agentMET4FOF Documentation

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Apr 07, 2020

Getting started:

agentMET4FOF is a Python library developed at the Institute for Manufacturing of the University of Cambridge (UK) as part of the European joint Research Project EMPIR 17IND12 Met4FoF.

For the *agentMET4FOF* homepage go to GitHub.

agentMET4FOF is written in Python 3.

CHAPTER 1

Getting started

Here goes your text.

More info on how to create the contents here

Multi-Agent System for Metrology for Factory of the Future (Met4FoF) Code This is supported by European Metrology Programme for Innovation and Research (EMPIR) under the project Metrology for the Factory of the Future (Met4FoF), project number 17IND12. (https://www.ptb.de/empir2018/met4fof/home/)

About — - How can metrological input be incorporated into an agent-based system for addressing uncertainty of machine learning in future manufacturing? - Includes agent-based simulation and implementation

Updates — - Implemented Sensor Agent, Aggregator Agent, Predictor Agent, DecisionMaker Agent, Sensor Network Agent - Able to handle multiple Sensor Agents & Predictor Agents (each equipped with a different model) - Implemented with ZEMA condition monitoring of hydraulic system data set as use case `[![DOI](https://zenodo.org/badge/DOI/10.5281/zenodo.1323611.svg){]}(https://doi.org/10.5281/zenodo.1323611)` - Implemented web visualization with user interface

To run — - Run Code 01-03 to prepare the ML models, and run Code 04 to start and run the agents. While Code 04 is running, run Code 05 in separate terminal to visualize them.

Screenshot of web visualization `![Web Screenshot](https://github.com/bangxiangyong/agentMet4FoF/blob/master/screenshot_met4fof.png)`

Note — - In the event of agents not terminating cleanly, run `` `taskkill /f /im python.exe /t` `` in Windows Command Prompt to terminate all background python processes.

CHAPTER 2

Download data

Firstly we download data for condition monitoring from zenodo at https://doi.org/10.5281/zenodo.1323611

[1]:
```
data_url='https://zenodo.org/record/1323611/files/data.zip?download=1'
```

[2]:
```
import os, requests, zipfile, io

def download_and_extract(url, destination, force=False):
    response = requests.get(url)
    zipDocument = zipfile.ZipFile(io.BytesIO(response.content))
    # Attempt to see if we are going to overwrite anything
    if not force:
        abort = False
        for file in zipDocument.filelist:
            if os.path.isfile(os.path.join(destination, file.filename)):
                print(file.filename,␣
↪'already exists. If you want to overwrite the file call the method with force=True')
                abort = True
        if abort:
            print('Zip file was not extracted')
            return

    zipDocument.extractall(destination)
```

[3]:
```
download_and_extract(data_url, 'Dataset/ZEMA_Hydraulic/')
```

[ ]:
```

```

CHAPTER 3

Data Preprocessing

We preprocess and resample the raw data .txt files we downloaded earlier into numpy.

3.1 Resample 10Hz and 100Hz data to 1Hz

[1]:
```
import numpy as np

data_path = "Dataset/ZEMA_Hydraulic/"

filenames_input_data_10Hz = ["fs1","fs2"]
filenames_input_data_10Hz = [file + ".txt" for file in filenames_input_data_10Hz]

filenames_input_data_100Hz = ["ps1","ps2","ps3","ps4","ps5","ps6","eps1"]
filenames_input_data_100Hz = [file + ".txt" for file in filenames_input_data_100Hz]

data_input_data_10Hz = np.zeros((2205,600,len(filenames_input_data_10Hz)))
data_input_data_100Hz = np.zeros((2205,6000,len(filenames_input_data_100Hz)))

for id_,file_name in enumerate(filenames_input_data_10Hz):
    input_data = np.loadtxt(data_path + file_name, delimiter = "\t")
    data_input_data_10Hz[:,:,id_] = input_data.copy()

for id_,file_name in enumerate(filenames_input_data_100Hz):
    input_data = np.loadtxt(data_path + file_name, delimiter = "\t")
    data_input_data_100Hz[:,:,id_] = input_data.copy()

filenames_input_data_10Hz_resampled = ["res_"+file for file in filenames_input_data_
↪10Hz]
filenames_input_data_100Hz_resampled = ["res_"+file for file in filenames_input_data_
↪100Hz]

#resample 10Hz
resample = np.linspace(0,600-1, num =60,dtype="int")
```

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```
data_resampled_10Hz=data_input_data_10Hz[:,resample,:]

#resample 100Hz
resample = np.linspace(0,5999, num =60,dtype="int")
data_resampled_100Hz=data_input_data_100Hz[:,resample,:]

#save file
for id_,file_name in enumerate(filenames_input_data_10Hz_resampled):
    np.savetxt(data_path+file_name,data_resampled_10Hz[:,:,id_],delimiter='\t')
for id_,file_name in enumerate(filenames_input_data_100Hz_resampled):
    np.savetxt(data_path+file_name,data_resampled_100Hz[:,:,id_],delimiter='\t')
```

3.2 Load all the 1Hz data

Load all data including the resampled sensors into numpy arrays

[2]:
```
#save data
datarows = 2205
seq_length = 60

#deal with inputs data
filenames_input_data_1Hz = ["ts1","ts2","ts3","ts4","vs1","se","res_fs1","res_fs2",
↪"res_ps1","res_ps2","res_ps3","res_ps4","res_ps5","res_ps6","res_eps1","ce","cp"]
filenames_input_data_1Hz = [file + ".txt" for file in filenames_input_data_1Hz]
filename_target_data = "profile.txt"

data_input_data_1Hz = np.zeros((datarows,seq_length,len(filenames_input_data_1Hz)))

for id_,file_name in enumerate(filenames_input_data_1Hz):
    input_data = np.loadtxt(data_path + file_name, delimiter = "\t")
    data_input_data_1Hz[:,:,id_] = input_data.copy()
```

3.3 Load the target multi-target, multi-class output data

We load them and preprocess into one hot vector

[3]:
```
#deal with output data now
targets_data = np.loadtxt(data_path+filename_target_data, delimiter = "\t")

#conversion of outputs to one hot
def makeOneHotVectorMap(length):
    map_toOneHot ={}
    for i in range(length):
        oneHot = np.zeros(length)
        oneHot[i] = 1
        map_toOneHot[i] = oneHot
    return map_toOneHot
```

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```
id2x_dictionaries = []
x2id_dictionaries = []
id2onehot_dictionaries = []

for label in range(targets_data.shape[1]):
    label_column = list(set(targets_data[:,label]))
    label_column.sort(reverse=True)
    id2x_dictionary = {}
    x2id_dictionary = {}
    id2onehot_dictionary = makeOneHotVectorMap(len(label_column))
    for i in range(len(label_column)):
        id2x_dictionary[i] = label_column[i]
        x2id_dictionary[label_column[i]] = i
    id2x_dictionaries+=[id2x_dictionary]
    x2id_dictionaries+=[x2id_dictionary]
    id2onehot_dictionaries+=[id2onehot_dictionary]

#convert a row into one-hot coded multi-class multi-label
onehot_tensor_output = []
id_output =[]
for row in range(targets_data.shape[0]):
    row_output_data= targets_data[row]
    onehots_row =[]
    id_row =[]
    for label in range(row_output_data.shape[0]):
        id_ = x2id_dictionaries[label][row_output_data[label]]
        onehot= id2onehot_dictionaries[label][id_]
        onehots_row =np.append(onehots_row,onehot)
        id_row = np.append(id_row,id_)
    id_output+=[id_row]
    onehot_tensor_output += [onehots_row]
onehot_tensor_output = np.array(onehot_tensor_output)
id_tensor_output = np.array(id_output)

tensor_output = id_tensor_output
all_tensor_output = id_tensor_output
```

3.4 Pickle data

[5]:
```
import os
import pickle

pickle_folder= "pickles"

if os.path.exists(pickle_folder) == False:
    os.mkdir(pickle_folder)

#Pickle them
pickle.dump(data_input_data_1Hz, open( pickle_folder+"/data_input_data_1Hz_full.p",␣
↪"wb" ) )
pickle.dump(data_input_data_10Hz, open( pickle_folder+"/data_input_data_10Hz.p", "wb"␣
↪) )
pickle.dump(data_input_data_100Hz, open( pickle_folder+"/data_input_data_100Hz.p",␣
↪"wb" ) )
```

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```
pickle.dump(id2onehot_dictionaries, open( pickle_folder+"/id2onehot_dictionaries.p",␣
↪"wb" ) )
pickle.dump(all_tensor_output, open( pickle_folder+"/zema_outputs.p", "wb" ) )
```

[ ]:

```

```

CHAPTER 4

Train model Bayesian Neural Network

We train and evaluate the BNN on the dataset which we loaded earlier.

Credits to Felix Laumann (https://github.com/felix-laumann/Bayesian_CNN) for the method of training BNN with Bayes by Backprop and the model code.

[1]:
```
import torch
import pickle
from sklearn.model_selection import KFold
from sklearn.preprocessing import StandardScaler, MinMaxScaler,RobustScaler
import random
from torch.autograd import Variable
import numpy as np
from sklearn.metrics import confusion_matrix
from sklearn.utils.multiclass import unique_labels
import matplotlib.pyplot as plt
import pandas as pd
from copy import copy
from ML_models.BBBlayers import BBBLinearFactorial
from ML_models.BBBlayers import GaussianVariationalInference
from ML_models.BNN_Wrapper import BNN_Wrapper
from ML_models.BNN_Wrapper import BNN_Full
import seaborn as sns

from scipy.stats import skew
from scipy.stats import kurtosis
from scipy.stats import sem
from scipy.fftpack import fft
from sklearn.metrics import f1_score
```

4.1 Load data and label outputs

[2]:
```
pickle_path="pickles/"
data_input = pickle.load( open( pickle_path+"data_input_data_1Hz_full.p", "rb" ) )
data_output = pickle.load( open( pickle_path+"zema_outputs.p", "rb" ) )

output_labels = [{0: "Optimal", 1: "Reduced", 2: "Nearly Fail"},
 {0: "Optimal", 1: "Small lag", 2: "Severe lag", 3: "Nearly Fail"},
 {0: "No Leakage", 1: "Weak Leakage", 2: "Severe Leakage"},
 {0: "Optimal", 1: "Slightly Reduced", 2: "Severely Reduced", 3: "Nearly Fail"},
 {0: "Stable", 1: "Unstable"}]
output_sizes = [3,4,3,4,2]
```

4.2 Initialization

Setup parameters such as learning rate, number of Monte Carlo samples during predictions, training epoch, certainty threshold

[3]:
```
learning_rate = 0.005
num_samples = 50
num_epochs = 300
certainty_threshold  = 80

X_data = data_input
Y_data = data_output
```

4.3 Shuffle data

1. Shuffle data randomly to have a random distribution
2. Split the time series into segments if necessary (n=1 means no segmentation occurs)

[4]:
```
randomShuffling= True

#randomShuffling
if(randomShuffling == True):
    index_list = np.arange(X_data.shape[0])
    random.shuffle(index_list)
    Y_data=Y_data[index_list,:]
    X_data=X_data[index_list,:,:]

def split_segment(X_data,split_n =1):
    X_data_split=np.split(X_data,split_n,axis=1)
    X_data_split=np.moveaxis(X_data_split, 0, -2)
    X_data_split=X_data_split.reshape((X_data_split.shape[0],X_data_split.shape[1],-
↪1))
    return X_data_split

X_data=split_segment(X_data)
```

4.4 Train and evaluate data in k-fold validation

- Setup empty arrays for keeping results from each k-fold validation iteration
- Training consists of two loops:
  1. Outer loop: Train a model for each prediction task (from valve, pump, accumulator, etc)
  2. Inner loop: k-fold iteration
- Results are stored in arrays

[5]:

```
simulate_broken_sensor = False #experimental and not fully implemented yet

y_pred_kfold =[]
y_actuals_kfold=[]
mse_kfold=[]
certainties_kfold=[]
confidences_kfold=[]
DL_model_kfold =[]
final_results =[]


for target in range(len(output_sizes)):
    selected_output = target
    output_size =output_sizes[selected_output]
    bnn_wrapper = BNN_Wrapper(BNN_Full,output_size=output_size)

    kfold_times = 0
    kfold_limit = 5
    #kfold validation training
    kf = KFold(n_splits=5)
    f1_score_model_kfold=[]
    p_accurate_certain_kfold=[]
    p_accurate_uncertain_kfold=[]

    for train, test in kf.split(X_data,y=Y_data):

        if(kfold_times >kfold_limit):
            break
        print("%s %s" % (train, test))


        x_train=X_data[train]
        y_train=Y_data[train,selected_output]
        x_test=X_data[test]
        y_test=Y_data[test,selected_output]

        #simulate broken sensors on test set
        if simulate_broken_sensor == True:
            x_test_brokenSensor = Variable(torch.from_numpy(x_test).float()).repeat(x_
↪train.shape[-1]+1,1,1,1)
            for corrupted_sensor in range(x_train.shape[-1]):
                x_test_brokenSensor[corrupted_sensor,:,:,corrupted_sensor] =torch.
↪randn_like(x_test_brokenSensor[corrupted_sensor,:,:,corrupted_sensor])
            x_test_brokenSensor = x_test_brokenSensor.view(-1,x_test_brokenSensor.
↪shape[2],x_test_brokenSensor.shape[3])
            x_test_brokenSensor = x_test_brokenSensor.cpu().detach().numpy()
            x_test = copy(x_test_brokenSensor)
```

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```
        y_test_tensor = Variable(torch.from_numpy(y_test).long())
        if simulate_broken_sensor == True:
            y_test_tensor_repeated = y_test_tensor.repeat(x_train.shape[-1]+1,1)
            y_test_tensor_repeated = y_test_tensor_repeated.view(-1)
        elif simulate_broken_sensor == False:
            y_test_tensor_repeated = y_test_tensor

        #perform feature extraction on train and test
        df_feats_train = bnn_wrapper.extract_features(x_train)
        x_train = df_feats_train.values
        df_feats_test = bnn_wrapper.extract_features(x_test)
        x_test = df_feats_test.values

        #train model
        bnn_wrapper.train_model(x_train,y_train,learning_rate= learning_rate,num_
↪epochs = num_epochs)

        #predict using model
        y_pred_test,certainties,confidences = bnn_wrapper.predict_model_wUnc(x_test,
↪num_samples=num_samples)

        #now form all the kfolds
        DL_model_kfold.append(bnn_wrapper.trained_model)
        y_pred_kfold.append(y_pred_test)
        y_actuals_kfold.append(y_test_tensor_repeated.cpu().detach().numpy())
        certainties_kfold.append(np.array(certainties))
        confidences_kfold.append(np.array(confidences))
        kfold_times = kfold_times+1

        #evaluate model
        y_true_np=np.array(y_actuals_kfold).reshape(-1)
        y_pred_np=np.array(y_pred_kfold).reshape(-1)
        certainties_np = np.array(certainties_kfold).reshape(-1)

        f1_score_model, p_accurate_certain, p_accurate_uncertain = bnn_wrapper.
↪evaluate_model(y_true_np,y_pred_np,certainties_np,certainty_threshold=certainty_
↪threshold)
        f1_score_model_kfold.append(f1_score_model)
        p_accurate_certain_kfold.append(p_accurate_certain)
        p_accurate_uncertain_kfold.append(p_accurate_uncertain)

    print("Target output: ", selected_output)
    print("F1 SCORE: ",np.mean(f1_score_model_kfold),"+-",sem(f1_score_model_kfold),␣
↪f1_score_model_kfold)
    print("P(Acc | Certain): ",np.mean(p_accurate_certain_kfold),"+-",sem(p_accurate_
↪certain_kfold),p_accurate_certain_kfold)
    print("P(Acc | Uncertain): ",np.mean(p_accurate_uncertain_kfold),"+-",sem(p_
↪accurate_uncertain_kfold),p_accurate_uncertain_kfold)

    final_results.append([f1_score_model_kfold, p_accurate_certain_kfold, p_accurate_
↪uncertain_kfold])

    pickle.dump(bnn_wrapper, open( pickle_path+"bnn_wrapper_"+str(selected_
↪output)+".p", "wb" ) )
```

```
[ 441  442  443 ... 2202 2203 2204] [  0   1   2   3   4   5   6   7   8   9  10  11 ␣
↪12  13  14  15  16  17
  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35
  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51  52  53
  54  55  56  57  58  59  60  61  62  63  64  65  66  67  68  69  70  71
  72  73  74  75  76  77  78  79  80  81  82  83  84  85  86  87  88  89
  90  91  92  93  94  95  96  97  98  99 100 101 102 103 104 105 106 107
 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125
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 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413
 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431
 432 433 434 435 436 437 438 439 440]
```
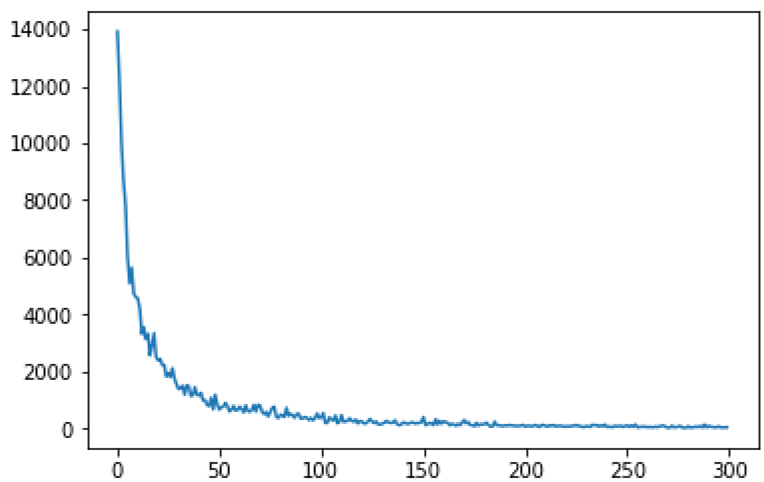
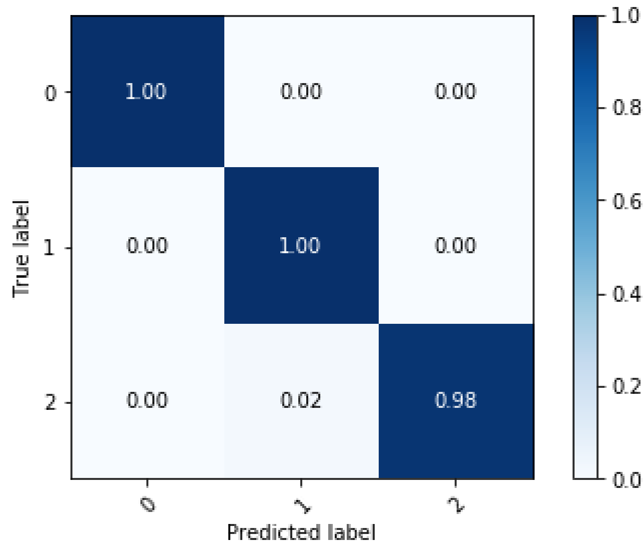
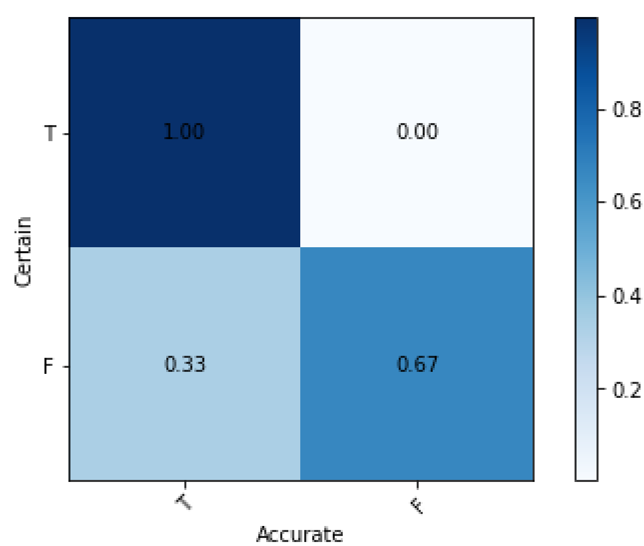



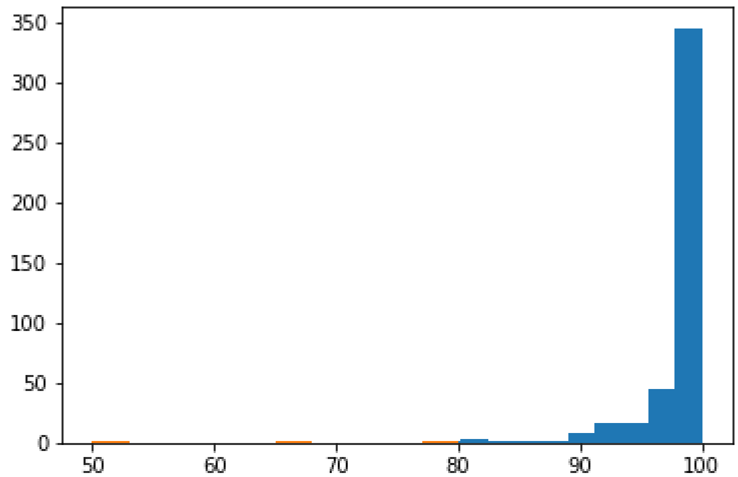

```
<Figure size 432x288 with 0 Axes>
```




```
<Figure size 432x288 with 0 Axes>
```




```
<Figure size 432x288 with 0 Axes>
```




```
[   0    1    2 ... 2202 2203 2204] [441 442 443 444 445 446 447 448 449 450 451 452␣
↪453 454 455 456 457 458
 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476
 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494
 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512
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 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710
 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728
 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746
 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764
 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782
 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800
 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818
 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836
 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854
 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872
 873 874 875 876 877 878 879 880 881]
```
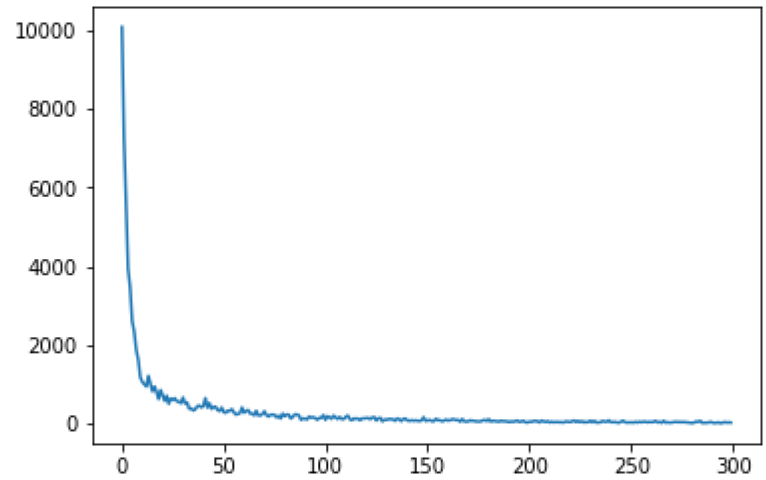
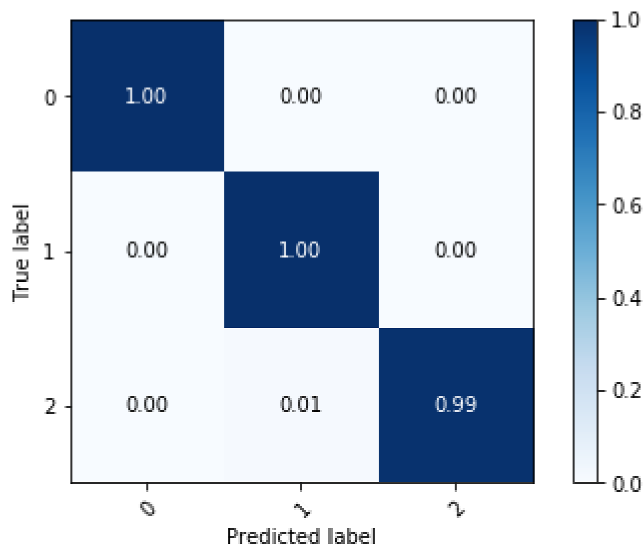
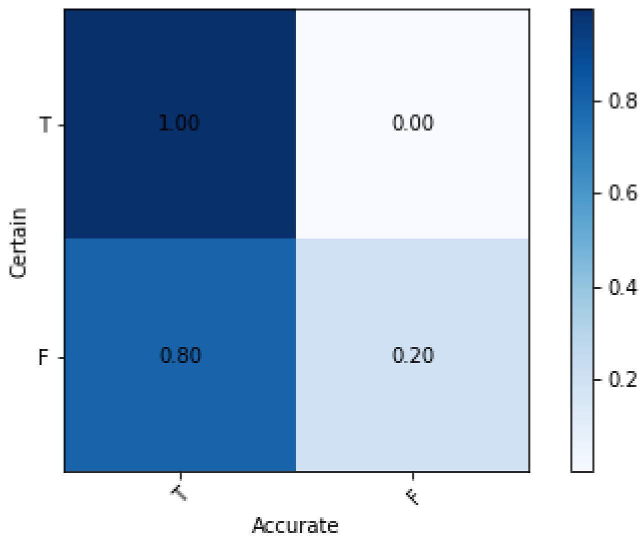

```
<Figure size 432x288 with 0 Axes>
```



