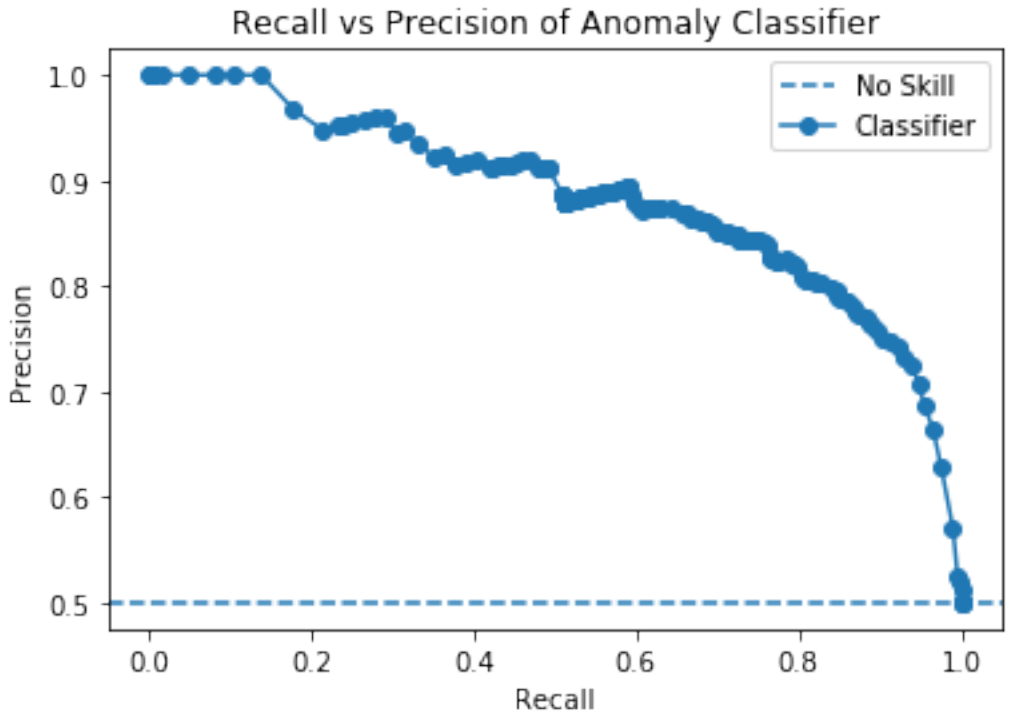
[20]:
```
anomaly_peaks = pickle.load(open("Data/anomaly_peaks.pkl", "rb"))
```

[21]:
```
#
#
anomaly_counts = []

len(anomaly_peaks)
for i in range(len(anomaly_peaks)):
    peaks, information = find_peaks(anomaly_peaks[i], prominence=1)
    anomaly_counts.append(information["prominences"].shape[0])



anomaly_counts = np.array(anomaly_counts)

anomaly_counts[anomaly_counts > 10] = 10




pr = []
np.arange(0.005, 0.4,0.005)

for prom in np.arange(0.005, 1,0.005):
    anomaly_counts = []

    for i in range(len(anomaly_peaks)):
        peaks, information = find_peaks(anomaly_peaks[i], prominence=prom)
        anomaly_counts.append(information["prominences"].shape[0])



    anomaly_counts = np.array(anomaly_counts)
    anomaly_counts[anomaly_counts > 10] = 10



    subset = anomaly_counts[(-10<anomaly_counts) & (anomaly_counts<=10)]
    fn= tp = fp = 0
    for count in subset:
        count = count - 5
        if(count>=0):
            tp += 5
            fp += count
        else:
            tp += 5 + count
            fn += np.abs(count)
```

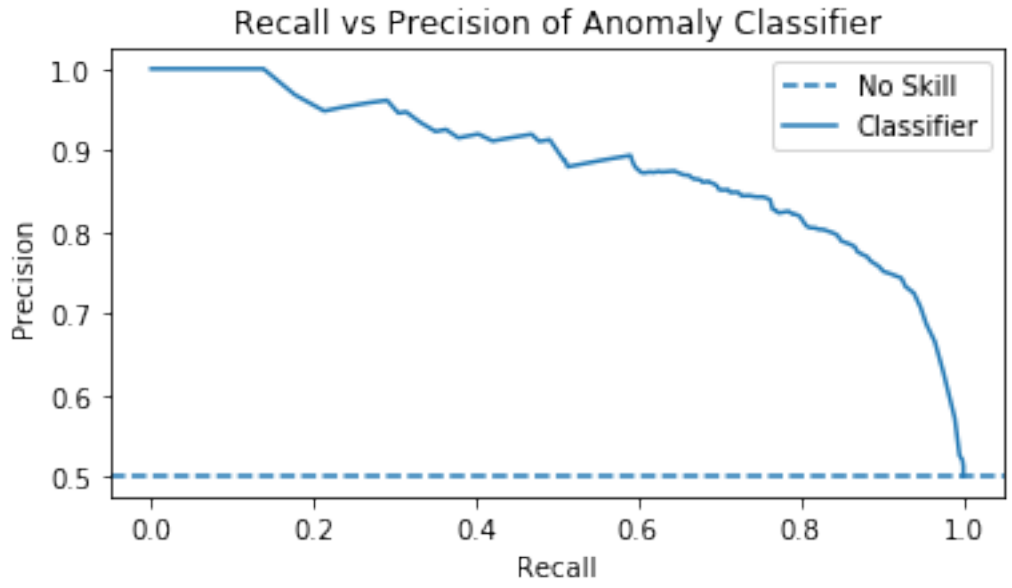
```
    p = tp / (tp + fp)
    r = tp / (tp + fn)
    pr.append([p,r])



p_list = np.array(pr)[:,0]
r_list = np.array(pr)[:,1]



plt.xlabel('Recall')
plt.ylabel('Precision')
plt.title('Recall vs Precision of Anomaly Classifier')
plt.axhline(y=0.5,linestyle='--',label='No Skill')
plt.plot(r_list,p_list,'-o',label='Classifier')
plt.legend()
```

```
/home/aviraj/anaconda3/envs/tf-gpu/lib/python3.7/site-
packages/ipykernel_launcher.py:48: RuntimeWarning: invalid value encountered in
long_scalars
```