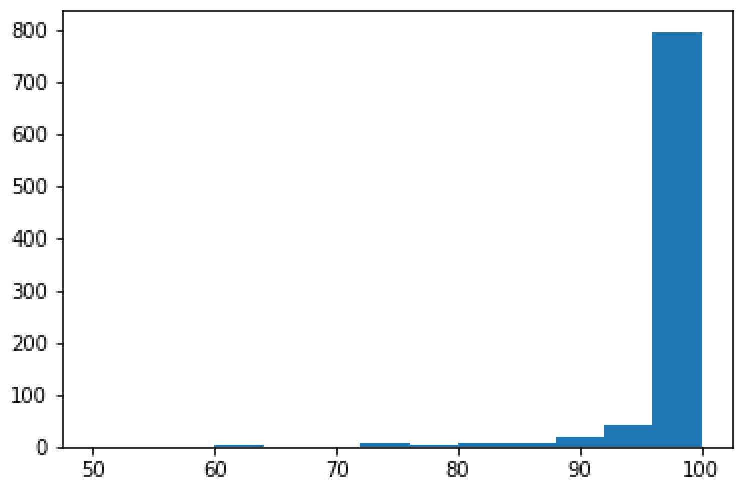

```
<Figure size 432x288 with 0 Axes>
```




```
<Figure size 432x288 with 0 Axes>
```




```
<Figure size 432x288 with 0 Axes>
```




```
[   0    1    2 ... 2202 2203 2204] [ 882  883  884  885  886  887  888  889  890 ␣
↪891  892  893  894  895
  896  897  898  899  900  901  902  903  904  905  906  907  908  909
  910  911  912  913  914  915  916  917  918  919  920  921  922  923
  924  925  926  927  928  929  930  931  932  933  934  935  936  937
  938  939  940  941  942  943  944  945  946  947  948  949  950  951
  952  953  954  955  956  957  958  959  960  961  962  963  964  965
  966  967  968  969  970  971  972  973  974  975  976  977  978  979
  980  981  982  983  984  985  986  987  988  989  990  991  992  993
  994  995  996  997  998  999 1000 1001 1002 1003 1004 1005 1006 1007
 1008 1009 1010 1011 1012 1013 1014 1015 1016 1017 1018 1019 1020 1021
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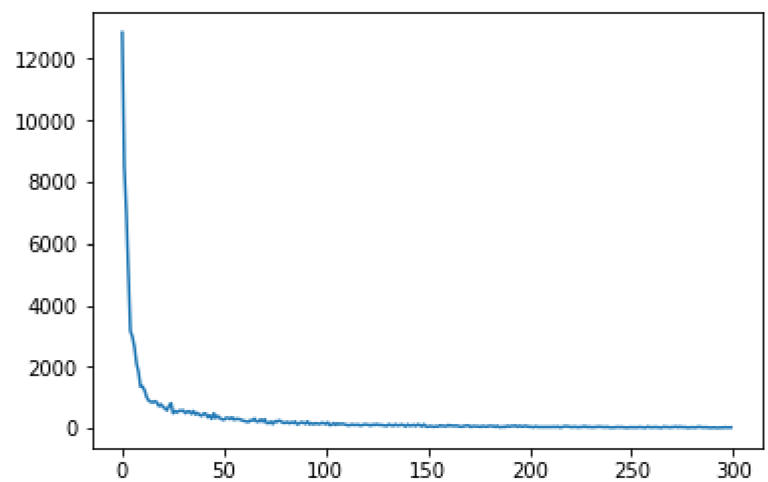


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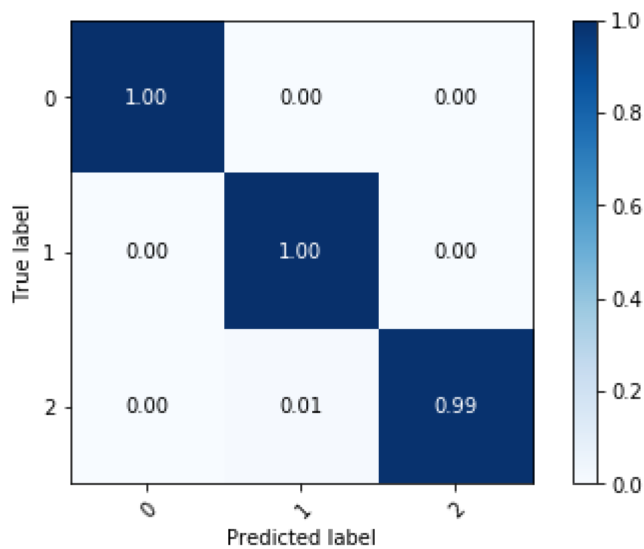

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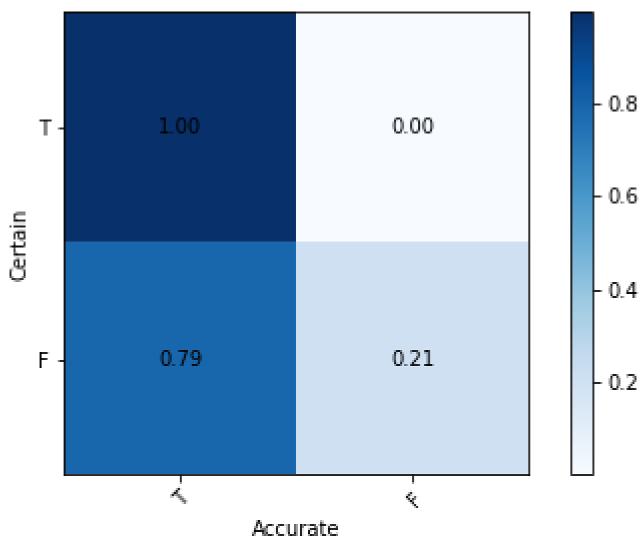


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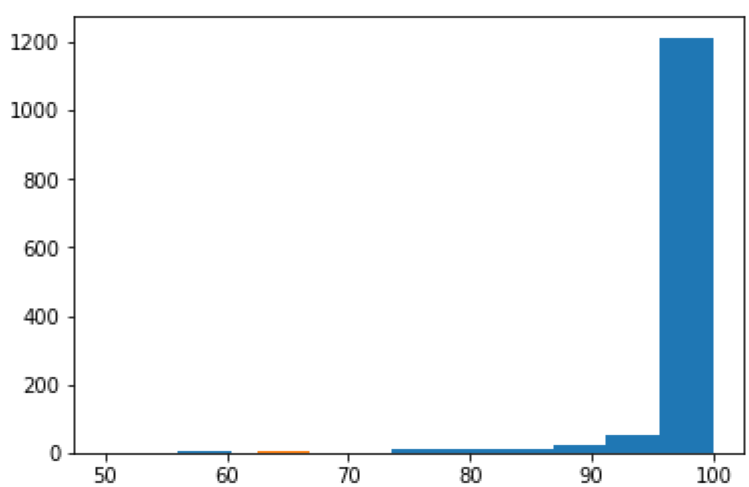


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1645 1646 1647 1648 1649 1650 1651 1652 1653 1654 1655 1656 1657 1658
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1673 1674 1675 1676 1677 1678 1679 1680 1681 1682 1683 1684 1685 1686
1687 1688 1689 1690 1691 1692 1693 1694 1695 1696 1697 1698 1699 1700
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1729 1730 1731 1732 1733 1734 1735 1736 1737 1738 1739 1740 1741 1742
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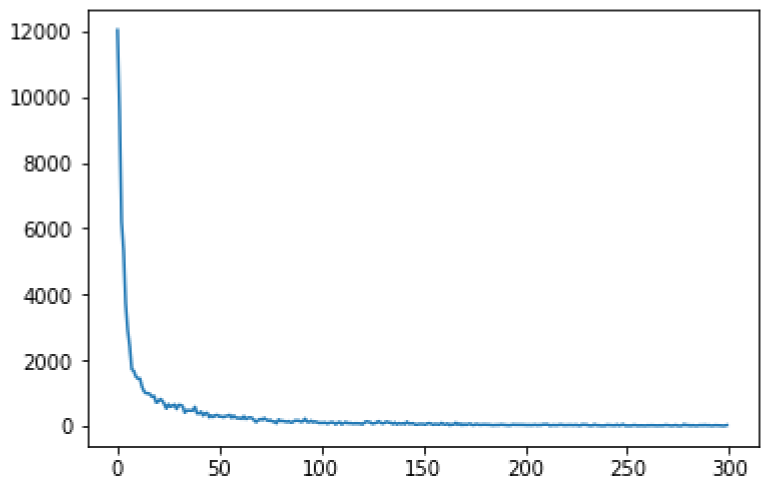


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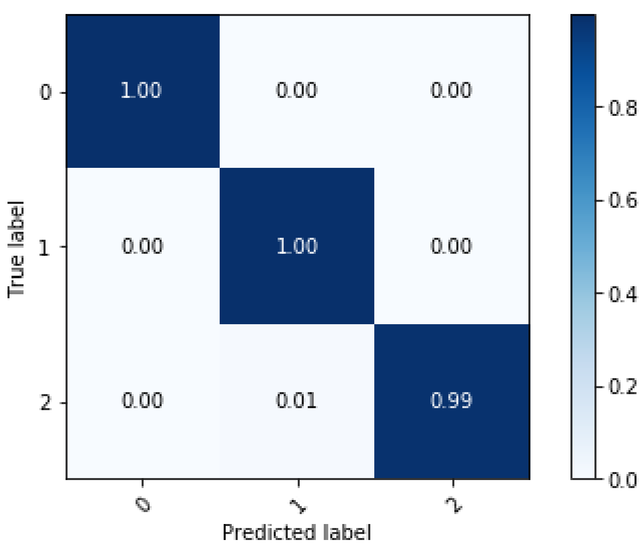

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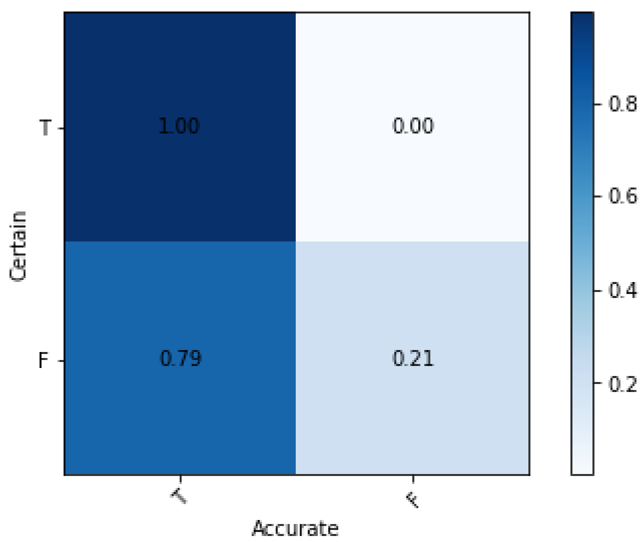


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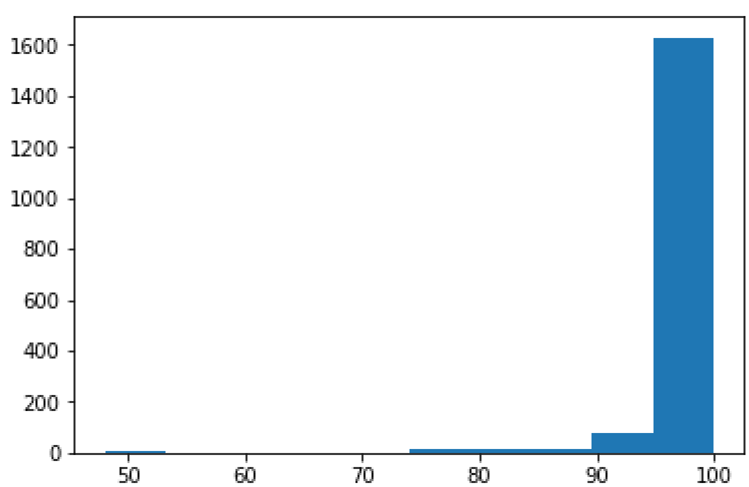


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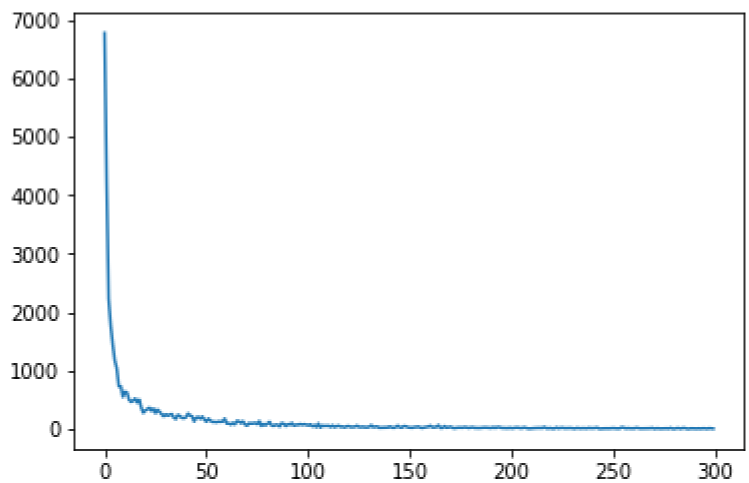


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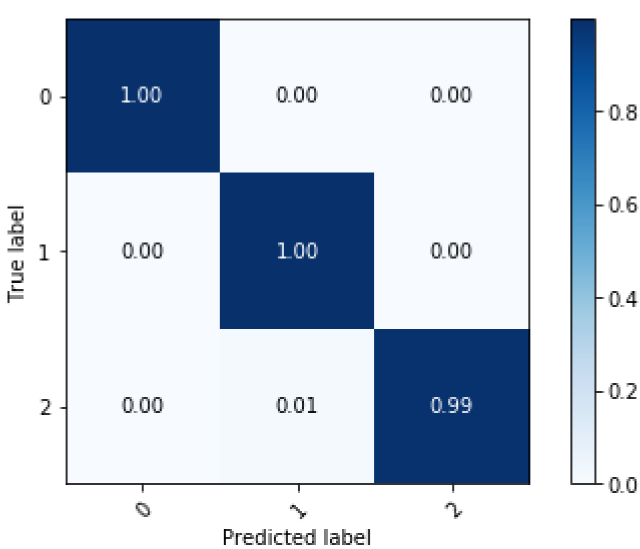

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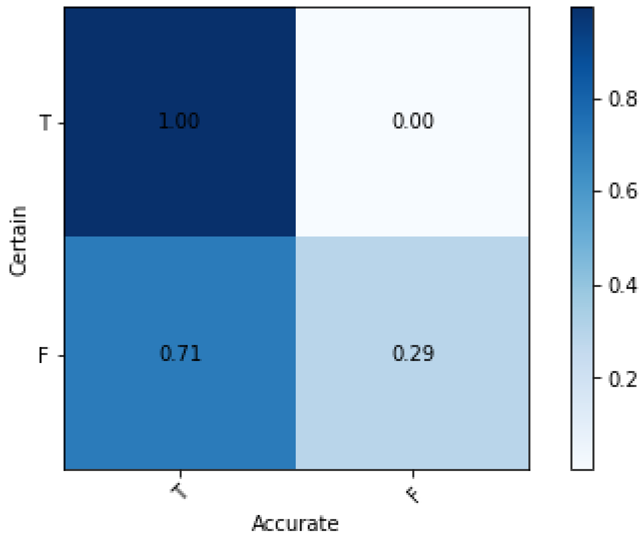


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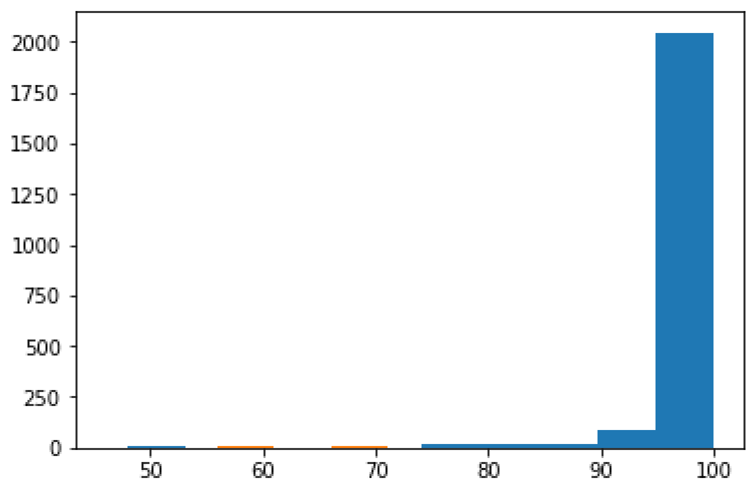


```
Target output:  0
F1 SCORE:  0.9945351473922903 +- 0.0004707605326990252 [0.9931972789115646, 0.
↪9954648526077098, 0.9954648526077098, 0.9948979591836735, 0.9936507936507937]
P(Acc | Certain):  0.9980861983060005 +- 0.00024045557469217787 [0.997716894977169, 0.
↪9988465974625144, 0.9984662576687117, 0.9977011494252873, 0.9977000919963201]
P(Acc | Uncertain):  0.6848302207130731 +- 0.08938562630975022 [0.3333333333333333, 0.
↪8, 0.7894736842105263, 0.7916666666666666, 0.7096774193548387]
[ 441  442  443 ... 2202 2203 2204] [   0    1    2    3    4    5    6    7    8    9   10   11 ␣
↪12   13   14   15   16   17
  18   19   20   21   22   23   24   25   26   27   28   29   30   31   32   33   34   35
  36   37   38   39   40   41   42   43   44   45   46   47   48   49   50   51   52   53
  54   55   56   57   58   59   60   61   62   63   64   65   66   67   68   69   70   71
  72   73   74   75   76   77   78   79   80   81   82   83   84   85   86   87   88   89
  90   91   92   93   94   95   96   97   98   99  100  101  102  103  104  105  106  107
 108  109  110  111  112  113  114  115  116  117  118  119  120  121  122  123  124  125
 126  127  128  129  130  131  132  133  134  135  136  137  138  139  140  141  142  143
 144  145  146  147  148  149  150  151  152  153  154  155  156  157  158  159  160  161
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 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197
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 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269
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 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341
 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359
 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377
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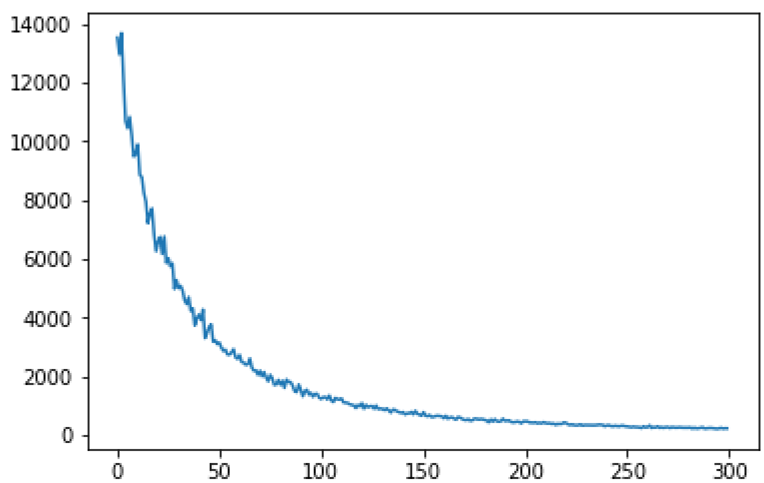


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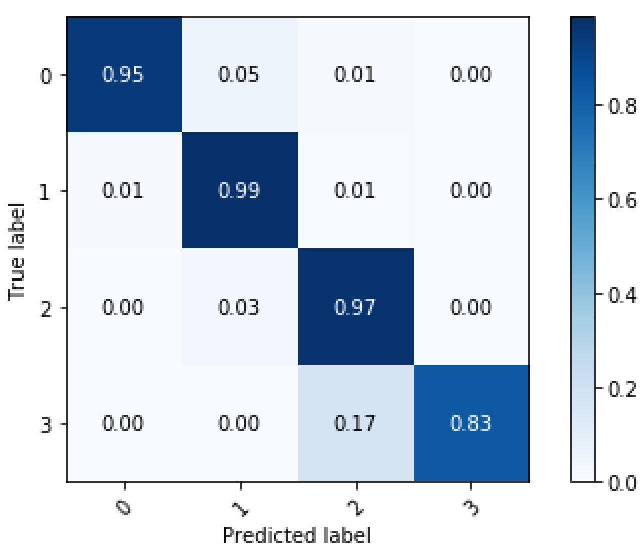

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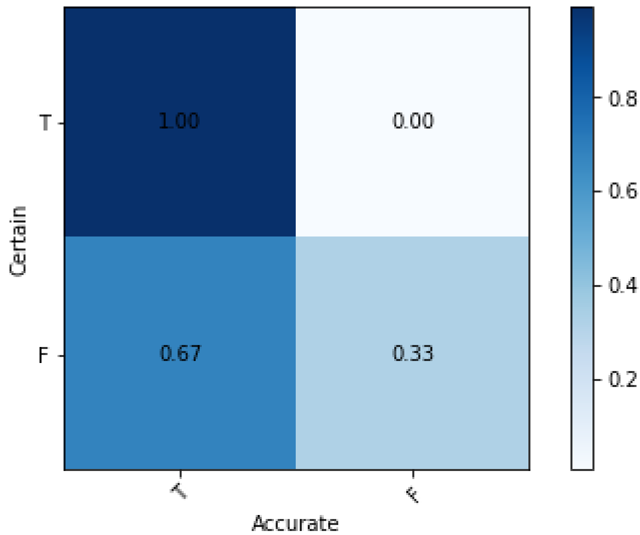


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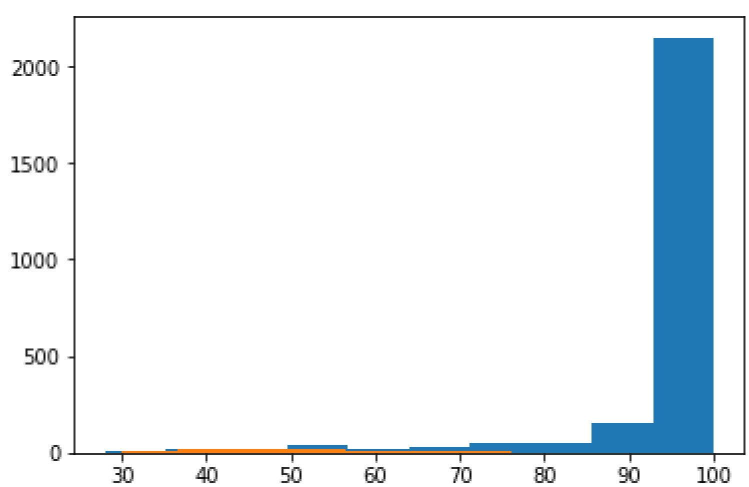


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 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656
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 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710
 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728
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729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746
747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764
765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782
783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800
801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818
819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836
837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854
855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872
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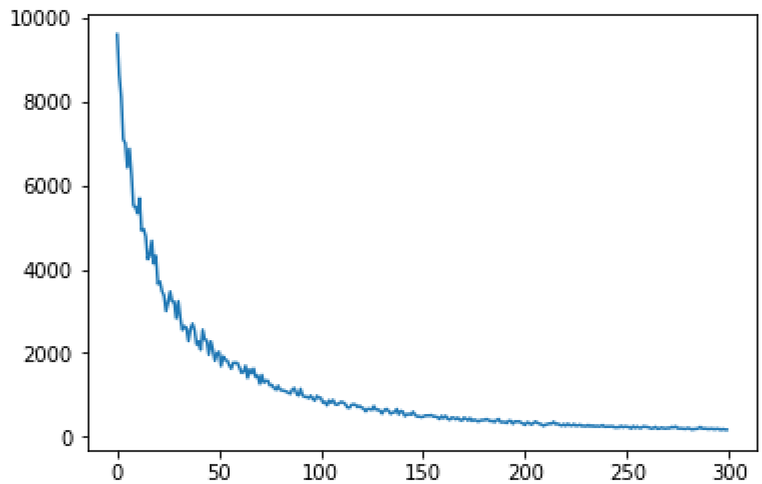


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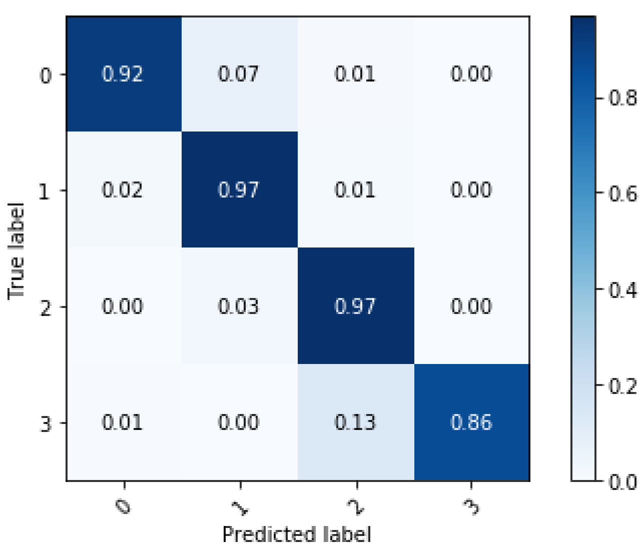


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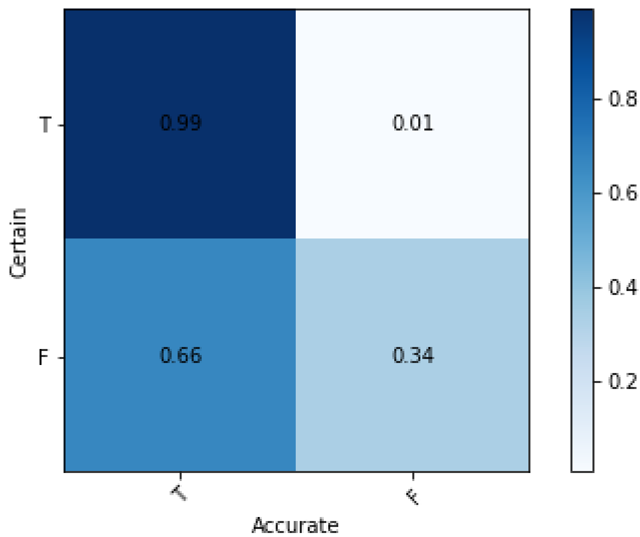


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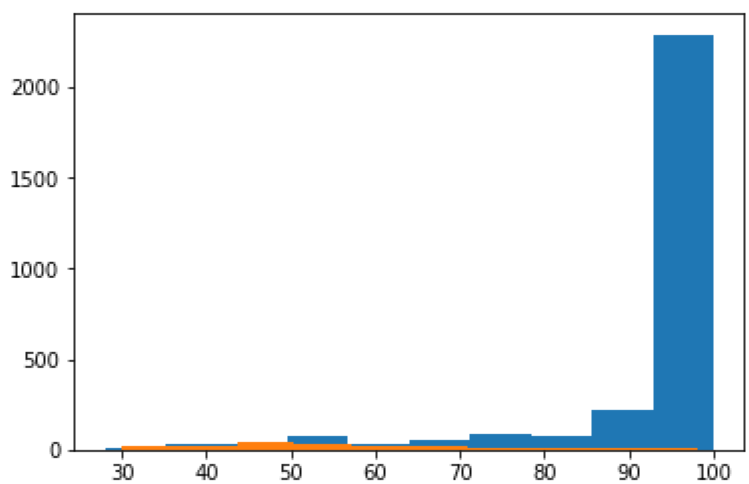


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  938  939  940  941  942  943  944  945  946  947  948  949  950  951
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  980  981  982  983  984  985  986  987  988  989  990  991  992  993
  994  995  996  997  998  999 1000 1001 1002 1003 1004 1005 1006 1007
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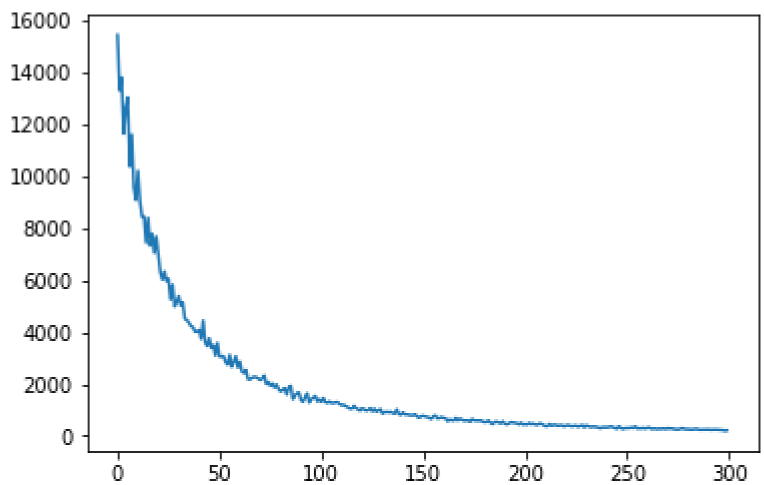


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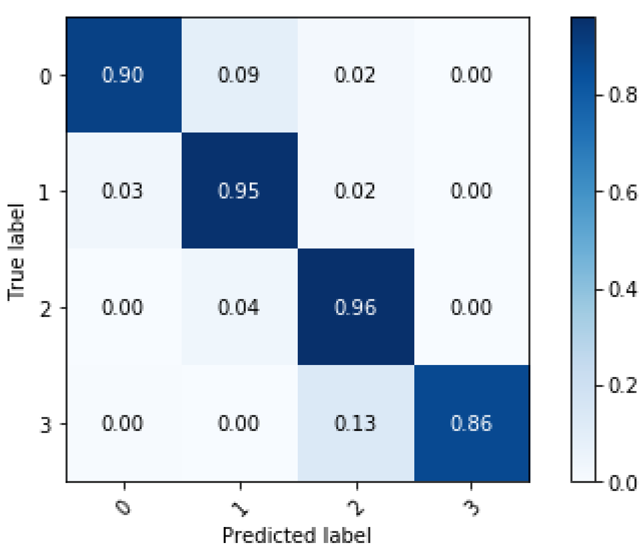

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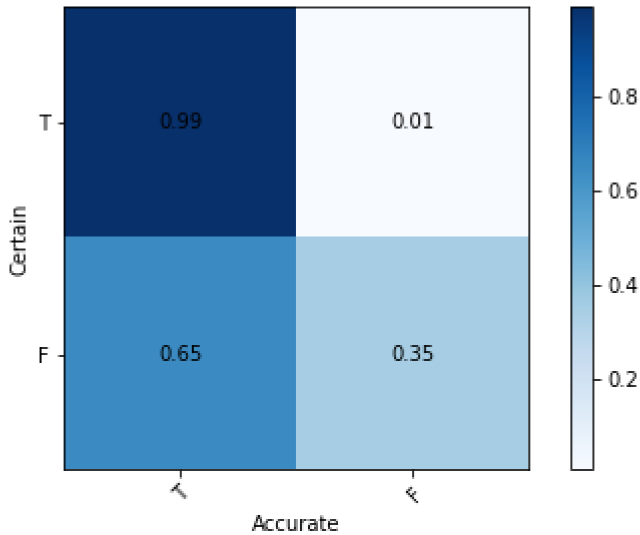


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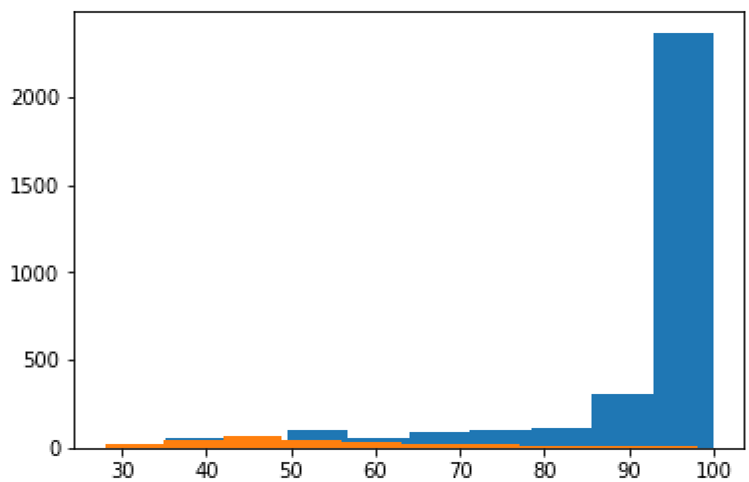


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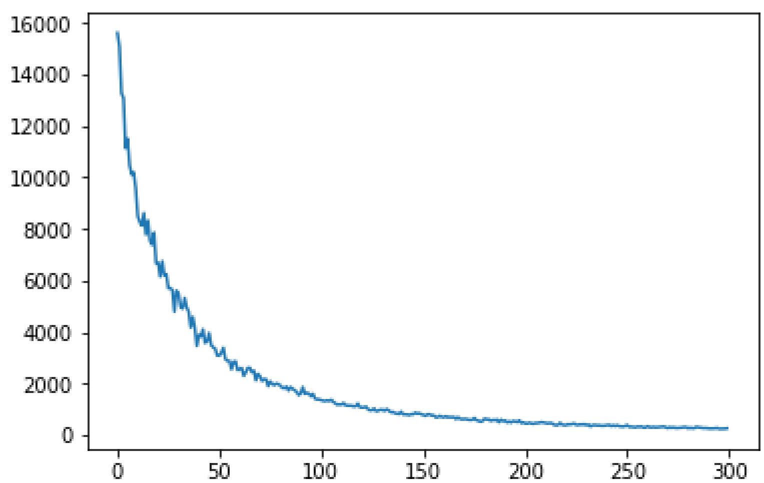


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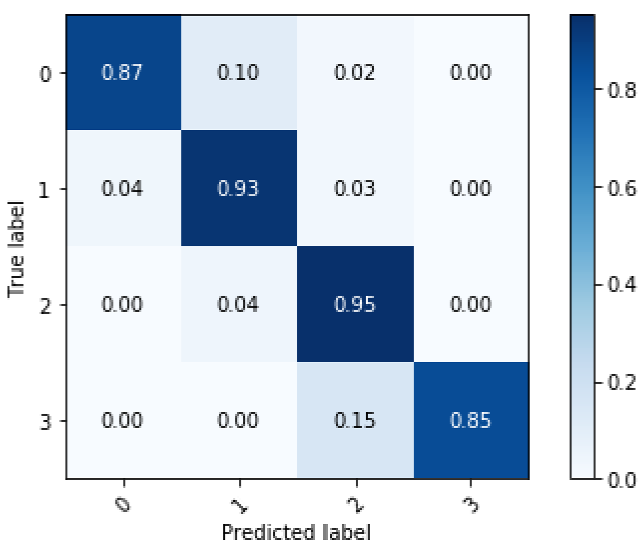

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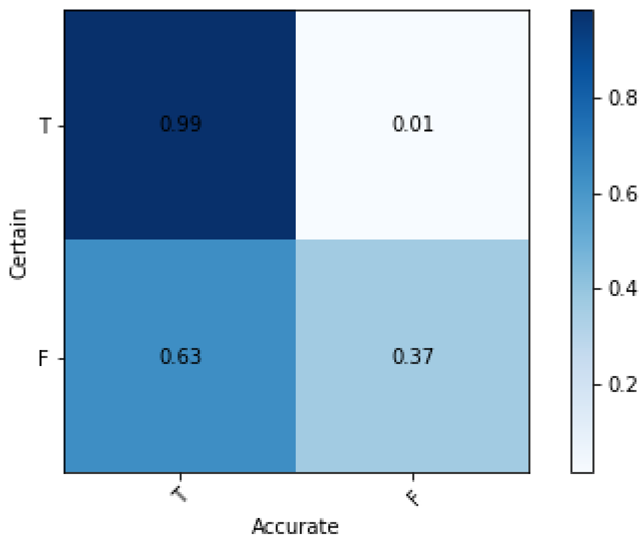


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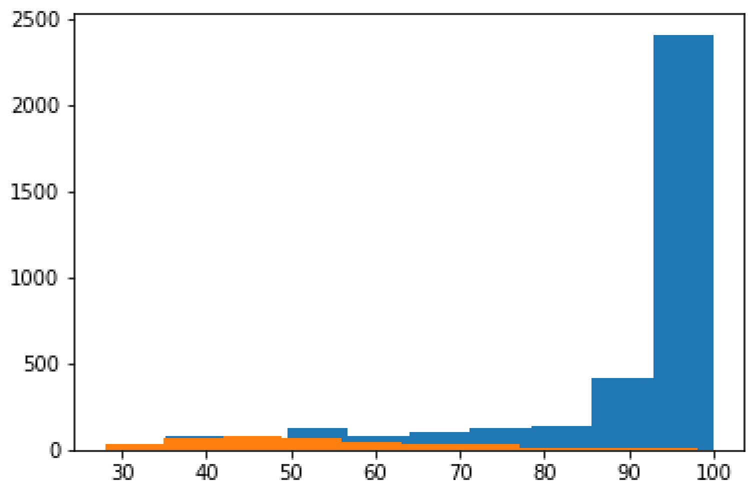


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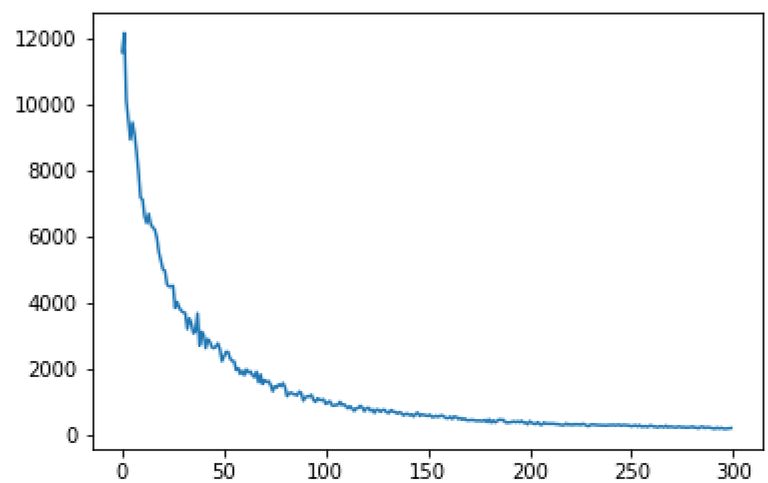


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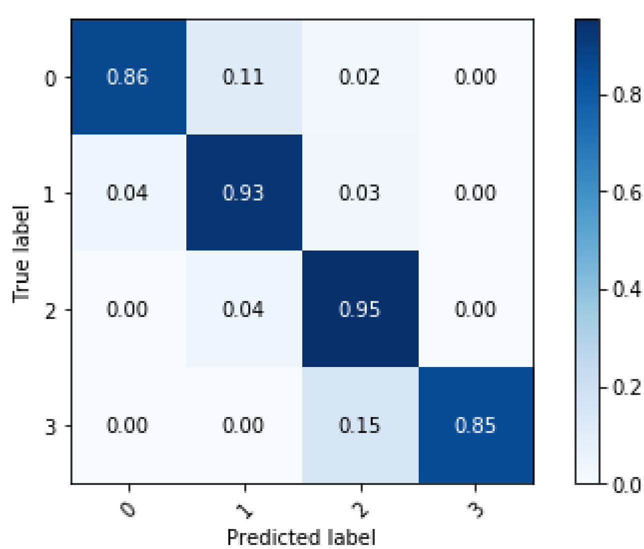

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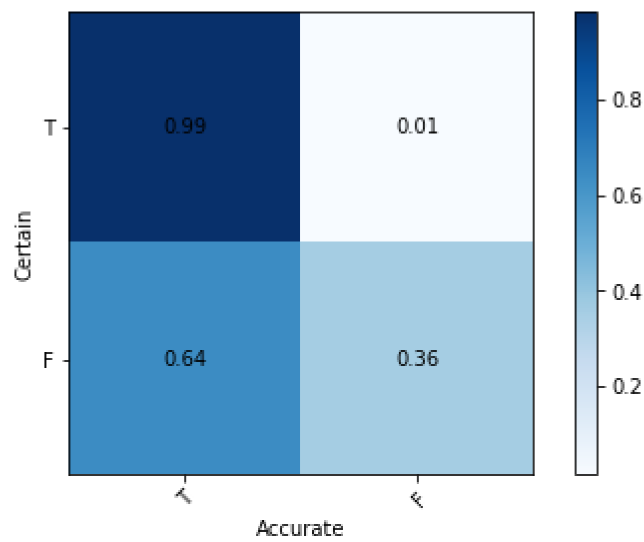


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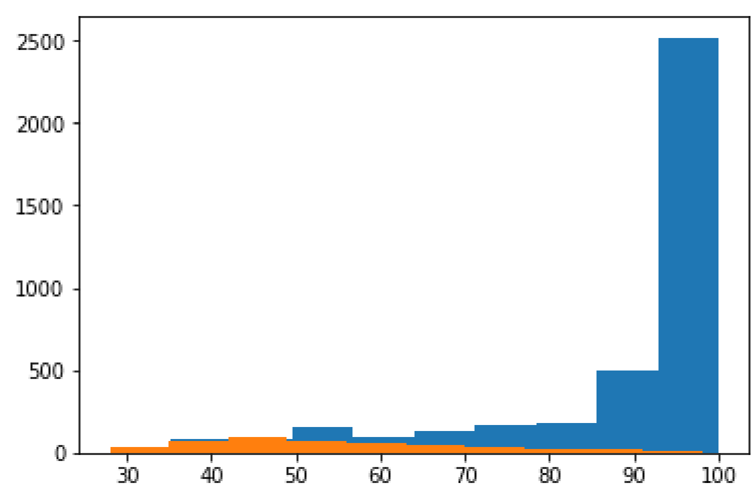


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↪9416909620991255, 0.9220521541950113, 0.9022423784328546, 0.8941043083900226]
P(Acc | Certain):  0.9909499081179456 +- 0.001979188876666969 [0.9966144731273805, 0.
↪9934665641813989, 0.9911253106141285, 0.9883488681757656, 0.9851943244910549]
P(Acc | Uncertain):  0.6525351521609853 +- 0.0074524186694632615 [0.6749116607773852,␣
↪0.6639175257731958, 0.6483825597749648, 0.6341968911917099, 0.6412671232876712]
[ 441  442  443 ... 2202 2203 2204] [   0    1    2    3    4    5    6    7    8    9   10   11 ␣
↪12   13   14   15   16   17
  18   19   20   21   22   23   24   25   26   27   28   29   30   31   32   33   34   35
  36   37   38   39   40   41   42   43   44   45   46   47   48   49   50   51   52   53
  54   55   56   57   58   59   60   61   62   63   64   65   66   67   68   69   70   71
  72   73   74   75   76   77   78   79   80   81   82   83   84   85   86   87   88   89
  90   91   92   93   94   95   96   97   98   99  100  101  102  103  104  105  106  107
 108  109  110  111  112  113  114  115  116  117  118  119  120  121  122  123  124  125
 126  127  128  129  130  131  132  133  134  135  136  137  138  139  140  141  142  143
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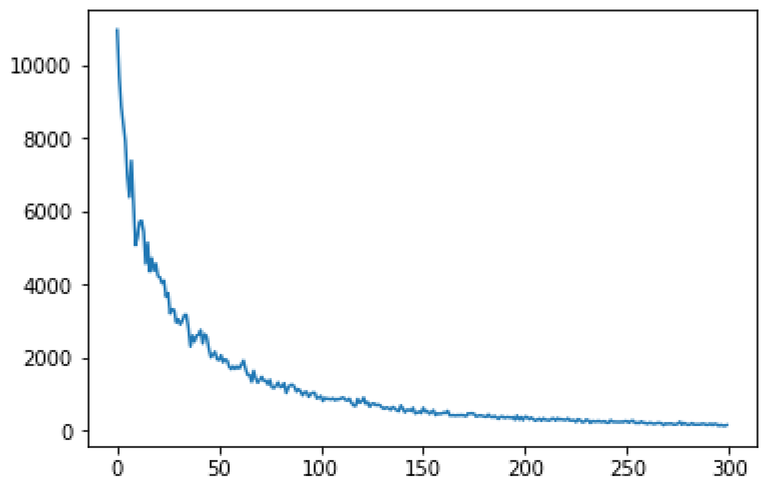


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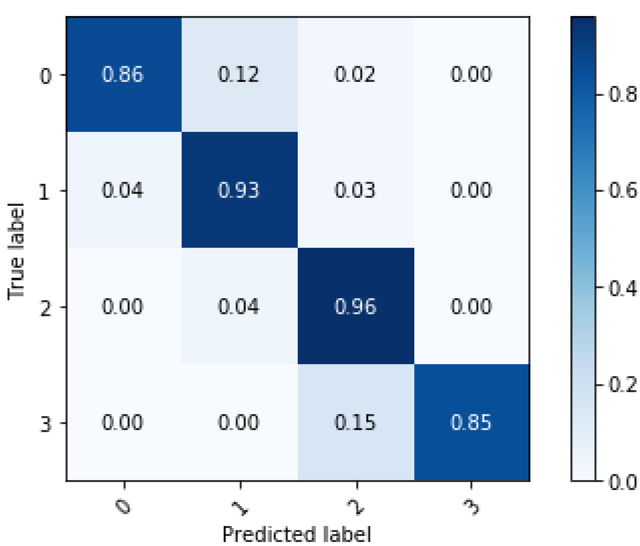

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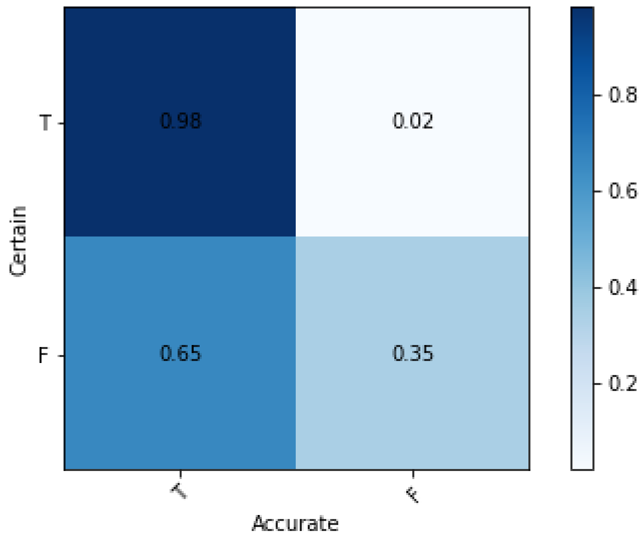