[21]: <matplotlib.legend.Legend at 0x7f5d545cb950>



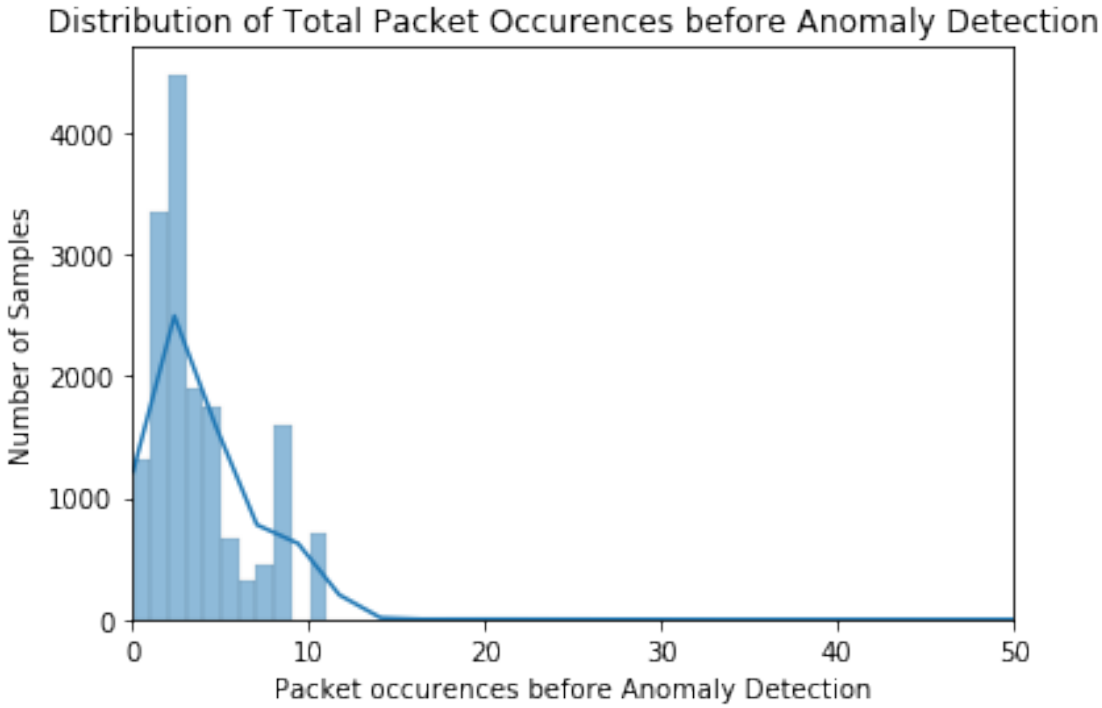
[22]:
```
plt.xlabel('Recall')
plt.ylabel('Precision')
plt.title('Recall vs Precision of Anomaly Classifier')
plt.axhline(y=0.5,linestyle='--',label='No Skill')
plt.plot(r_list,p_list,'-',label='Classifier')
plt.legend()
plt.gca().set_aspect('equal', adjustable='box')
```



[24]:
```
import seaborn as sns


widths = []

for i in range(len(anomaly_peaks)):
    peaks, information = find_peaks(anomaly_peaks[i], width=10,prominence=.45)
    widths.append(np.abs((information["widths"] - 1500)/2))



all_widths = np.concatenate(widths).flatten()

all_widths

import seaborn as sns
ax = sns.histplot(data=all_widths,kde=True, binwidth=1)
```

```
ax.set(title="Distribution of Total Packet Occurences before Anomaly Detection",
    ylabel='Number of Samples',
    xlabel='Packet occurences before Anomaly Detection',xlim=(0,50))


peaks, information = find_peaks(anomaly_peaks[20], prominence=.45)
information["prominences"].shape
```

[24]: (0,)



[25]:
```
widths = []

for i in range(len(anomaly_peaks)):
    peaks, information = find_peaks(anomaly_peaks[i], prominence=.15)
    widths.append(information["prominences"].shape[0])




ax = sns.histplot(data=widths,kde=True, binwidth=1)
ax.set(title="Total Anomaly Detections after 5 Anomalies Injected",
    ylabel='Number of Samples',
    xlabel='Anomalies Predicted in after 5 Anomaly Injections', xlim=(0,15))
```

```
ax.axvline(5)
```

[25]: <matplotlib.lines.Line2D at 0x7f5d3972a190>