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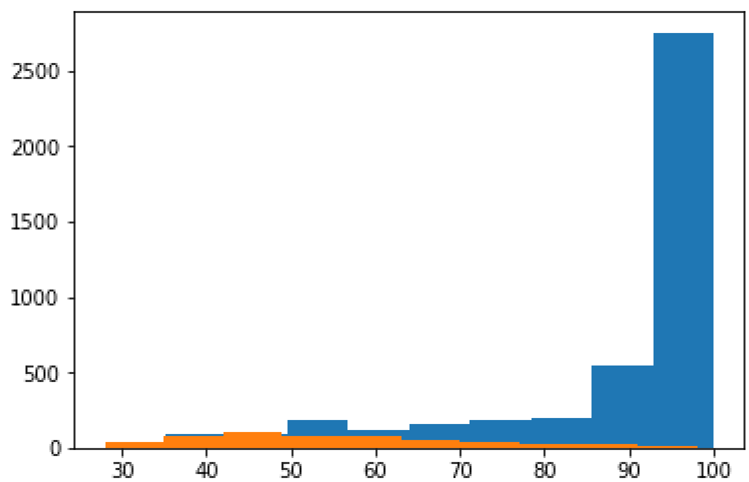


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 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746
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 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782
 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800
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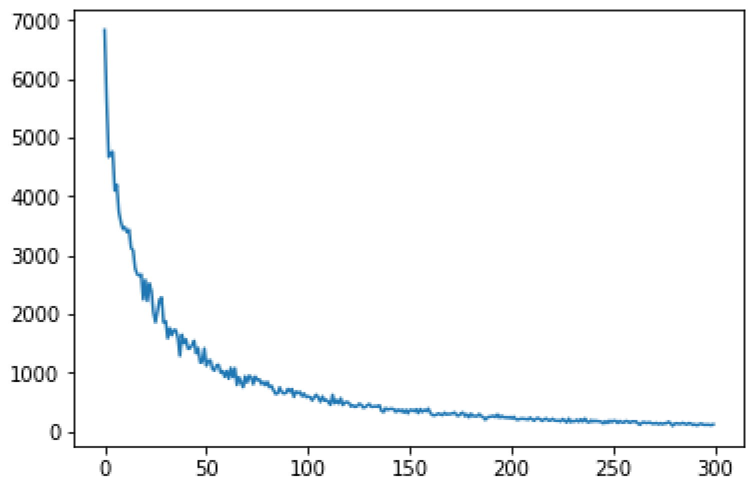


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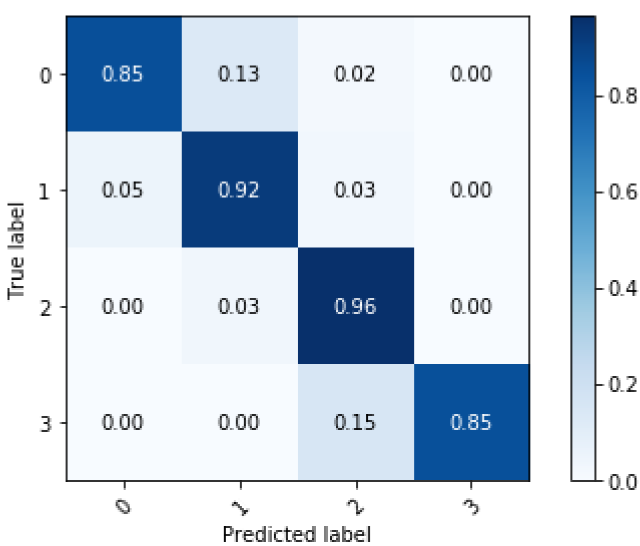


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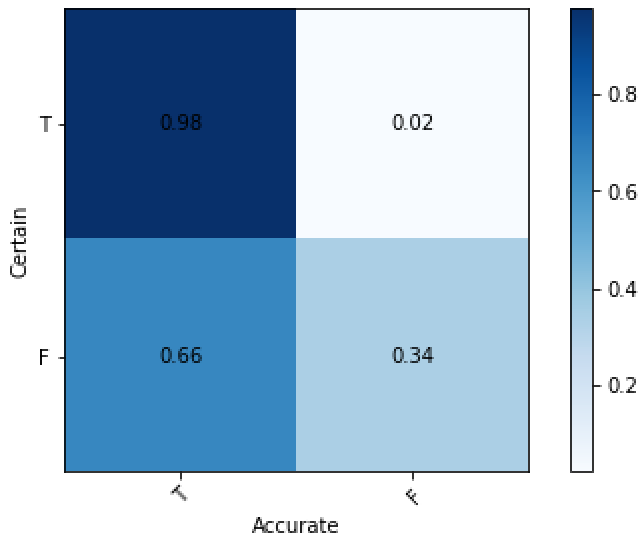


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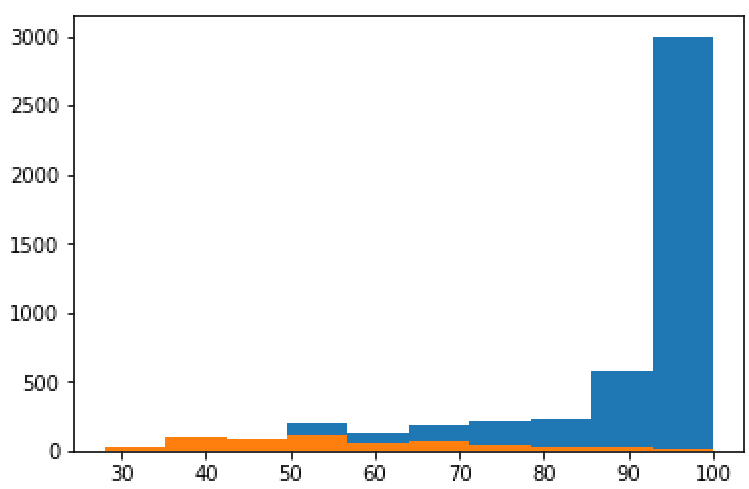


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  994  995  996  997  998  999 1000 1001 1002 1003 1004 1005 1006 1007
 1008 1009 1010 1011 1012 1013 1014 1015 1016 1017 1018 1019 1020 1021
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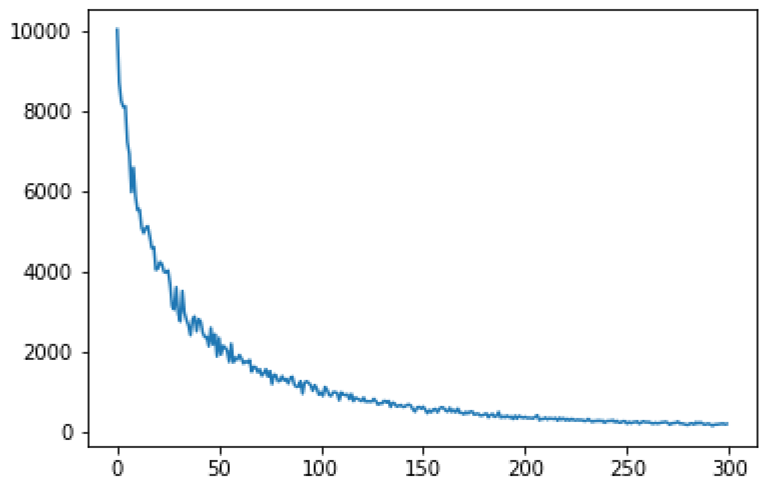


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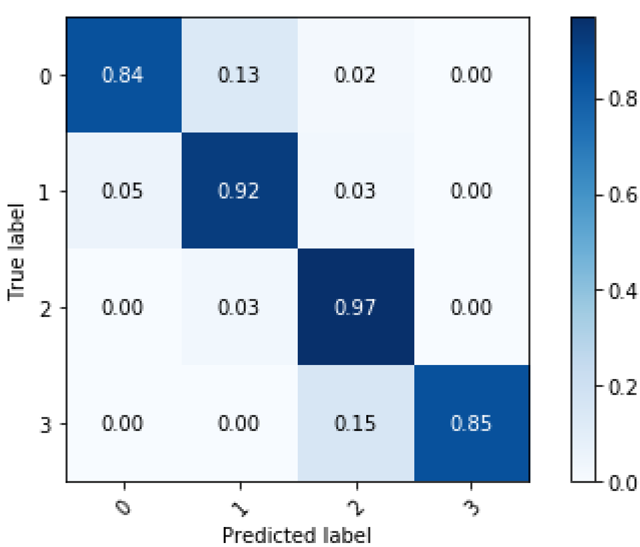

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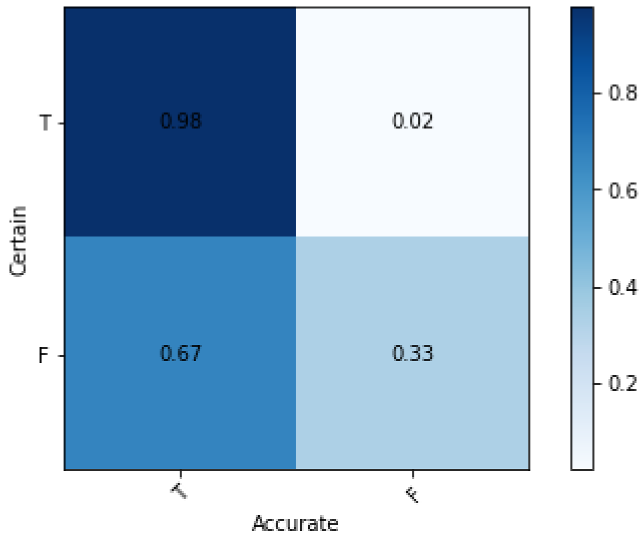


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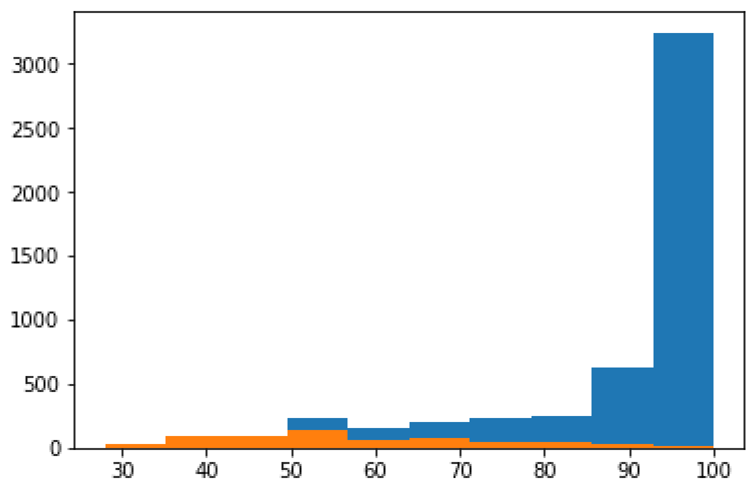


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1701 1702 1703 1704 1705 1706 1707 1708 1709 1710 1711 1712 1713 1714
1715 1716 1717 1718 1719 1720 1721 1722 1723 1724 1725 1726 1727 1728
1729 1730 1731 1732 1733 1734 1735 1736 1737 1738 1739 1740 1741 1742
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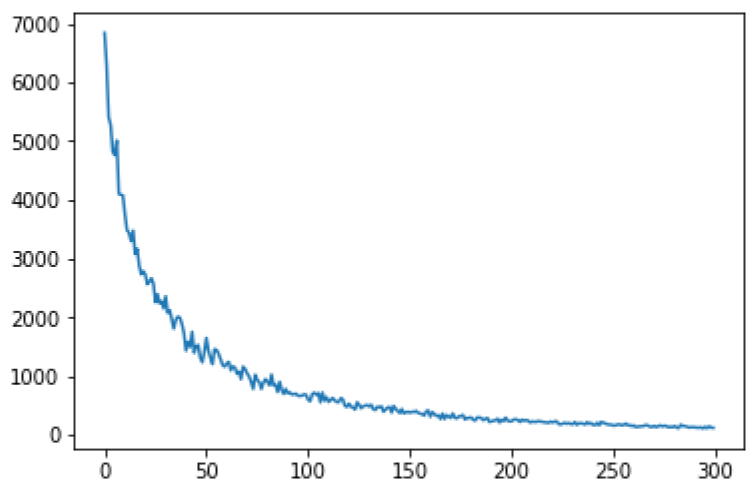


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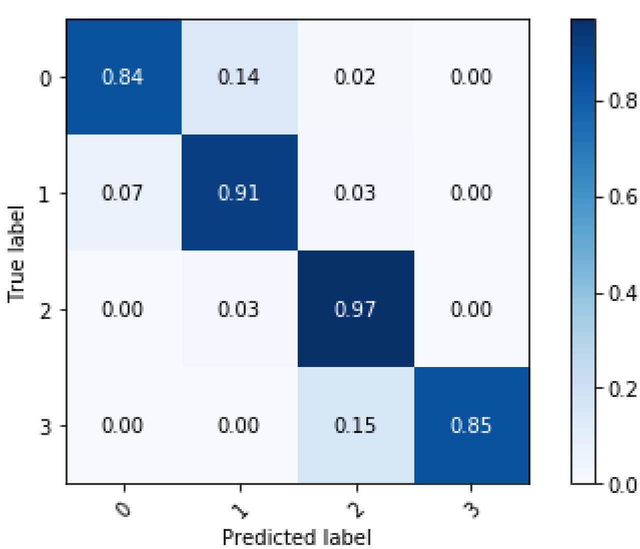

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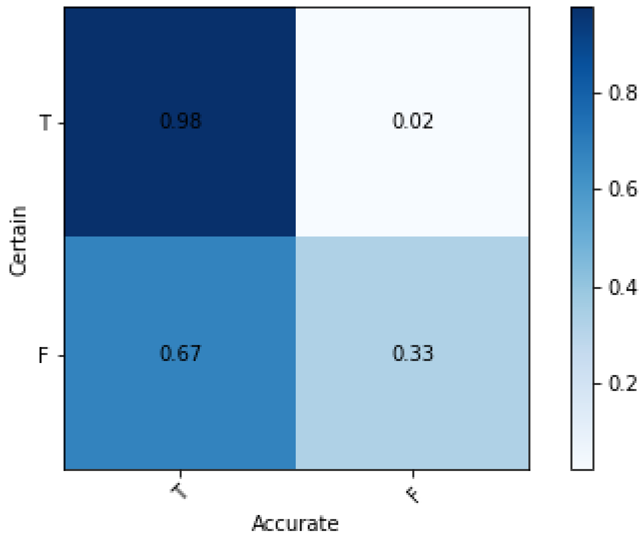


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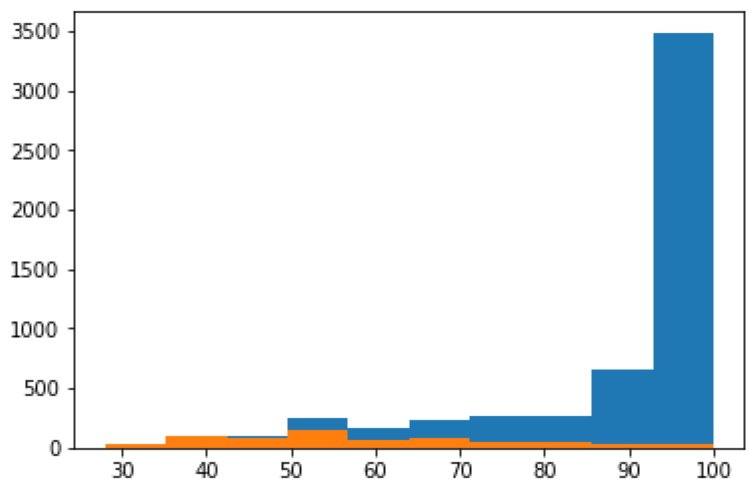


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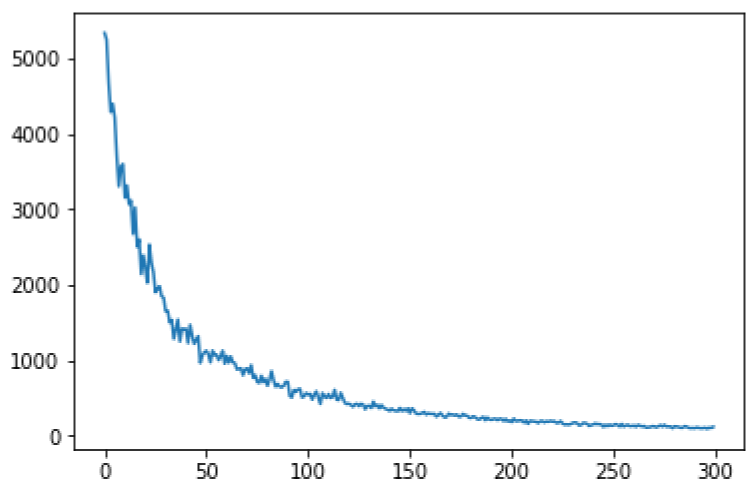


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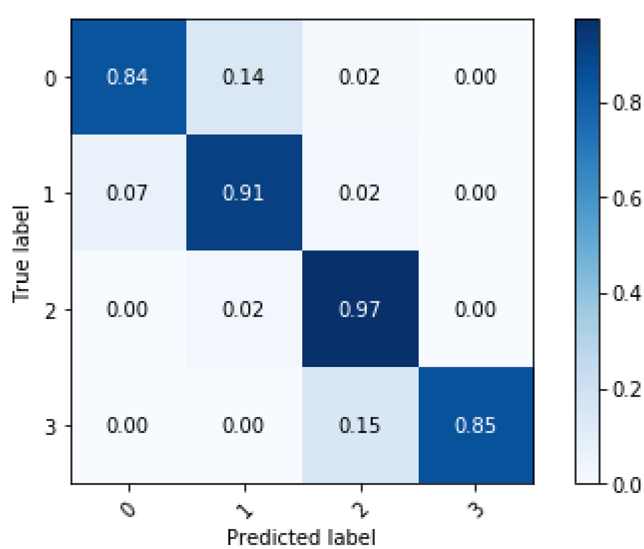

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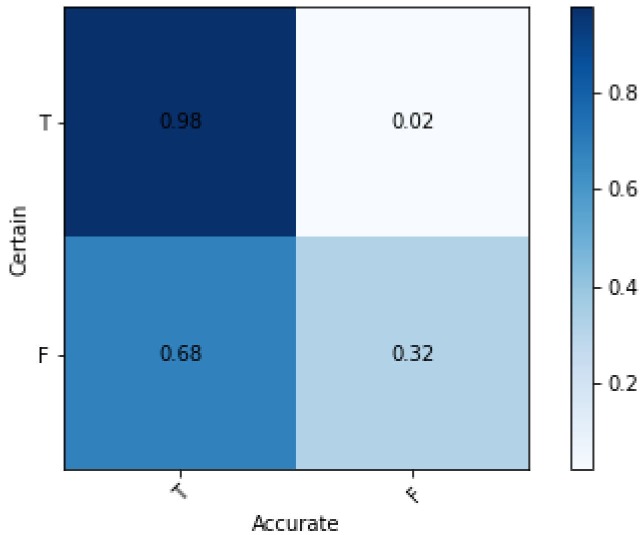


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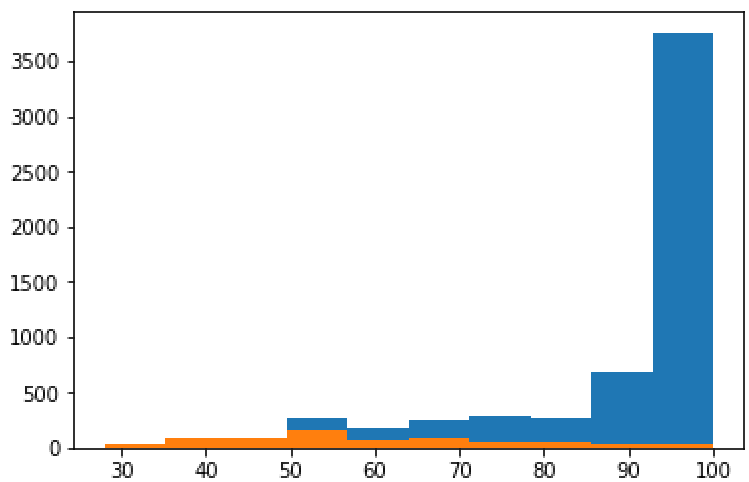


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Target output:  2
F1 SCORE:  0.8956939054898239 +- 0.0004668869383694529 [0.8954854669140383, 0.
↪8945578231292517, 0.8958660387231816, 0.8952057013281504, 0.8973544973544973]
P(Acc | Certain):  0.9802237531820188 +- 0.0008447896849073807 [0.983127109111361, 0.
↪9806651198762568, 0.98018147086915, 0.9788841964881084, 0.9782608695652174]
P(Acc | Uncertain):  0.6658386804182905 +- 0.004254498716107378 [0.6548262548262548,␣
↪0.6581740976645435, 0.6673139158576051, 0.6704477611940298, 0.6784313725490196]
[ 441  442  443 ... 2202 2203 2204] [   0    1    2    3    4    5    6    7    8    9   10   11 ␣
↪12   13   14   15   16   17
  18   19   20   21   22   23   24   25   26   27   28   29   30   31   32   33   34   35
  36   37   38   39   40   41   42   43   44   45   46   47   48   49   50   51   52   53
  54   55   56   57   58   59   60   61   62   63   64   65   66   67   68   69   70   71
  72   73   74   75   76   77   78   79   80   81   82   83   84   85   86   87   88   89
  90   91   92   93   94   95   96   97   98   99  100  101  102  103  104  105  106  107
 108  109  110  111  112  113  114  115  116  117  118  119  120  121  122  123  124  125
 126  127  128  129  130  131  132  133  134  135  136  137  138  139  140  141  142  143
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 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269
 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287
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 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323
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 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359
 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377
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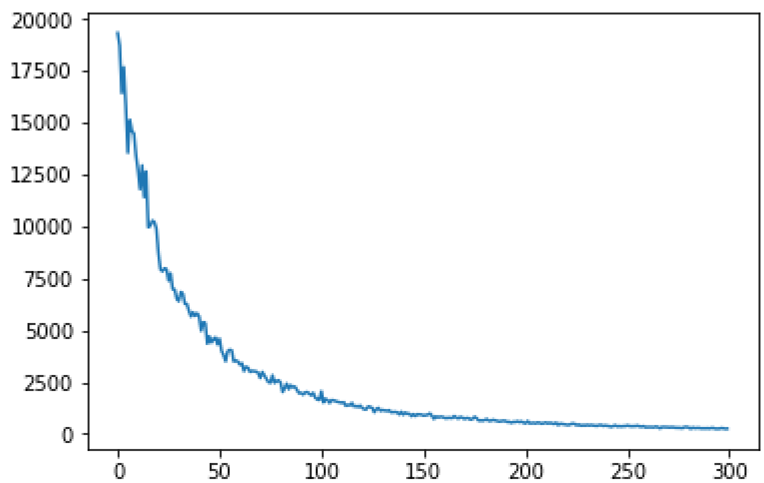


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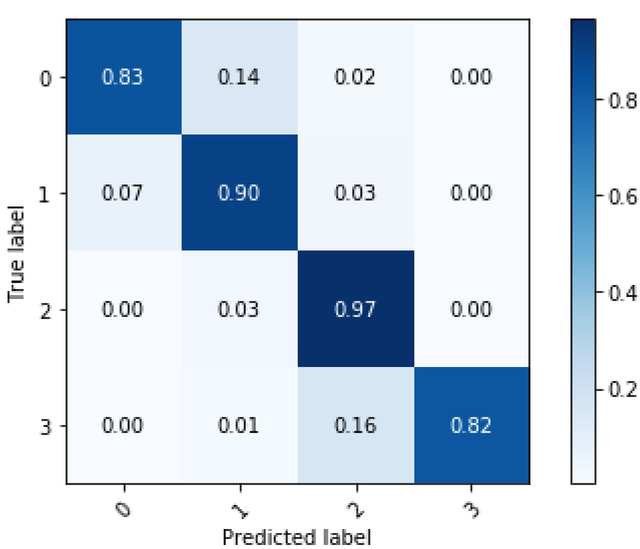

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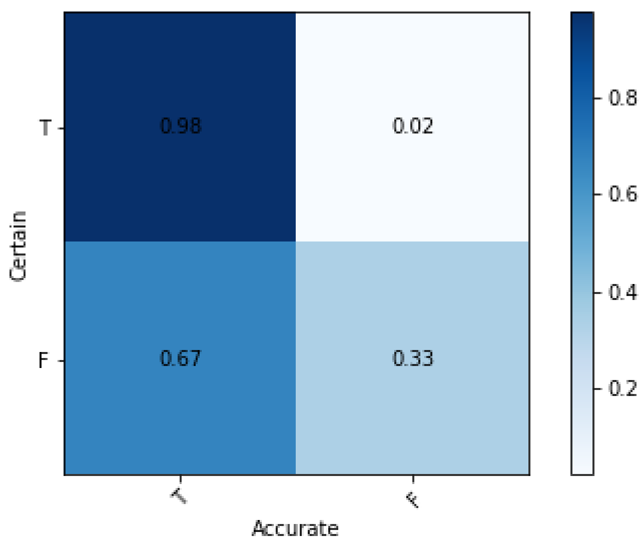


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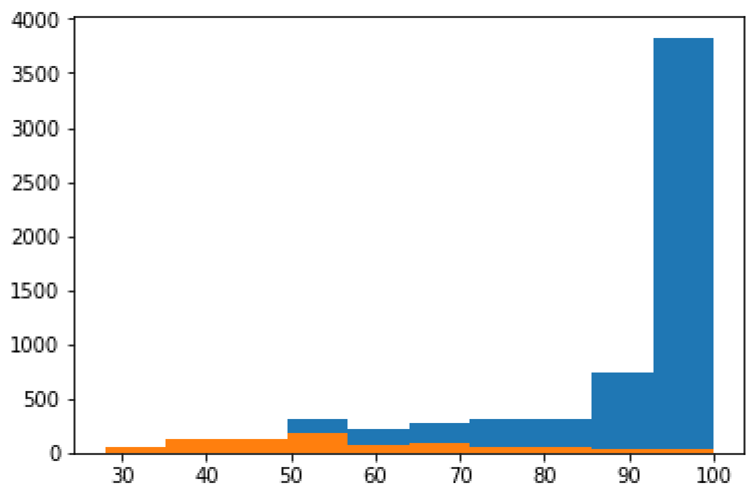


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 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710
 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728
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 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746
 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764
 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782
 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800
 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818
 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836
 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854
 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872
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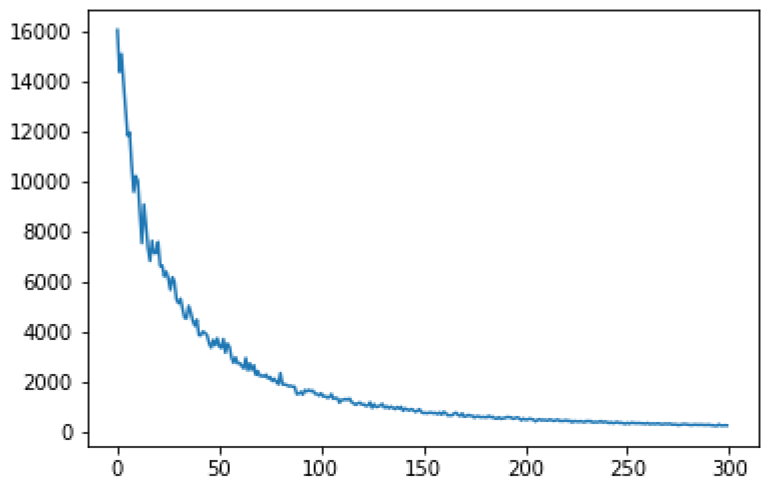


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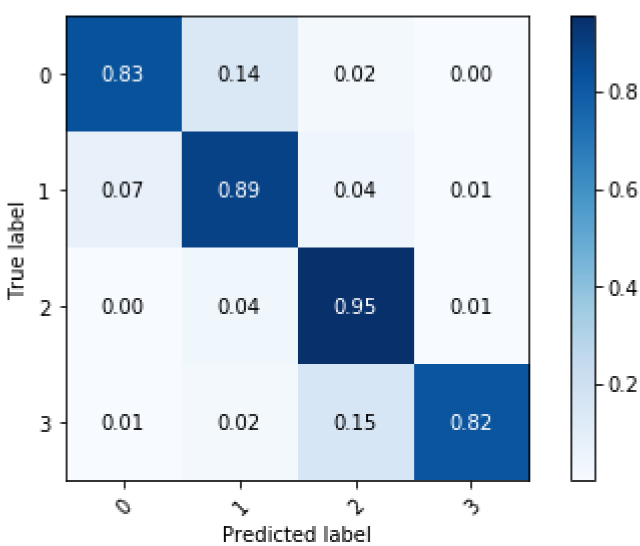


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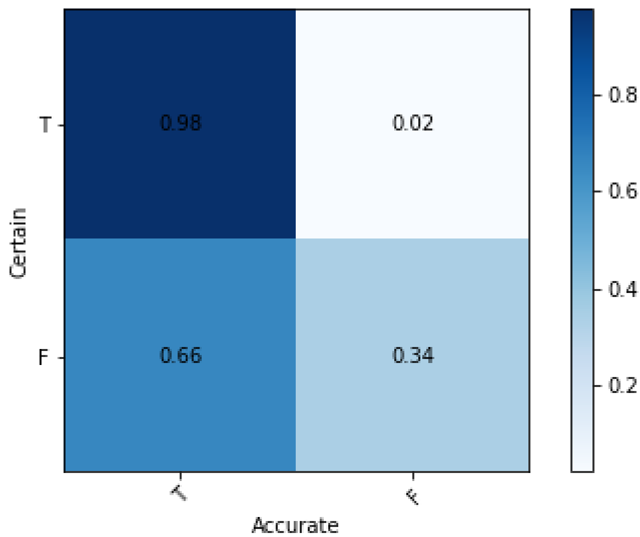


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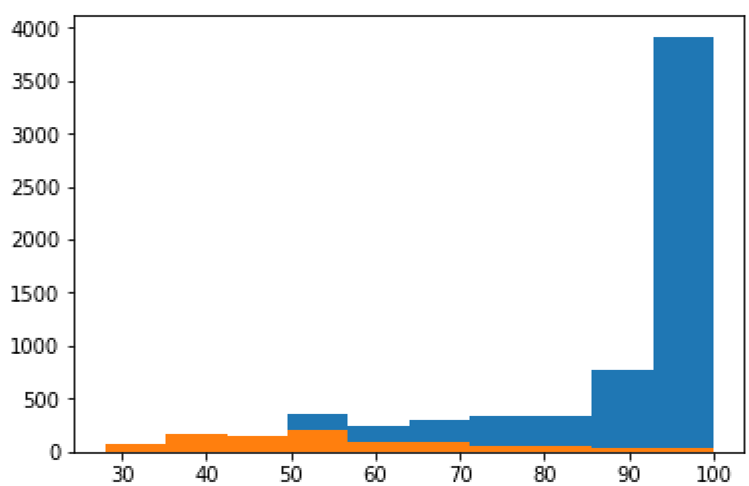


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  924  925  926  927  928  929  930  931  932  933  934  935  936  937
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  980  981  982  983  984  985  986  987  988  989  990  991  992  993
  994  995  996  997  998  999 1000 1001 1002 1003 1004 1005 1006 1007
 1008 1009 1010 1011 1012 1013 1014 1015 1016 1017 1018 1019 1020 1021
 1022 1023 1024 1025 1026 1027 1028 1029 1030 1031 1032 1033 1034 1035
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 1106 1107 1108 1109 1110 1111 1112 1113 1114 1115 1116 1117 1118 1119
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1274 1275 1276 1277 1278 1279 1280 1281 1282 1283 1284 1285 1286 1287
1288 1289 1290 1291 1292 1293 1294 1295 1296 1297 1298 1299 1300 1301
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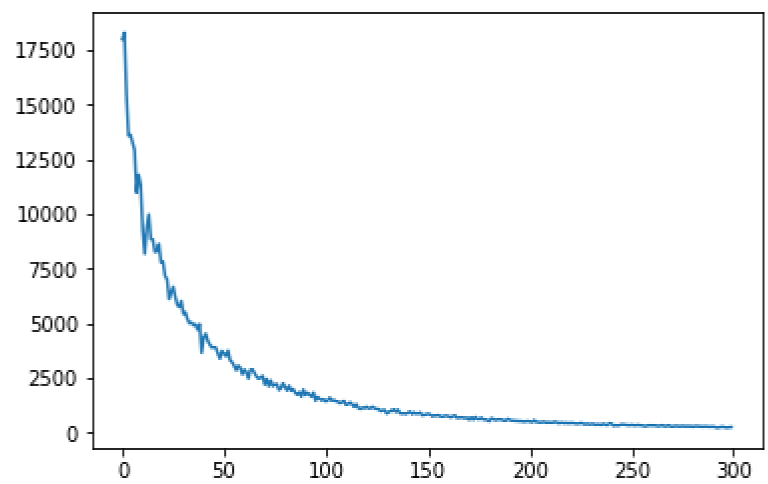


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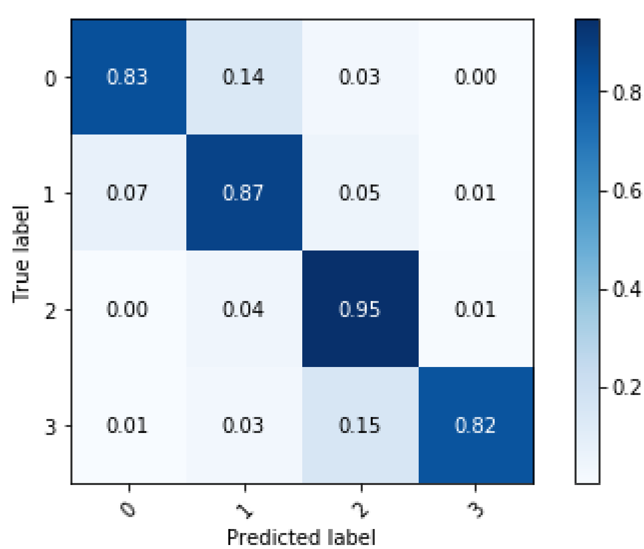

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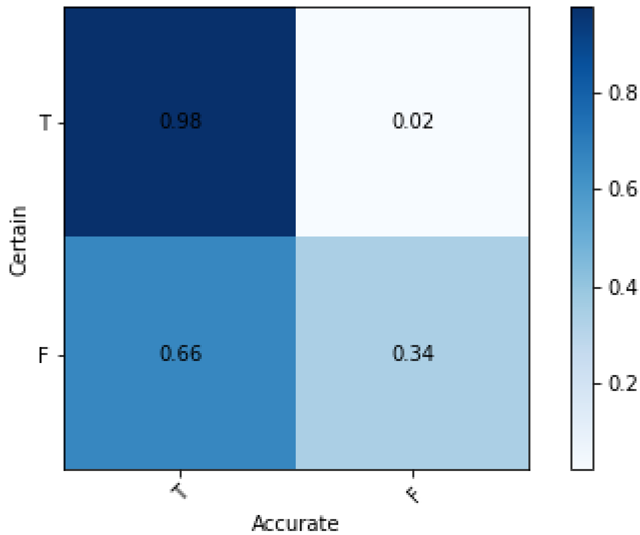


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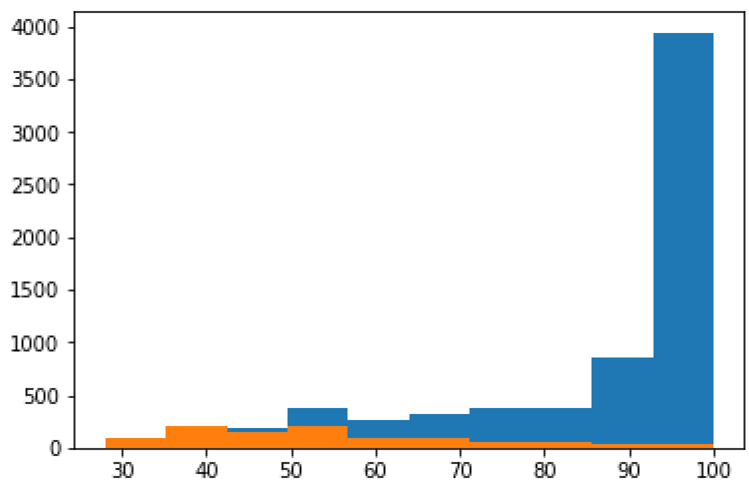


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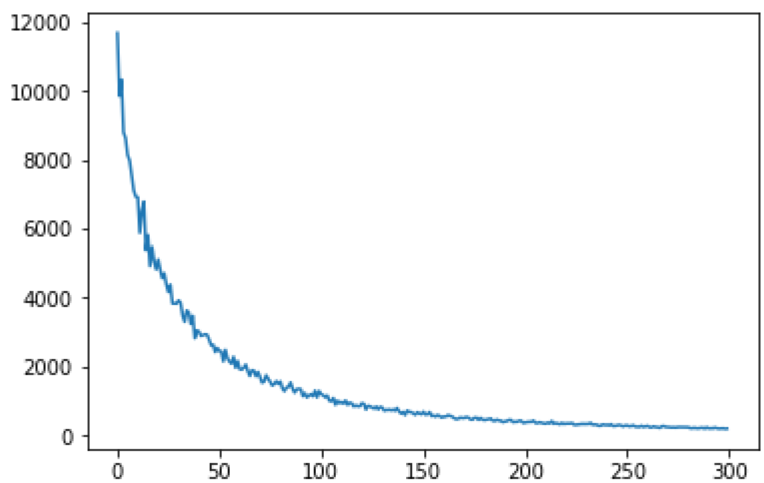


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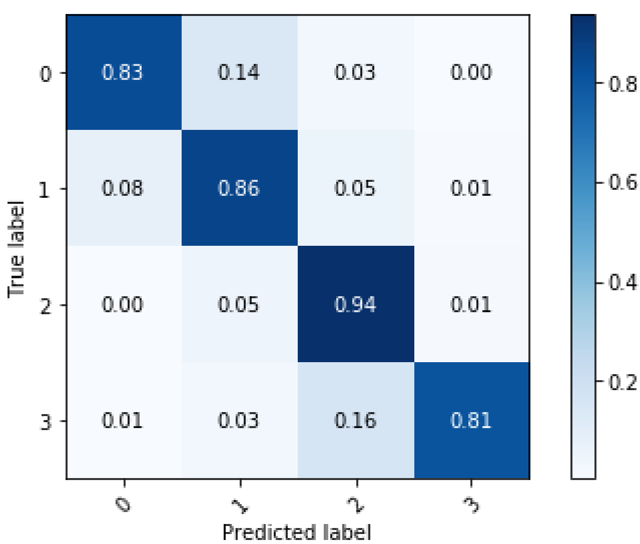

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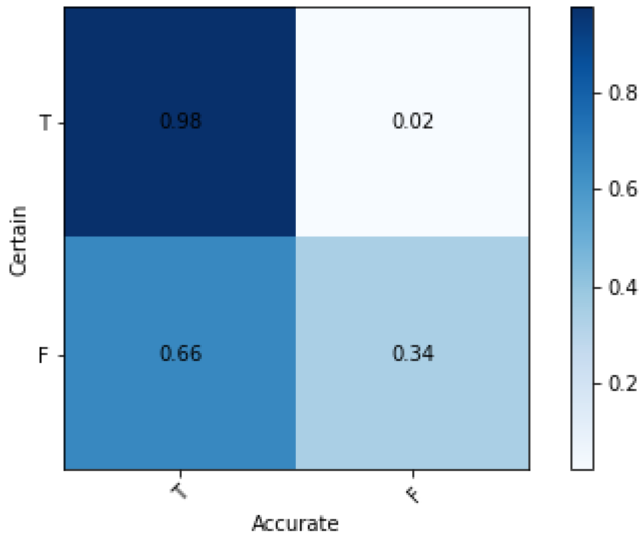


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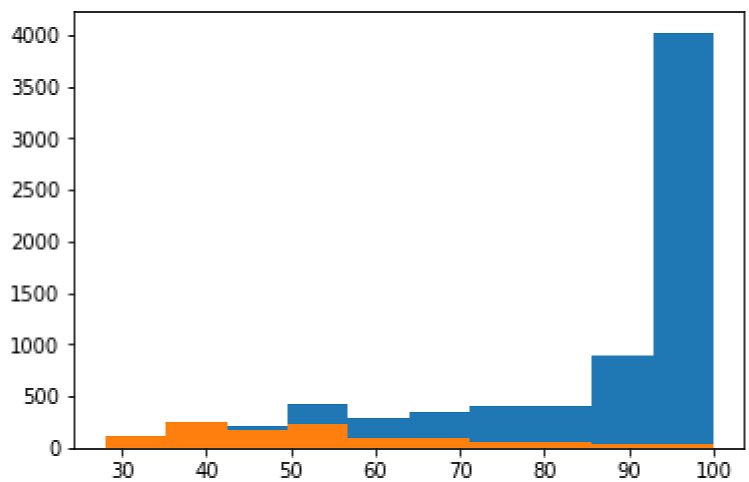


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 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001
 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029
 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043
 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057
 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071
 2072 2073 2074 2075 2076 2077 2078 2079 2080 2081 2082 2083 2084 2085
 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099
 2100 2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113
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 2170 2171 2172 2173 2174 2175 2176 2177 2178 2179 2180 2181 2182 2183
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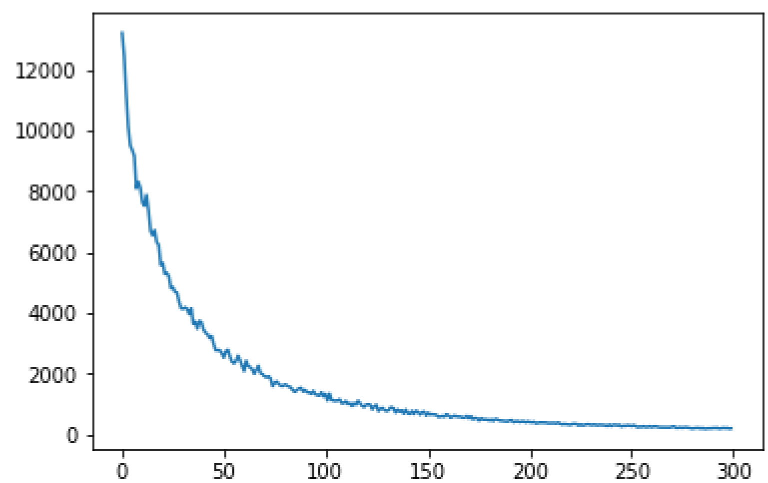


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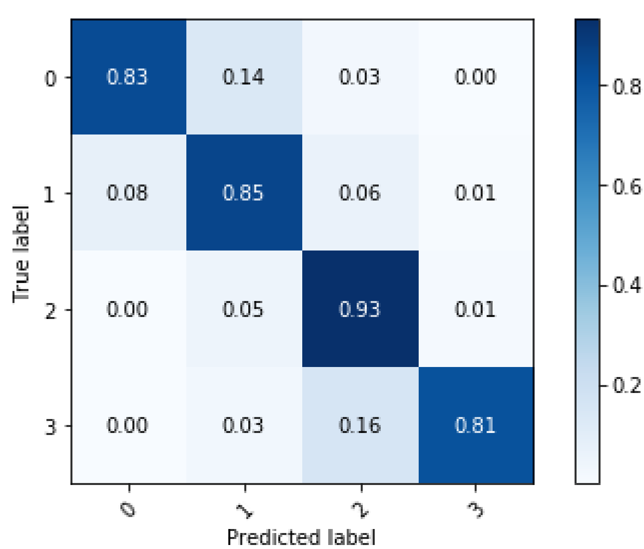

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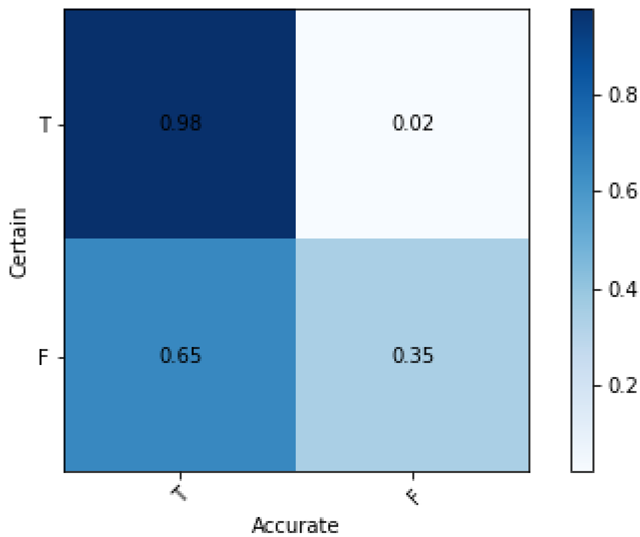


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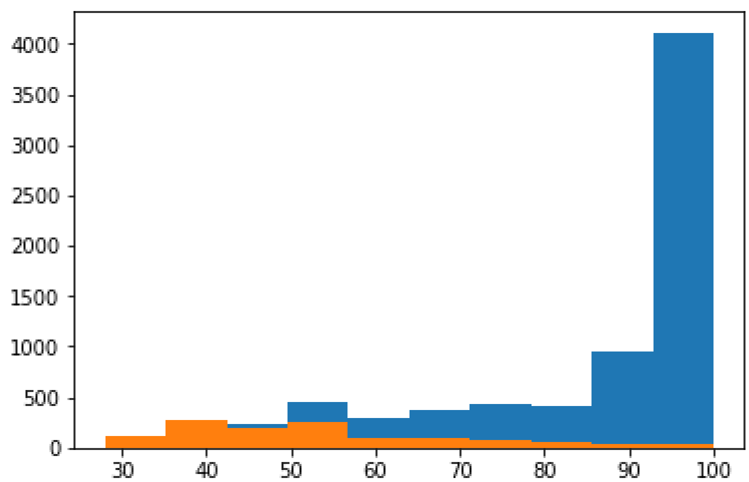


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P(Acc | Certain):  0.9782688014829797 +- 8.581726290369855e-05 [0.9781036560867818, 0.
↪9780241151302995, 0.9784090909090909, 0.9784490698102781, 0.9783580754784476]
P(Acc | Uncertain):  0.6594160576349053 +- 0.002161149247641815 [0.6669874879692012,␣
↪0.6602972399150743, 0.6591422121896162, 0.656271186440678, 0.6543821616599567]
[ 441  442  443 ... 2202 2203 2204] [   0    1    2    3    4    5    6    7    8    9   10   11 ␣
↪12   13   14   15   16   17
  18   19   20   21   22   23   24   25   26   27   28   29   30   31   32   33   34   35
  36   37   38   39   40   41   42   43   44   45   46   47   48   49   50   51   52   53
  54   55   56   57   58   59   60   61   62   63   64   65   66   67   68   69   70   71
  72   73   74   75   76   77   78   79   80   81   82   83   84   85   86   87   88   89
  90   91   92   93   94   95   96   97   98   99  100  101  102  103  104  105  106  107
 108  109  110  111  112  113  114  115  116  117  118  119  120  121  122  123  124  125
 126  127  128  129  130  131  132  133  134  135  136  137  138  139  140  141  142  143
 144  145  146  147  148  149  150  151  152  153  154  155  156  157  158  159  160  161
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 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269
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 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323
 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341
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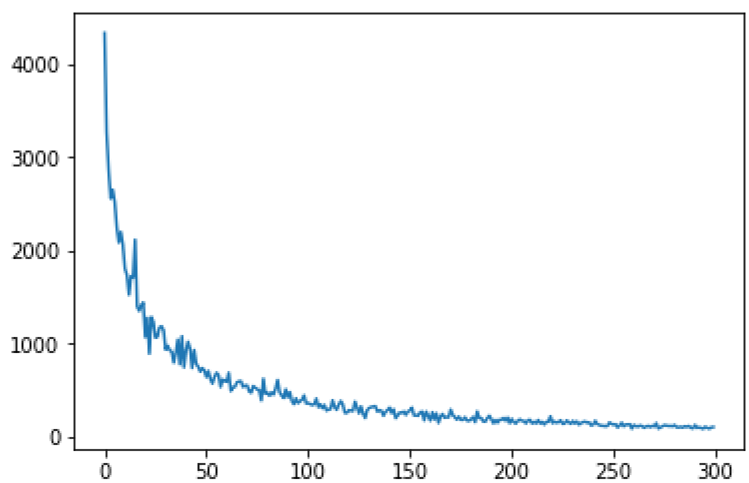


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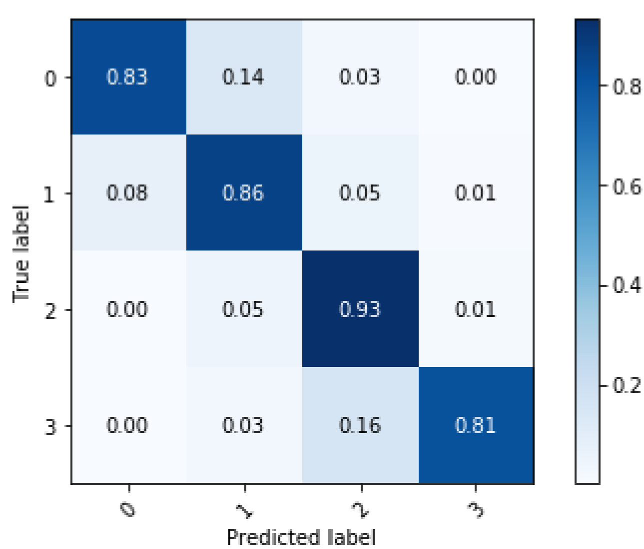

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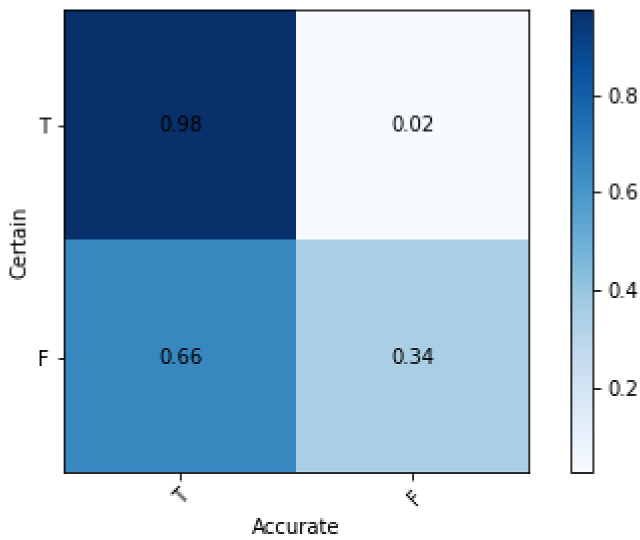


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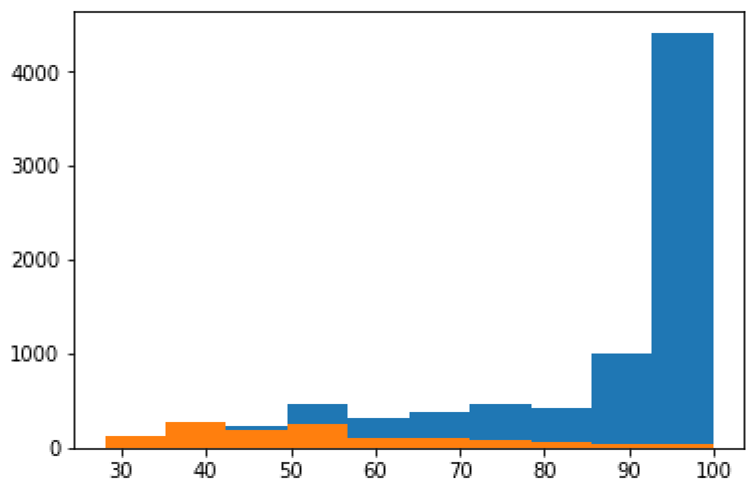


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↪453 454 455 456 457 458
 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476
 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494
 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512
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 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620
 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638
 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656
 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674
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 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710
 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728
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729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746
747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764
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783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800
801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818
819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836
837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854
855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872
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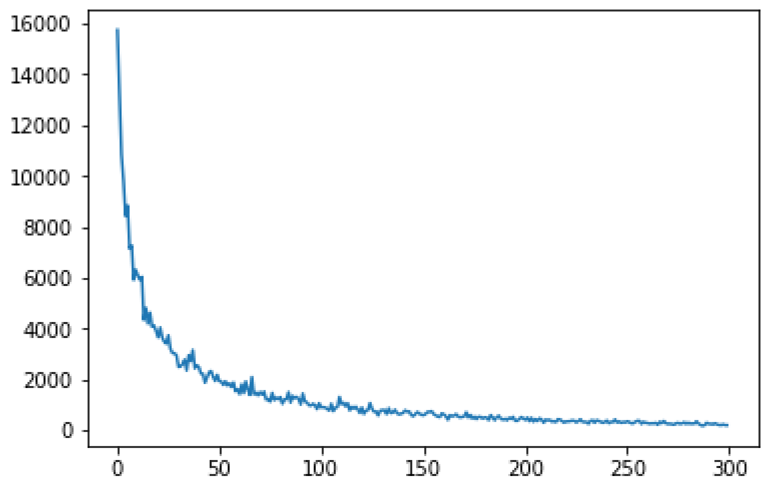


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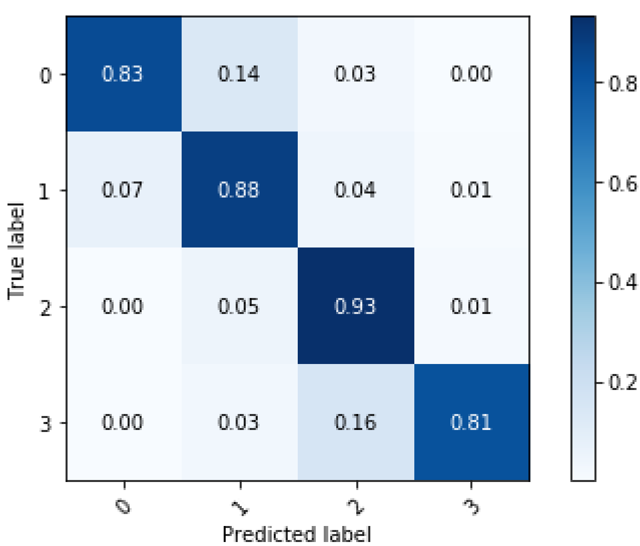


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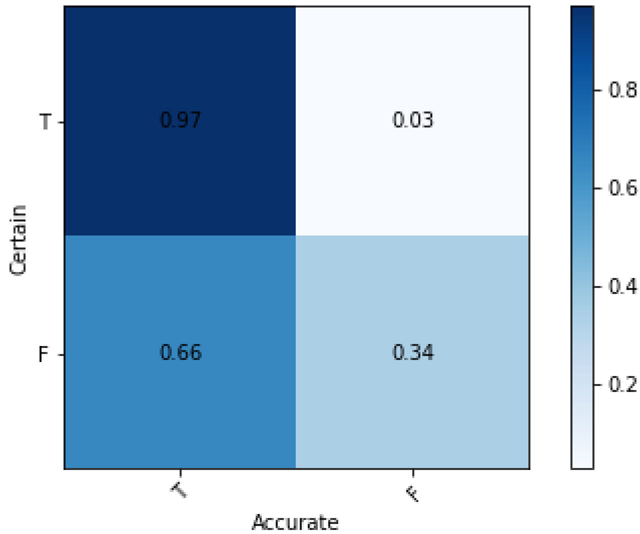


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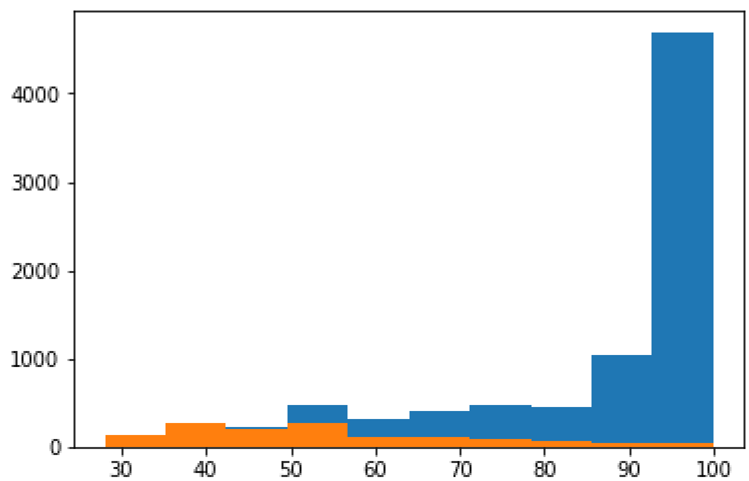


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↪891  892  893  894  895
  896  897  898  899  900  901  902  903  904  905  906  907  908  909
  910  911  912  913  914  915  916  917  918  919  920  921  922  923
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  938  939  940  941  942  943  944  945  946  947  948  949  950  951
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  980  981  982  983  984  985  986  987  988  989  990  991  992  993
  994  995  996  997  998  999 1000 1001 1002 1003 1004 1005 1006 1007
 1008 1009 1010 1011 1012 1013 1014 1015 1016 1017 1018 1019 1020 1021
 1022 1023 1024 1025 1026 1027 1028 1029 1030 1031 1032 1033 1034 1035
 1036 1037 1038 1039 1040 1041 1042 1043 1044 1045 1046 1047 1048 1049
 1050 1051 1052 1053 1054 1055 1056 1057 1058 1059 1060 1061 1062 1063
 1064 1065 1066 1067 1068 1069 1070 1071 1072 1073 1074 1075 1076 1077
 1078 1079 1080 1081 1082 1083 1084 1085 1086 1087 1088 1089 1090 1091
 1092 1093 1094 1095 1096 1097 1098 1099 1100 1101 1102 1103 1104 1105
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1120 1121 1122 1123 1124 1125 1126 1127 1128 1129 1130 1131 1132 1133
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1162 1163 1164 1165 1166 1167 1168 1169 1170 1171 1172 1173 1174 1175
1176 1177 1178 1179 1180 1181 1182 1183 1184 1185 1186 1187 1188 1189
1190 1191 1192 1193 1194 1195 1196 1197 1198 1199 1200 1201 1202 1203
1204 1205 1206 1207 1208 1209 1210 1211 1212 1213 1214 1215 1216 1217
1218 1219 1220 1221 1222 1223 1224 1225 1226 1227 1228 1229 1230 1231
1232 1233 1234 1235 1236 1237 1238 1239 1240 1241 1242 1243 1244 1245
1246 1247 1248 1249 1250 1251 1252 1253 1254 1255 1256 1257 1258 1259
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1274 1275 1276 1277 1278 1279 1280 1281 1282 1283 1284 1285 1286 1287
1288 1289 1290 1291 1292 1293 1294 1295 1296 1297 1298 1299 1300 1301
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1316 1317 1318 1319 1320 1321 1322]
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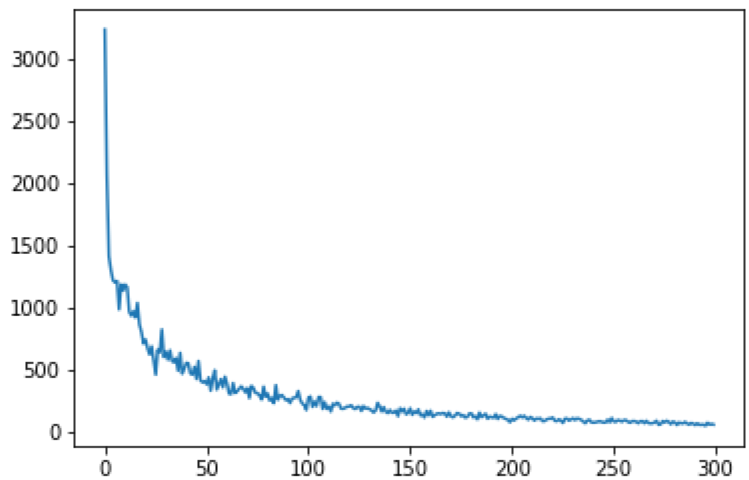


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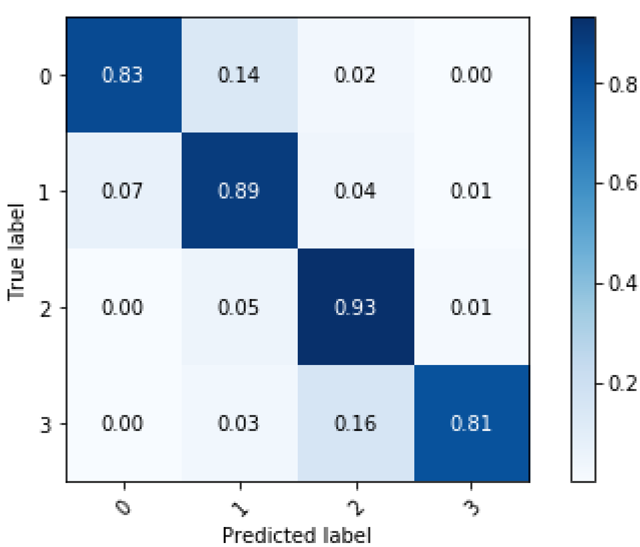

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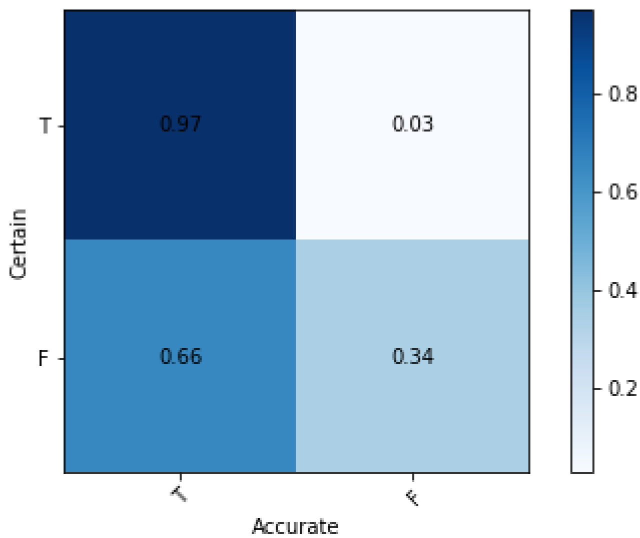


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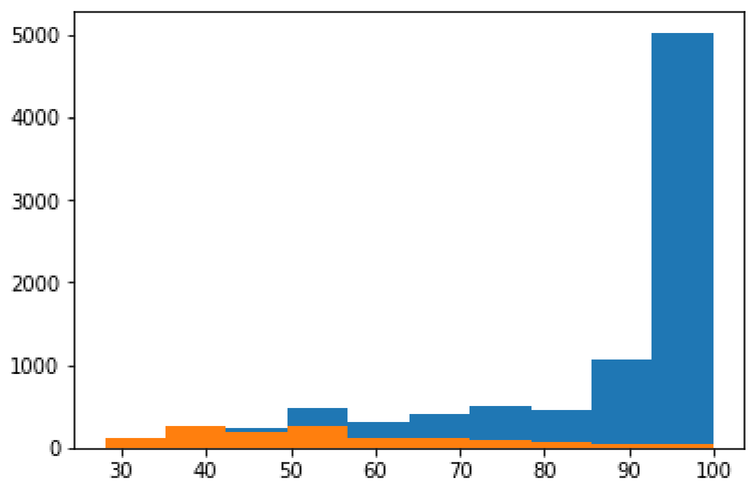


```
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↪1332 1333 1334 1335 1336
 1337 1338 1339 1340 1341 1342 1343 1344 1345 1346 1347 1348 1349 1350
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 1365 1366 1367 1368 1369 1370 1371 1372 1373 1374 1375 1376 1377 1378
 1379 1380 1381 1382 1383 1384 1385 1386 1387 1388 1389 1390 1391 1392
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 1477 1478 1479 1480 1481 1482 1483 1484 1485 1486 1487 1488 1489 1490
 1491 1492 1493 1494 1495 1496 1497 1498 1499 1500 1501 1502 1503 1504
 1505 1506 1507 1508 1509 1510 1511 1512 1513 1514 1515 1516 1517 1518
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 1547 1548 1549 1550 1551 1552 1553 1554 1555 1556 1557 1558 1559 1560
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 1589 1590 1591 1592 1593 1594 1595 1596 1597 1598 1599 1600 1601 1602
 1603 1604 1605 1606 1607 1608 1609 1610 1611 1612 1613 1614 1615 1616
 1617 1618 1619 1620 1621 1622 1623 1624 1625 1626 1627 1628 1629 1630
 1631 1632 1633 1634 1635 1636 1637 1638 1639 1640 1641 1642 1643 1644
 1645 1646 1647 1648 1649 1650 1651 1652 1653 1654 1655 1656 1657 1658
 1659 1660 1661 1662 1663 1664 1665 1666 1667 1668 1669 1670 1671 1672
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 1687 1688 1689 1690 1691 1692 1693 1694 1695 1696 1697 1698 1699 1700
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 1715 1716 1717 1718 1719 1720 1721 1722 1723 1724 1725 1726 1727 1728
 1729 1730 1731 1732 1733 1734 1735 1736 1737 1738 1739 1740 1741 1742
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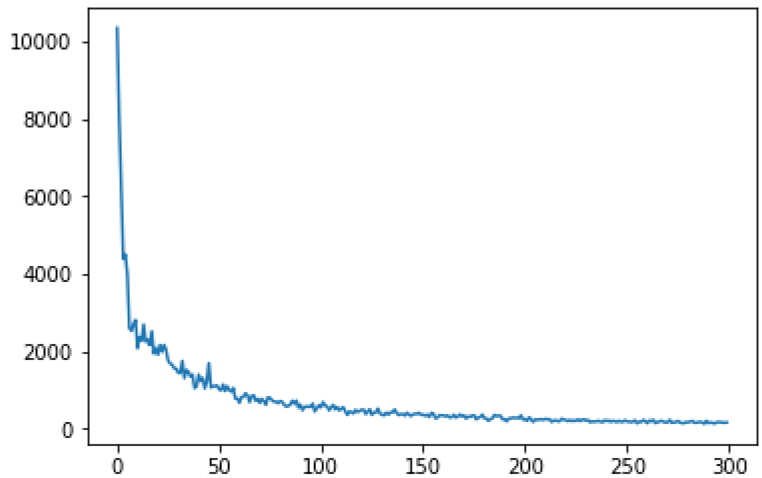


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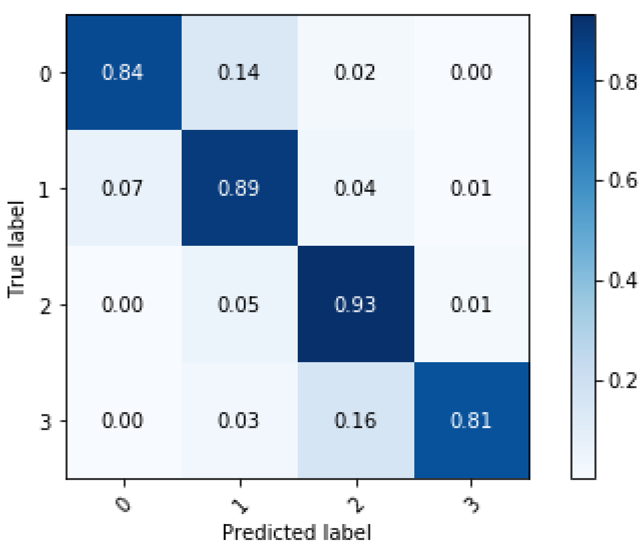

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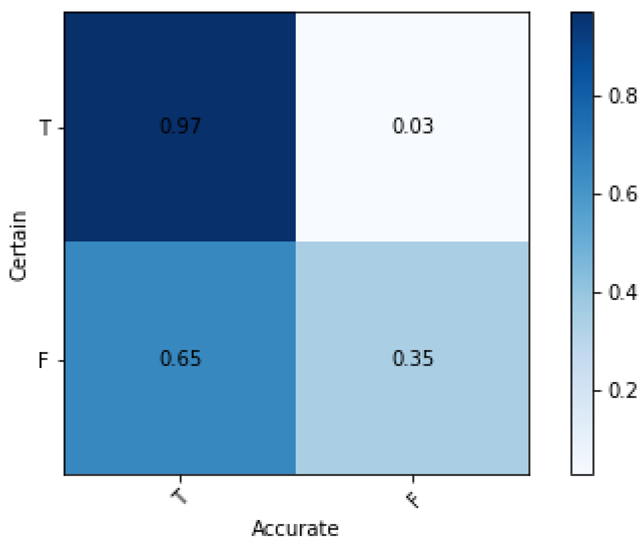


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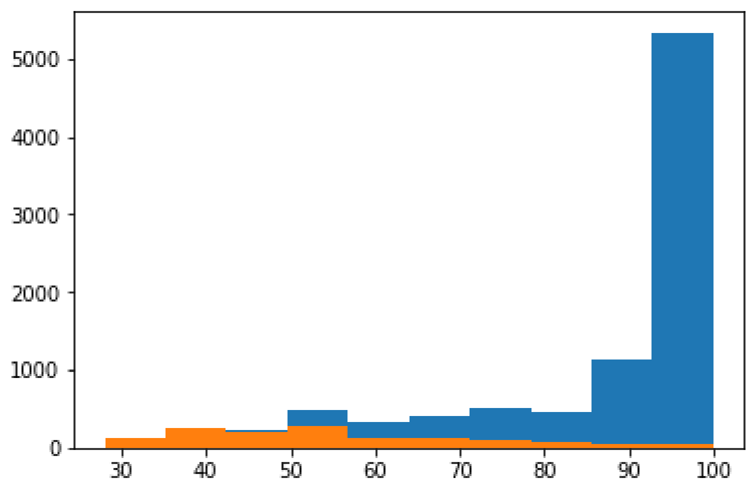


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 1792 1793 1794 1795 1796 1797 1798 1799 1800 1801 1802 1803 1804 1805
 1806 1807 1808 1809 1810 1811 1812 1813 1814 1815 1816 1817 1818 1819
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 1862 1863 1864 1865 1866 1867 1868 1869 1870 1871 1872 1873 1874 1875
 1876 1877 1878 1879 1880 1881 1882 1883 1884 1885 1886 1887 1888 1889
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 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913 1914 1915 1916 1917
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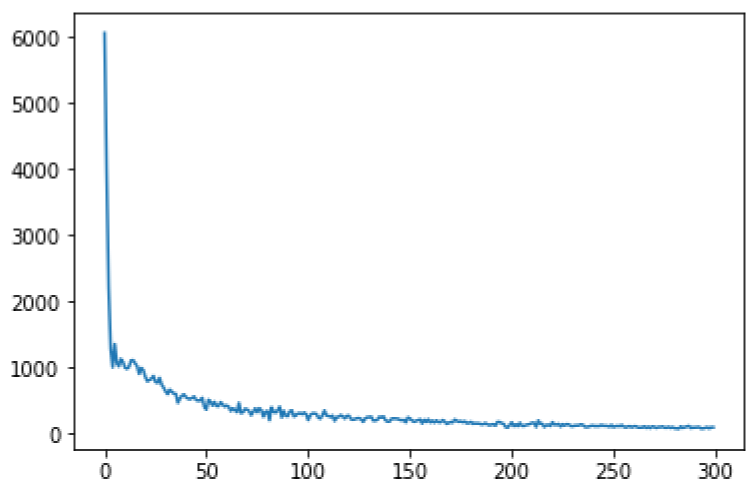


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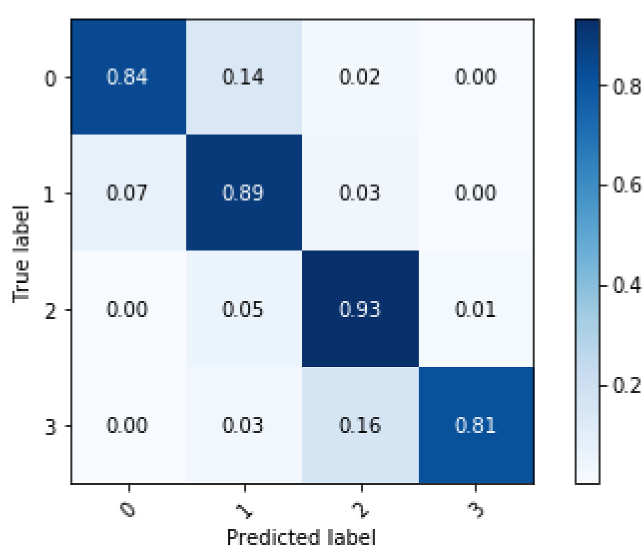

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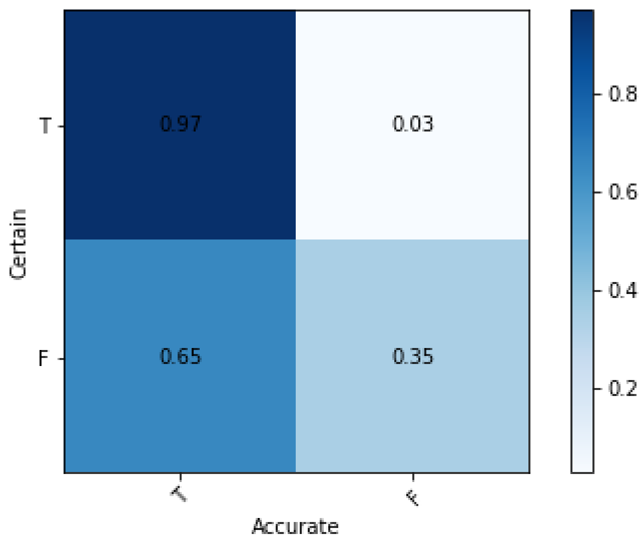


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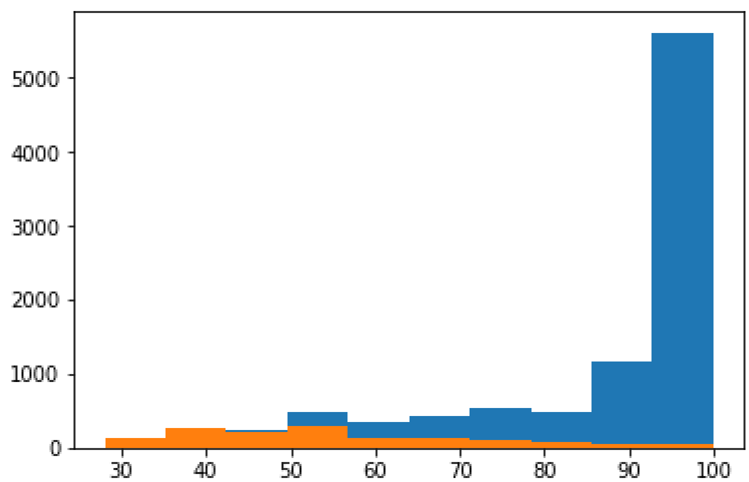


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↪8646670789527933, 0.8673962338558612, 0.8693310657596371, 0.8703854875283448]
P(Acc | Certain):  0.974729743470298 +- 0.0005165493723274688 [0.9765494137353434, 0.
↪9749290444654684, 0.9745838287752675, 0.9741173160782107, 0.9734691142971995]
P(Acc | Uncertain):  0.6555131429772774 +- 0.00039401996474623446 [0.6554238833181404,
↪ 0.656547619047619, 0.6562225475841874, 0.6549640287769785, 0.654407636159461]
```

```
<Figure size 432x288 with 0 Axes>
```

[6]:

```
# print results
task_names = ["Cooler Condition", "Valve Condition", "Internal Pump Leakage",␣
↪"Accumulator", "Stable Flag"]

for i in range(len(final_results)):
    f1_score_model_kfold = final_results[i][0]
    p_accurate_certain_kfold = final_results[i][1]
```

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```
    p_accurate_uncertain_kfold = final_results[i][2]
    print("Target output: ", task_names[i])
    print("F1 SCORE: ",np.mean(f1_score_model_kfold),"+-",sem(f1_score_model_kfold),␣
↪f1_score_model_kfold)
    print("P(Acc | Certain): ",np.mean(p_accurate_certain_kfold),"+-",sem(p_accurate_
↪certain_kfold),p_accurate_certain_kfold)
    print("P(Acc | Uncertain): ",np.mean(p_accurate_uncertain_kfold),"+-",sem(p_
↪accurate_uncertain_kfold),p_accurate_uncertain_kfold)
    print("\n")
```

```
Target output:  Cooler Condition
F1 SCORE:  0.9945351473922903 +- 0.0004707605326990252 [0.9931972789115646, 0.
↪9954648526077098, 0.9954648526077098, 0.9948979591836735, 0.9936507936507937]
P(Acc | Certain):  0.9980861983060005 +- 0.00024045557469217787 [0.997716894977169, 0.
↪9988465974625144, 0.9984662576687117, 0.9977011494252873, 0.9977000919963201]
P(Acc | Uncertain):  0.6848302207130731 +- 0.08938562630975022 [0.3333333333333333, 0.
↪8, 0.7894736842105263, 0.7916666666666666, 0.7096774193548387]


Target output:  Valve Condition
F1 SCORE:  0.9244593816362524 +- 0.012535227234323546 [0.9622071050642479, 0.
↪9416909620991255, 0.9220521541950113, 0.9022423784328546, 0.8941043083900226]
P(Acc | Certain):  0.9909499081179456 +- 0.001979188876666969 [0.9966144731273805, 0.
↪9934665641813989, 0.9911253106141285, 0.9883488681757656, 0.9851943244910549]
P(Acc | Uncertain):  0.6525351521609853 +- 0.0074524186694632615 [0.6749116607773852,␣
↪0.6639175257731958, 0.6483825597749648, 0.6341968911917099, 0.6412671232876712]


Target output:  Internal Pump Leakage
F1 SCORE:  0.8956939054898239 +- 0.0004668869383694529 [0.8954854669140383, 0.
↪8945578231292517, 0.8958660387231816, 0.8952057013281504, 0.8973544973544973]
P(Acc | Certain):  0.9802237531820188 +- 0.0008447896849073807 [0.983127109111361, 0.
↪9806651198762568, 0.98018147086915, 0.9788841964881084, 0.9782608695652174]
P(Acc | Uncertain):  0.6658386804182905 +- 0.004254498716107378 [0.6548262548262548,␣
↪0.6581740976645435, 0.6673139158576051, 0.6704477611940298, 0.6784313725490196]


Target output:  Accumulator
F1 SCORE:  0.8721943923768338 +- 0.004728381107143069 [0.8864795918367347, 0.
↪8782179538482061, 0.871504157218443, 0.8650196920873613, 0.859750566893424]
P(Acc | Certain):  0.9782688014829797 +- 8.581726290369855e-05 [0.9781036560867818, 0.
↪9780241151302995, 0.9784090909090909, 0.9784490698102781, 0.9783580754784476]
P(Acc | Uncertain):  0.6594160576349053 +- 0.0021611149247641815 [0.6669874879692012,␣
↪0.6602972399150743, 0.6591422121896162, 0.656271186440678, 0.6543821616599567]


Target output:  Stable Flag
F1 SCORE:  0.8668427457060999 +- 0.0014700490292759586 [0.8624338624338624, 0.
↪8646670789527933, 0.8673962338558612, 0.8693310657596371, 0.8703854875283448]
P(Acc | Certain):  0.974729743470298 +- 0.0005165493723274688 [0.9765494137353434, 0.
↪9749290444654684, 0.9745838287752675, 0.9741173160782107, 0.9734691142971995]
P(Acc | Uncertain):  0.6555131429772774 +- 0.00039401996474623446 [0.6554238833181404,
↪ 0.656547619047619, 0.6562225475841874, 0.6549640287769785, 0.654407636159461]
```

CHAPTER 5

Run Multi Agent System

We initialize the data source and create the agent network, once the agents are fully up and running, run the dashboard code in a separate terminal to visualize the agents.

[1]:
```
import osbrain
from osbrain.agent import run_agent
from osbrain.agent import Agent

import pandas as pd
from datetime import datetime

import time

import pickle
import numpy as np
import random
from copy import copy

from .Agent_models.agents import Sensor, Aggregator, Predictor, DecisionMaker,␣
↪SensorNetwork

# TYPES OF AGENT
# 0 - SENSOR NETWORK
# 1 - SENSOR
# 2 - AGGREGATOR
# 3 - PREDICTOR
# 4 - DECISIONMAKER
```

```
---------------------------------------------------------------------------
ModuleNotFoundError                       Traceback (most recent call last)
<ipython-input-1-6053d4936c6f> in <module>
     13 from copy import copy
     14
---> 15 from .Agent_models.agents import Sensor, Aggregator, Predictor, DecisionMaker,
↪ SensorNetwork
     16
```

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```
     17 # TYPES OF AGENT

ModuleNotFoundError: No module named '__main__.Agent_models'; '__main__' is not a␣
↪package
```

[2]:
```
DemoMode= True
pickle_path = "pickles/"
data_input = pickle.load(open(pickle_path + "data_input_data_1Hz_full.p", "rb"))
data_output = pickle.load(open(pickle_path + "zema_outputs.p", "rb"))

X_data = data_input
Y_data = data_output
randomShuffling = True

if (randomShuffling == True):
    index_list = np.arange(X_data.shape[0])
    random.shuffle(index_list)
    Y_data = Y_data[index_list, :]
    X_data = X_data[index_list, :, :]
```

```
---------------------------------------------------------------------------
FileNotFoundError                         Traceback (most recent call last)
<ipython-input-2-8d9935992e57> in <module>
      1 DemoMode= True
      2 pickle_path = "pickles/"
----> 3 data_input = pickle.load(open(pickle_path + "data_input_data_1Hz_full.p", "rb
↪"))
      4 data_output = pickle.load(open(pickle_path + "zema_outputs.p", "rb"))
      5

FileNotFoundError: [Errno 2] No such file or directory: 'pickles/data_input_data_1Hz_
↪full.p'
```

5.1 Starting server

[3]:
```

ns = osbrain.nameserver.run_nameserver(addr='127.0.0.1:14065')
```

```
Broadcast server running on 0.0.0.0:9091
NS running on 127.0.0.1:14065 (127.0.0.1)
URI = PYRO:Pyro.NameServer@127.0.0.1:14065
```

5.2 Creating Agent

We firstly create a SensorNetwork Agent which enable wrapper functions and manages agents

[4]:
```
sensor_network = run_agent('sensor_network', base=SensorNetwork)
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-4-75226932f9c3> in <module>
```

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```
----> 1 sensor_network = run_agent('sensor_network', base=SensorNetwork)

NameError: name 'SensorNetwork' is not defined
```

5.3 Sensor Agents

1. Next, we create a Sensor Agent by `sensor_network.addsimsensor(type,unit)`, and store into a list `sensors`.
2. We set the data source of the Sensor Agent : `sensor_new.set_generatorDataSet(dataSet)` where dataSet is a 3-dimensional numpy array with: [Row x Sequence Length x Sensor]

[5]:
```
#add sensors
sensors=[]
sensorTypes = ["Temperature","Temperature","Temperature","Temperature","Vibration",
↪"EfficiencyFactor","VolumeFlow","VolumeFlow","Pressure","Pressure","Pressure",
↪"Pressure","Pressure","Pressure","MotorPower","CoolingEfficiency","CoolingPower"]
sensorUnits = ["C","C","C","C","mm/s","%","l/min","l/min","bar","bar","bar","bar",
↪"bar","bar","W","%","kW"]

for sensor_num in range(X_data.shape[2]):
    sensor_new = sensor_network.add_simsensor(type=sensorTypes[sensor_num], unit_
↪v=sensorUnits[sensor_num])
    sensor_new.set_generatorDataSet(X_data[:,:,sensor_num])
    sensors.append(sensor_new)
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-5-ada498f69a90> in <module>
      4 sensorUnits = ["C","C","C","C","mm/s","%","l/min","l/min","bar","bar","bar",
↪"bar","bar","bar","W","%","kW"]
      5
----> 6 for sensor_num in range(X_data.shape[2]):
      7     sensor_new = sensor_network.add_simsensor(type=sensorTypes[sensor_num],␣
↪unit_v=sensorUnits[sensor_num])
      8     sensor_new.set_generatorDataSet(X_data[:,:,sensor_num])

NameError: name 'X_data' is not defined
```

1. We can access the Sensor Agents stored in array `sensors`.
2. Alternatively, the SensorNetwork Agent automatically keeps track of sensors added by it, we can access the list by calling `get_attr('sensor_list')`
3. Here, we demonstrate a function of Sensor Agent which is `read_generator` which returns a random data row from the loaded dataset

[6]:
```
#the sensors are loaded into array sensors
sensor1 = sensors[0]
print(len(sensors))

#access sensors by either way
sensor_network.get_attr('sensor_list')[0].read_generator()
sensor1.read_generator()
```

```
---------------------------------------------------------------------------
IndexError                                Traceback (most recent call last)
<ipython-input-6-fe35f12d5c0e> in <module>
      1 #the sensors are loaded into array sensors
----> 2 sensor1 = sensors[0]
      3 print(len(sensors))
      4
      5 #access sensors by either way

IndexError: list index out of range
```

5.4 Aggregator Agents

1. We add an Aggregator Agent to the `sensor_network` by calling the function `.add_aggregator(sensorList)` where `sensorList` is an optional list of Sensor Agents which automatically binds the aggregator to the Sensor Agents.
2. Aggregator Agent can bind to Sensor Agent in runtime by calling `.bind_sensors(sensorList)`.

[7]:
```
#add aggregators and bind them to sensors
aggregator1 = sensor_network.add_aggregator(sensors)
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-7-f1ff1ca81bf3> in <module>
      1 #add aggregators and bind them to sensors
----> 2 aggregator1 = sensor_network.add_aggregator(sensors)

NameError: name 'sensor_network' is not defined
```

5.5 Predictor Agents

1. Similarly, we can add Predictor Agent by `.add_predictor(aggregator)` with the optional `aggregator` to be binded to.
2. For each Predictor Agent, we load the prediction model by `.load_predictor_model(model)` where `model` is a trained ML_Wrapper with signature such as `.predict_model_wUnc(x_test, num_samples)` where `x_test` is the data input and `num_samples` is the number of samples for Monte Carlo sampling.
3. Here, we load the previously pickled prediction model.

[8]:
```
#add predictor and bind to aggregator
predictor1 = sensor_network.add_predictor(aggregator=aggregator1)
predictor2 = sensor_network.add_predictor(aggregator=aggregator1)
predictor3 = sensor_network.add_predictor(aggregator=aggregator1)
predictor4 = sensor_network.add_predictor(aggregator=aggregator1)
predictor5 = sensor_network.add_predictor(aggregator=aggregator1)

#load predictor models
predictor1.load_predictor_model(pickle.load(open("pickles/" + "bnn_wrapper_0.p",␣
↪"rb")))
```

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```
predictor2.load_predictor_model(pickle.load(open("pickles/" + "bnn_wrapper_1.p",␣
↪"rb")))
predictor3.load_predictor_model(pickle.load(open("pickles/" + "bnn_wrapper_2.p",␣
↪"rb")))
predictor4.load_predictor_model(pickle.load(open("pickles/" + "bnn_wrapper_3.p",␣
↪"rb")))
predictor5.load_predictor_model(pickle.load(open("pickles/" + "bnn_wrapper_4.p",␣
↪"rb")))
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-8-cfeb5649323c> in <module>
      1 #add predictor and bind to aggregator
----> 2 predictor1 = sensor_network.add_predictor(aggregator=aggregator1)
      3 predictor2 = sensor_network.add_predictor(aggregator=aggregator1)
      4 predictor3 = sensor_network.add_predictor(aggregator=aggregator1)
      5 predictor4 = sensor_network.add_predictor(aggregator=aggregator1)

NameError: name 'sensor_network' is not defined
```

5.6 DecisionMaker Agent

1. We add Decision Maker Agent calling `.add_decisionMaker()` on SensorNetwork agent
2. The DM Agent is binded to every predictor by calling `.bind_predictor(predictor)` function

[9]:
```
decisionMaker = sensor_network.add_decisionMaker()
decisionMaker.bind_predictor(predictor1)
decisionMaker.bind_predictor(predictor2)
decisionMaker.bind_predictor(predictor3)
decisionMaker.bind_predictor(predictor4)
decisionMaker.bind_predictor(predictor5)
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-9-180d2cc1fe2f> in <module>
----> 1 decisionMaker = sensor_network.add_decisionMaker()
      2 decisionMaker.bind_predictor(predictor1)
      3 decisionMaker.bind_predictor(predictor2)
      4 decisionMaker.bind_predictor(predictor3)
      5 decisionMaker.bind_predictor(predictor4)

NameError: name 'sensor_network' is not defined
```

5.7 Demo

1. For demo, we run an infinite loop which continuously runs the `.request_sensors_data()`
2. Due to the bindings, the requested data will immediately be propagated to all binded Predictor Agents and to Decision Maker Agent
3. While this is running, run the dashboard code in a separate terminal to visualize the multi-agent testbed

[10]:
```
#send request to aggregator agents for data from sensors

if DemoMode:
    for i in range(99999999999):
        aggregator1.request_sensors_data()
        time.sleep(3)
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-10-c6d4a27820dd> in <module>
      3 if DemoMode:
      4     for i in range(99999999999):
----> 5         aggregator1.request_sensors_data()
      6         time.sleep(3)

NameError: name 'aggregator1' is not defined
```

[ ]:
```

```

CHAPTER 6

Agent Dashboard User Interface

1. Run this code after the Agents are setup and running
2. View the web visualization at port 8054 using Internet Browser

[1]:
```
portNumber = 8054
```

[2]:
```
import osbrain
from osbrain.agent import run_agent
from osbrain import NSProxy

# -*- coding: utf-8 -*-
import dash
import dash_core_components as dcc
import dash_html_components as html
import dash_cytoscape as cyto
import dash_daq as daq
import plotly.graph_objs as go
import networkx as nx
import numpy as np

import pickle
external_css =␣
↪["https://cdnjs.cloudflare.com/ajax/libs/skeleton/2.0.4/skeleton.min.css",
                "https://fonts.googleapis.com/css?family=Raleway:400,400i,700,700i",
                ␣
↪"https://fonts.googleapis.com/css?family=Product+Sans:400,400i,700,700i"]
app = dash.Dash(__name__, external_stylesheets=external_css)

#================APP LAYOUT=========
agent_names =['aggregator_1', 'sensor_0', 'sensor_1', 'sensor_2', 'sensor_3',␣
↪'sensor_4', 'sensor_5', 'sensor_6', 'sensor_7', 'sensor_8', 'sensor_9', 'sensor_10',
↪ 'sensor_11', 'sensor_12', 'sensor_13', 'sensor_14', 'predictor_0',␣
↪'decisionMaker_0']
```

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```
G = nx.Graph()
G.add_nodes_from(agent_names)
myEdges = []

for agent_x in agent_names:
    for agent_y in agent_names:
        include=False
        if 'sensor' in agent_x and 'aggregator' in agent_y:
            include = True
        elif 'aggregator' in agent_x and 'predictor' in agent_y:
            include = True
        elif 'predictor' in agent_x and 'decisionMaker' in agent_y:
            include = True
        if include:
            new_edge = (agent_x, agent_y)
            myEdges.append(new_edge)

G.add_edges_from(myEdges)
pos=nx.fruchterman_reingold_layout(G)

nodes_ct = [{'data': {'id': k, 'label': k}, 'position': {'x': pos[k][0], 'y':␣
↪pos[k][1]},'classes': k.split('_')[0]} for k in agent_names]

edges_ct = [{'data': {'source': k[0], 'target': k[1]}} for k in myEdges]
elements = nodes_ct+edges_ct

tab_div_style ={
            "padding": "2",
            "marginLeft": "5",
            "marginRight": "5",
            "backgroundColor":"white",
            "border": "1px solid #C8D4E3",
            "borderRadius": "3px"
        }
tab_title = { 'textAlign': 'center',}

output_labels = [{0: "Optimal", 1: "Reduced", 2: "Nearly Fail"},
 {0: "Optimal", 1: "Small lag", 2: "Severe lag", 3: "Nearly Fail"},
 {0: "No Leakage", 1: "Weak Leakage", 2: "Severe Leakage"},
 {0: "Optimal", 1: "Slightly Reduced", 2: "Severely Reduced", 3: "Nearly Fail"},
 {0: "Stable", 1: "Unstable"}]

output_category = ["Cooler Condition", "Valve Condition", "Internal Pump",␣
↪"Accumulator", "Stable Flag"]

def getConditionIndicator(condition_text="Optimal",certain=True):
    color = "#00cc96" if certain else "#ff0000"
    label = "Certain" if certain else "Uncertain"
    return [
        html.H5(condition_text, style=tab_title),
        daq.Indicator(
            value=True,
            color=color,
            label=label,
            style=tab_title
        )]
```

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```
app.layout = html.Div(children=[
html.Div([
        html.H3("Multi Agents for Machine Learning under Uncertainty Testbed",style={
            'textAlign': 'center',

        }),
        ]),
    html.Div([
        html.Div([
            html.H6("Cooler Condition",style= { 'textAlign': 'center',"border":␣
↪"1px solid #C8D4E3"}),
            html.Div(children=getConditionIndicator("Optimal",certain=True),
↪id='cooler-indicator')
        ],className="two columns",style=tab_div_style),
        html.Div([
            html.H6("Valve Condition", style={'textAlign': 'center', "border":␣
↪"1px solid #C8D4E3"}),
            html.Div(children=getConditionIndicator("Optimal", certain=True),
↪id='valve-indicator')
        ], className="two columns", style=tab_div_style),
        html.Div([
            html.H6("Internal Pump", style={'textAlign': 'center', "border":␣
↪"1px solid #C8D4E3"}),
            html.Div(children=getConditionIndicator("Optimal", certain=True),
↪id='pump-indicator')
        ], className="two columns", style=tab_div_style),
        html.Div([
            html.H6("Accumulator", style={'textAlign': 'center', "border":␣
↪"1px solid #C8D4E3"}),
            html.Div(children=getConditionIndicator("Optimal", certain=True),
↪id='accumulator-indicator')
        ], className="two columns", style=tab_div_style),
        html.Div([
            html.H6("Stable Flag", style={'textAlign': 'center', "border":␣
↪"1px solid #C8D4E3"}),
            html.Div(children=getConditionIndicator("Optimal", certain=True),
↪id='stability-indicator')
        ], className="two columns", style=tab_div_style),
    ],className="row"),

    html.Div([
        html.Div([
            html.H5('Agent Network Dashboard', style=tab_title
        ),
        cyto.Cytoscape(
            id='agents-network',
            layout={'name': 'circle'},
            style={'width': '100%', 'height': '400px'},
            elements=elements,
            stylesheet= [
                {
                    'selector': 'node',
                    'style': {
                        'label': 'data(id)'
                    }
                },
                {
```

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```
                'selector': '.sensor',
                'style': {
                    'background-color': 'green',
                    'line-color': 'black'
                }
            },
                {
                'selector': '.aggregator',
                'style': {
                    'background-color': 'blue',
                    'line-color': 'black'
                }
            },
                {
                    'selector': '.predictor',
                    'style': {
                        'background-color': 'red',
                        'line-color': 'black'
                    }
                },
                {
                    'selector': '.decisionMaker',
                    'style': {
                        'background-color': 'yellow',
                        'line-color': 'black'
                    }
                },
            ]
        ),], className="six columns",style=tab_div_style),
        html.Div([
            html.H5(
                children='Select Predictor Agent',
                style={
                    'textAlign': 'left',
                }
            ),
            html.Div(
                id='predictor-dropdown-div',
                children=dcc.Dropdown(
                    id='predictor-dropdown',
                    options=[],
                    value='predictor_0',
                    style={'width': 250},
                )),
            html.Div([
                html.H5("Prediction Graph",style=tab_title)
            ]),
            dcc.Graph(id='prediction-graph'),
        ], className='six columns ', style=tab_div_style)
],className="row"),

    html.Div([

        html.Div([
            html.Div([
                html.H5("Sensor Graph",style=tab_title)
            ]),
```

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```
            html.H5(
                children='Select Sensor Agent',
                style={
                    'textAlign': 'left',
                }
            ),
            html.Div(
                id='sensor-dropdown-div',
                children=dcc.Dropdown(
                    id='sensor-dropdown',
                    options=[],
                    value='sensor_number_0',
                    style={'width': 250},
                )),
            dcc.Graph(id='sensor-graph'),
        ], className='six columns ',style=tab_div_style),
        html.Div([
            html.Div([
                html.H5("Uncertainty Graph",style=tab_title)
            ]),
            dcc.Graph(id='uncertainty-graph'),
        ], className='six columns ',style=tab_div_style),
    ], className='row'),

    dcc.Interval(
        id='interval-component',
        interval=3 * 1000,  # in milliseconds
        n_intervals=0
    ),
    dcc.Interval(
        id='interval-component-network-graph',
        interval=1000 * 1000,  # in milliseconds
        n_intervals=0
    )


],style={
            "padding": "8",
            "marginLeft": "45",
            "marginRight": "45",
            "backgroundColor":"white",
            "border": "1px solid #C8D4E3",
            "borderRadius": "3px"
        })

@app.callback(dash.dependencies.Output('sensor-dropdown', 'value'),
              [dash.dependencies.Input('agents-network', 'tapNodeData')])
def displayTapNodeData(data):
    if 'sensor' in data['label'] and 'sensor_network' not in data['label']:
        return data['label']

@app.callback([dash.dependencies.Output('agents-network', 'elements'),dash.
↪dependencies.Output('sensor-dropdown-div', 'children'),dash.dependencies.
↪Output('predictor-dropdown-div', 'children')],
              [dash.dependencies.Input('interval-component-network-graph',␣
↪'n_intervals')])
def update_network_graph(n):
```

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```
    ns_temp = NSProxy(nsaddr='127.0.0.1:14065')
    agent_names = ns_temp.agents()
    print(agent_names)
    G = nx.Graph()
    G.add_nodes_from(agent_names)
    myEdges = []

    for agent_x in agent_names:
        for agent_y in agent_names:
            include = False
            if 'sensor' in agent_x and 'aggregator' in agent_y and 'sensor_network'␣
↪not in agent_x:
                include = True
            elif 'aggregator' in agent_x and 'predictor' in agent_y:
                include = True
            elif 'predictor' in agent_x and 'decisionMaker' in agent_y:
                include = True
            if include:
                new_edge = (agent_x, agent_y)
                myEdges.append(new_edge)

    G.add_edges_from(myEdges)
    pos = nx.fruchterman_reingold_layout(G)

    nodes_ct = [{'data': {'id': k, 'label': k}, 'position': {'x': pos[k][0], 'y':␣
↪pos[k][1]},'classes': k.split('_')[0]} for k in agent_names]
    edges_ct = [{'data': {'source': k[0], 'target': k[1]}} for k in myEdges]
    elements = nodes_ct + edges_ct

    sensor_options = [{'label': name, 'value': name} for name in agent_names if␣
↪'sensor' in name and 'sensor_network' not in name]
    predictor_options = [{'label': name, 'value': name} for name in agent_names if␣
↪'predictor' in name ]

    sensor_dropdown_component = dcc.Dropdown(
        id='sensor-dropdown',
        options=sensor_options,
        value=sensor_options[0]['value'],
        style={'width': 250},
    )
    predictor_dropdown_component = dcc.Dropdown(
        id='predictor-dropdown',
        options=predictor_options,
        value=predictor_options[0]['value'],
        style={'width': 250},
    )
    print("HELLO")
    return [elements, sensor_dropdown_component,predictor_dropdown_component]

@app.callback(dash.dependencies.Output('sensor-graph', 'figure'),
              [dash.dependencies.Input('interval-component', 'n_intervals'),dash.
↪dependencies.Input('sensor-dropdown', 'value')])
def update_sensor_graph(n,chosen_sensor_name):
    ns_temp = NSProxy(nsaddr='127.0.0.1:14065')
    sensor_type = ns_temp.proxy(chosen_sensor_name).get_attr('type')
    sensor_unit = ns_temp.proxy(chosen_sensor_name).get_attr('unit_v')
```

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```
    final_data = ns_temp.proxy(chosen_sensor_name).get_attr('current_data')

    final_data = np.array(final_data)

    y_data = final_data
    N_sequence = y_data.shape[0]
    x_data = np.linspace(0, N_sequence - 1, N_sequence)

    traces_sensor = go.Scatter(
        x=x_data,
        y=y_data,
        mode='lines',
        name='lines'
    )
    layout = {'title': 'Sensor '+sensor_type+" #"+chosen_sensor_name.split('_')[-1],
              'xaxis': {'title': 'Time (s)'},
              'yaxis': {'title': sensor_type+" ("+sensor_unit+")"},
              }

    return {
        'data': [traces_sensor],
        'layout': layout
    }

predictions = []
uncertainties = []
probabilities_accurate = []

def getTimeSeriesGraph(y_data,title='Prediction Certainty vs Time',xaxis='Time (s)',
↪yaxis='Certainty (%) '):
    N_sequence = y_data.shape[0]
    x_data = np.linspace(0, N_sequence - 1, N_sequence)

    traces_sensor = go.Scatter(
        x=x_data,
        y=y_data,
        mode='lines',
        name='lines'
    )
    layout = {'title': title,
              'xaxis': {'title': xaxis},
              'yaxis': {'title': yaxis},
              }

    return {
        'data': [traces_sensor],
        'layout': layout
    }

@app.callback([dash.dependencies.Output('prediction-graph', 'figure'), dash.
↪dependencies.Output('uncertainty-graph', 'figure'), dash.dependencies.
↪Output('cooler-indicator', 'children'), dash.dependencies.Output('valve-indicator',␣
↪'children'), dash.dependencies.Output('pump-indicator', 'children'), dash.
↪dependencies.Output('accumulator-indicator', 'children'), dash.dependencies.
↪Output('stability-indicator', 'children')],
              [dash.dependencies.Input('interval-component', 'n_intervals'),dash.
↪dependencies.Input('predictor-dropdown', 'value')])
```

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```
def update_prediction_graph(n,selected_predictor):
    ns_temp = NSProxy(nsaddr='127.0.0.1:14065')
    overall_new_data = ns_temp.proxy('decisionMaker_0').get_attr('current_inference')
    column_numbers = [x.split('_')[-1] for x in overall_new_data.columns]
    overall_new_data.columns = column_numbers
    overall_new_data.sort_index(axis=1, inplace=True)
    #condition_indicators = [getConditionIndicator(output_labels[int(predictor['label
↪'].split('_')[-1])][overall_new_data[predictor['label']].pred],certain=overall_new_
↪data[predictor['label']].unc_state) for id_,predictor in enumerate(predictors) ]
    print(overall_new_data)
    print(overall_new_data.loc['pred'])


    new_prediction = overall_new_data.loc['pred']
    new_uncertainty = overall_new_data.loc['unc']
    new_uncertainty_state = overall_new_data.loc['unc_state']

    condition_indicators = [getConditionIndicator(output_labels[_id][new_prediction[_
↪id]],certain=unc_state ) for _id,unc_state in enumerate(new_uncertainty_state)]

    predictions.append(new_prediction)
    uncertainties.append(new_uncertainty)
    selected_predictor_id=int(selected_predictor.split("_")[-1])
    # dim 0 = samples, dim 1 = predictor
    y_data_pred = np.array(predictions)[:,selected_predictor_id]
    y_data_unc = np.array(uncertainties)[:, selected_predictor_id]

    #pred
    prediction_graph = getTimeSeriesGraph(y_data_pred,'Model Prediction ('+output_
↪category[selected_predictor_id]+') vs Time','Time (s)','Prediction ')
    uncertainties_graph = getTimeSeriesGraph(y_data_unc,
↪'Prediction Certainty vs Time','Time (s)','Certainty (%) ')


    return [prediction_graph,uncertainties_graph] +condition_indicators

if __name__ == '__main__':

    app.run_server(debug=False, port=portNumber)
```

```
---------------------------------------------------------------------------
ModuleNotFoundError                       Traceback (most recent call last)
<ipython-input-2-3d73c4fa70ad> in <module>()
      7 import dash_core_components as dcc
      8 import dash_html_components as html
----> 9 import dash_cytoscape as cyto
     10 import dash_daq as daq
     11 import plotly.graph_objs as go

ModuleNotFoundError: No module named 'dash_cytoscape'
```

CHAPTER 7

agentMET4FOF agents

class agentMET4FOF.agents.**AgentMET4FOF**(*name=''*, *host=None*, *serializer=None*, *transport=None*, *attributes=None*)

Base class for all agents with specific functions to be overridden/supplied by user.

Behavioural functions for users to provide are init_parameters, agent_loop and on_received_message. Communicative functions are bind_output, unbind_output and send_output.

agent_loop()

User defined method for the agent to execute for *loop_wait* seconds specified either in *self.loop_wait* or explicitly via'init_agent_loop(loop_wait)'

To start a new loop, call *init_agent_loop(loop_wait)* on the agent Example of usage is to check the *current_state* of the agent and send data periodically

before_loop()

This action is executed before initiating the loop

bind_output(*output_agent*)

Forms Output connection with another agent. Any call on send_output will reach this newly binded agent

Adds the agent to its list of Outputs.

Parameters **output_agent** (AgentMET4FOF *or list*) – Agent(s) to be binded to this agent's output channel

convert_to_plotly(*matplotlib_fig*)

Internal method to convert matplotlib figure to plotly figure

Parameters **matplotlib_fig** (*plt.Figure*) – Matplotlib figure to be converted

handle_process_data(*message*)

Internal method to handle incoming message before calling user-defined on_received_message method.

If current_state is either Stop or Reset, it will terminate early before entering on_received_message

init_agent_loop(*loop_wait=1.0*)

Initiates the agent loop, which iterates every'loop_wait' seconds

Stops every timers and initiate a new loop.

Parameters **loop_wait** (*int*) – The wait between each iteration of the loop

init_parameters()
User provided function to initialize parameters of choice.

log_info(*message*)
Prints logs to be saved into logfile with Logger Agent

Parameters **message** (*str*) – Message to be logged to the internal Logger Agent

on_init()
Internal initialization to setup the agent: mainly on setting the dictionary of Inputs, Outputs, PubAddr.

Calls user-defined *init_parameters()* upon finishing.

Inputs
Dictionary of Agents connected to its input channels. Messages will arrive from agents in this dictionary. Automatically updated when *bind_output()* function is called
Type dict

Outputs
Dictionary of Agents connected to its output channels. Messages will be sent to agents in this dictionary. Automatically updated when *bind_output()* function is called
Type dict

PubAddr_alias
Name of Publish address socket
Type str

PubAddr
Publish address socket handle
Type str

AgentType
Name of class
Type str

current_state
Current state of agent. Can be used to define different states of operation such as "Running", "Idle, "Stop", etc.. Users will need to define their own flow of handling each type of *self.current_state* in the *agent_loop*
Type str

loop_wait
The interval to wait between loop. Call *init_agent_loop* to restart the timer or set the value of loop_wait in *init_parameters* when necessary.
Type int

memory_buffer_size
The total number of elements to be stored in the agent *memory* When total elements exceeds this number, the latest elements will be replaced with the incoming data elements
Type int

on_received_message(*message*)
User-defined method and is triggered to handle the message passed by Input.

Parameters **message** (*Dictionary*) – The message received is in form {'from':agent_name, 'data': data, 'senderType': agent_class, 'channel':channel_name} agent_name is the name of the Input agent which sent the message data is the actual content of the message

pack_data (*data*, *channel='default'*)
Internal method to pack the data content into a dictionary before sending out.

Special case : if the *data* is already a *message*, then the *from* and *senderType* will be altered to this agent, without altering the *data* and *channel* within the message this is used for more succinct data processing and passing.

Parameters

- **data** (*argument*) – Data content to be packed before sending out to agents.
- **channel** (*str*) – Key of dictionary which stores data

Returns **Packed message data**

Return type dict of the form {'from':agent_name, 'data': data, 'senderType': agent_class, 'channel':channel_name}.

reset ()
This method will be called on all agents when the global *reset_agents* is called by the AgentNetwork and when the Reset button is clicked on the dashboard.

Method to reset the agent's states and parameters. User can override this method to reset the specific parameters.

send_output (*data*, *channel='default'*)
Sends message data to all connected agents in self.Outputs.

Output connection can first be formed by calling bind_output. By default calls pack_data(data) before sending out. Can specify specific channel as opposed to 'default' channel.

Parameters

- **data** (*argument*) – Data content to be sent out
- **channel** (*str*) – Key of *message* dictionary which stores data

Returns **message**

Return type dict of the form {'from':agent_name, 'data': data, 'senderType': agent_class, 'channel':channel_name}.

send_plot (*fig=<Figure size 640x480 with 0 Axes>*)
Sends plot to agents connected to this agent's Output channel.

This method is different from send_output which will be sent to through the 'plot' channel to be handled.

Parameters **fig** (*Figure*) – Can be either matplotlib figure or plotly figure

Returns **The message format is {'from'**

Return type agent_name, 'plot': data, 'senderType': agent_class}.

stop_agent_loop ()
Stops agent_loop from running. Note that the agent will still be responding to messages

unbind_output (*output_agent*)
Remove existing output connection with another agent. This reverses the bind_output method

Parameters **output_agent** (AgentMET4FOF) – Agent binded to this agent's output channel

update_data_memory (*message*)
Updates data stored in *self.memory* with the received message

Checks if sender agent has sent any message before If it did,then append, otherwise create new entry for it

Parameters **message** (*dict*) – Standard message format specified by AgentMET4FOF class

class agentMET4FOF.agents.**AgentNetwork**(*ip_addr='127.0.0.1'*, *port=3333*, *connect=False*, *log_filename='log_file.csv'*, *dashboard_modules=True*, *dashboard_update_interval=3*, *dashboard_max_monitors=10*, *dashboard_port=8050*)

Object for starting a new Agent Network or connect to an existing Agent Network specified by ip & port

Provides function to add agents, (un)bind agents, query agent network state, set global agent states Interfaces with an internal _AgentController which is hidden from user

add_agent(*name=' '*, *agentType=<class 'agentMET4FOF.agents.AgentMET4FOF'>*, *log_mode=True*, *memory_buffer_size=1000000*, *ip_addr=None*)

Instantiates a new agent in the network.

Parameters

- **str** (*name*) – with the same name. Defaults to the agent's class name.
- **AgentMET4FOF** (*agentType*) – network. Defaults to *AgentMET4FOF*
- **bool** (*log_mode*) – Logger Agent. Defaults to *True*.

Returns AgentMET4FOF

Return type Newly instantiated agent

agents(*filter_agent=None*)

Returns all agent names connected to Agent Network.

Returns list

Return type names of all agents

bind_agents(*source*, *target*)

Binds two agents communication channel in a unidirectional manner from *source* Agent to *target* Agent

Any subsequent calls of *source.send_output()* will reach *target* Agent's message queue.

Parameters

- **source** (AgentMET4FOF) – Source agent whose Output channel will be binded to *target*
- **target** (AgentMET4FOF) – Target agent whose Input channel will be binded to *source*

connect(*ip_addr='127.0.0.1'*, *port=3333*, *verbose=True*)

Parameters

- **ip_addr** (*str*) – IP Address of server to connect to
- **port** (*int*) – Port of server to connect to

get_agent(*agent_name*)

Returns a particular agent connected to Agent Network.

Parameters **agent_name** (*str*) – Name of agent to search for in the network

set_agents_state(*filter_agent=None*, *state='Idle'*)

Blanket operation on all agents to set their *current_state* attribute to given state

Can be used to define different states of operation such as "Running", "Idle, "Stop", etc.. Users will need to define their own flow of handling each type of *self.current_state* in the *agent_loop*

Parameters

- **filter_agent** (*str*) – (Optional) Filter name of agents to set the states
- **state** (*str*) – State of agents to set

set_running_state (*filter_agent=None*)
Blanket operation on all agents to set their *current_state* attribute to "Running"

Users will need to define their own flow of handling each type of *self.current_state* in the *agent_loop*

Parameters **filter_agent** (*str*) – (Optional) Filter name of agents to set the states

set_stop_state (*filter_agent=None*)
Blanket operation on all agents to set their *current_state* attribute to "Stop"

Users will need to define their own flow of handling each type of *self.current_state* in the *agent_loop*

Parameters **filter_agent** (*str*) – (Optional) Filter name of agents to set the states

shutdown ()
Shutdowns the entire agent network and all agents

start_server (*ip_addr='127.0.0.1'*, *port=3333*)

Parameters

- **ip_addr** (*str*) – IP Address of server to start
- **port** (*int*) – Port of server to start

unbind_agents (*source*, *target*)
Unbinds two agents communication channel in a unidirectional manner from *source* Agent to *target* Agent

This is the reverse of *bind_agents()*

Parameters

- **source** (AgentMET4FOF) – Source agent whose Output channel will be unbinded from *target*
- **target** (AgentMET4FOF) – Target agent whose Input channel will be unbinded from *source*

class agentMET4FOF.agents.**DataStreamAgent** (*name=''*, *host=None*, *serializer=None*, *transport=None*, *attributes=None*)
Able to simulate generation of datastream by loading a given DataStreamMET4FOF object.

Can be used in incremental training or batch training mode. To simulate batch training mode, set *pretrain_size=-1* , otherwise, set pretrain_size and batch_size for the respective See *DataStreamMET4FOF* on loading your own data set as a data stream.

agent_loop ()
User defined method for the agent to execute for *loop_wait* seconds specified either in *self.loop_wait* or explicitly via'init_agent_loop(loop_wait)'

To start a new loop, call *init_agent_loop(loop_wait)* on the agent Example of usage is to check the *current_state* of the agent and send data periodically

init_parameters (*stream=<agentMET4FOF.streams.DataStreamMET4FOF object>*, *pretrain_size=None*, *batch_size=1*, *loop_wait=1*, *randomize=False*)

Parameters

- **stream** (DataStreamMET4FOF) – A DataStreamMET4FOF object which provides the sample data
- **pretrain_size** (*int*) – The number of sample data to send through in the first loop cycle, and subsequently, the batch_size will be used

- **batch_size** (*int*) – The number of sample data to send in every loop cycle
- **loop_wait** (*int*) – The duration to wait (seconds) at the end of each loop cycle before going into the next cycle
- **randomize** (*bool*) – Determines if the dataset should be shuffled before streaming

reset()

This method will be called on all agents when the global *reset_agents* is called by the AgentNetwork and when the Reset button is clicked on the dashboard.

Method to reset the agent's states and parameters. User can override this method to reset the specific parameters.

class agentMET4FOF.agents.**MonitorAgent**(*name=''*, *host=None*, *serializer=None*, *transport=None*, *attributes=None*)

Unique Agent for storing plots and data from messages received from input agents.

The dashboard searches for Monitor Agents' *memory* and *plots* to draw the graphs "plot" channel is used to receive base64 images from agents to plot on dashboard

memory

Dictionary of format *{agent1_name : agent1_data, agent2_name : agent2_data}*

Type dict

plots

Dictionary of format *{agent1_name : agent1_plot, agent2_name : agent2_plot}*

Type dict

plot_filter

List of keys to filter the 'data' upon receiving message to be saved into memory Used to specifically select only a few keys to be plotted

Type list of str

init_parameters(*plot_filter=[]*, *custom_plot_function=-1*, ***kwargs*)

User provided function to initialize parameters of choice.

on_received_message(*message*)

Handles incoming data from 'default' and 'plot' channels.

Stores 'default' data into *self.memory* and 'plot' data into *self.plots*

Parameters message (*dict*) – Acceptable channel values are 'default' or 'plot'

reset()

This method will be called on all agents when the global *reset_agents* is called by the AgentNetwork and when the Reset button is clicked on the dashboard.

Method to reset the agent's states and parameters. User can override this method to reset the specific parameters.

update_plot_memory(*message*)

Updates plot figures stored in *self.plots* with the received message

Parameters message (*dict*) – Standard message format specified by AgentMET4FOF class Message['data'] needs to be base64 image string and can be nested in dictionary for multiple plots Only the latest plot will be shown kept and does not keep a history of the plots.

class agentMET4FOF.agents.**TransformerAgent**(*name=''*, *host=None*, *serializer=None*, *transport=None*, *attributes=None*)

init_parameters(*method=None*, ***kwargs*)
User provided function to initialize parameters of choice.

on_received_message(*message*)
User-defined method and is triggered to handle the message passed by Input.

Parameters message (*Dictionary*) – The message received is in form {'from':agent_name, 'data': data, 'senderType': agent_class, 'channel':channel_name} agent_name is the name of the Input agent which sent the message data is the actual content of the message

CHAPTER 8

agentMET4FOF streams

class agentMET4FOF.streams.**CosineGenerator**(*num_cycles=1000*)

class agentMET4FOF.streams.**DataStreamMET4FOF**

Class for creating finite datastream for ML with *x* as inputs and *y* as target Data can be fetched sequentially using *next_sample()* or all at once *all_samples()*

For sensors data: The format shape for 2D data stream (num_samples, n_sensors) The format shape for 3D data stream (num_samples, sample_length , n_sensors)

all_samples()

Returns all the samples in the data stream

Returns samples

Return type dict of the form *{'x': current_sample_x, 'y': current_sample_y}*

next_sample(*batch_size=1*)

Fetches the samples from the data stream and advances the internal pointer *current_idx*

Parameters **batch_size** (*int*) – number of batches to get from data stream

Returns samples

Return type dict of the form *{'x': current_sample_x, 'y': current_sample_y}*

class agentMET4FOF.streams.**SineGenerator**(*num_cycles=1000*)

agentMET4FOF.streams.**extract_x_y**(*message*)

Extracts features & target from *message['data']* with expected structure such as :

1. tuple - (x,y)
2. dict - {'x':x_data,'y':y_data}

Handle data structures of dictionary to extract features & target

CHAPTER 9

Indices and tables

- genindex
- modindex
- search

CHAPTER 10

References

Bibliography

[Bang2019] Bang X. Yong, A. Brintrup Multi Agent System for Machine Learning Under Uncertainty in Cyber Physical Manufacturing System, 9th Workshop on Service Oriented, Holonic and Multi-agent Manufacturing Systems for Industry of the Future

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