Dataset2_Friedman1_output_5

October 20, 2021

1 Dataset 2 - Friedman 1

1.1 Experiment Details

The aim of the experiment is to verify if the: 1. ABC_GAN model corrects model misspecification 2. ABC_GAN model performs better and converges faster than a simple C-GAN model

In the experiment we predict the distribution that represents the real data and simulate realistic fake data points using statistical mode, C-GAN and ABC-GAN model with 3 priors. We analyze and compare their performance using metrics like mean squared error, mean absolute error , manhattan distance and euclidean distance between y_{real} and y_{pred}

The models are as follows:

1. The statistical model assumes the distribution $Y = \beta X + \mu$ where $\mu \sim N(0, 1)$
2. The Conditional GAN consists of
    1. Generator with 2 hidden layers with 100 nodes each and ReLu activation.
    2. Discriminator with 2 hidden layers with 25 and 50 nodes and ReLu activation. We use Adam's optimser and BCE Logit Loss to train the model. The input to the Generator of the GAN is (x,e) where x are the features and $e \sim N(0, 1)$. The discriminator output is linear.
3. The ABC GAN Model consists of
    1. ABC generator is defined as follows:
        1. $Y = 1 + \beta_1 x_1 + \beta_2 x_2 + \beta_2 x_3 + ... + \beta_n x_n + N(0, \sigma)$ where $\sigma = 0.1$
        2. $\beta_i \sim N(0, \sigma^*)$ when $\mu = 0$ else $\beta_i \sim N(\beta_i^*, \sigma^*)$ where $\beta_i^* s$ are coefficients obtained from statistical model
        3. σ^* takes the values 0.01,0.1 and 1

    2. C-GAN network is as defined above. However the input to the Generator of the GAN is (x, y_{abc}) where y_{abc} is the output of the ABC Generator.

1.2 Import Libraries

[1]:
```
import warnings
warnings.filterwarnings('ignore')
```

[2]:
```
import train_test
import ABC_train_test
import regressionDataset
import network
```

```
import statsModel
import performanceMetrics
import friedman1Dataset
import dataset
import sanityChecks
import torch
import matplotlib.pyplot as plt
import seaborn as sns
from scipy.stats import norm
from torch.utils.data import Dataset,DataLoader
from torch import nn
```

1.3 Parameters

General Parameters

1. Number of Samples
2. Number of features

ABC-Generator parameters are as mentioned below: 1. mean : 1 ($\beta \sim N(\beta^*, \sigma)$ where β^* are coefficients of statistical model) or 1 ($\beta \sim N(0, \sigma)$ 2. std : $\sigma = 1, 0.1, 0.01$ (standard deviation)

[3]:
```
n_features = 10
n_samples= 100

#ABC Generator Parameters
mean = 1
variance = 0.001
```

[4]:
```
# Parameters
n_samples = 10
n_features = 10
mean = 0
variance = 0.01
```

1.4 Dataset

Friedman 1 Dataset

- $y(X) = 10 * sin(pi * X_0 * X_1) + 20 * (X_2 - 0.5) * *2 + 10 * X_3 + 5 * X_4 + noise * N(0, 1)$.
- Only 5 features used to calculate y
- Noise is Gaussian
- 1000 datapoints and 10 features used in the following experiment

[5]:
```
X, Y = friedman1Dataset.friedman1_data(n_samples,n_features)
```

```
         X0        X1        X2        X3        X4        X5        X6  \
0  0.320567  0.407436  0.494248  0.887519  0.687441  0.374252  0.701353
1  0.870573  0.422217  0.096807  0.806529  0.116306  0.620213  0.162936
2  0.121992  0.959921  0.026261  0.960916  0.240006  0.965835  0.699085
```

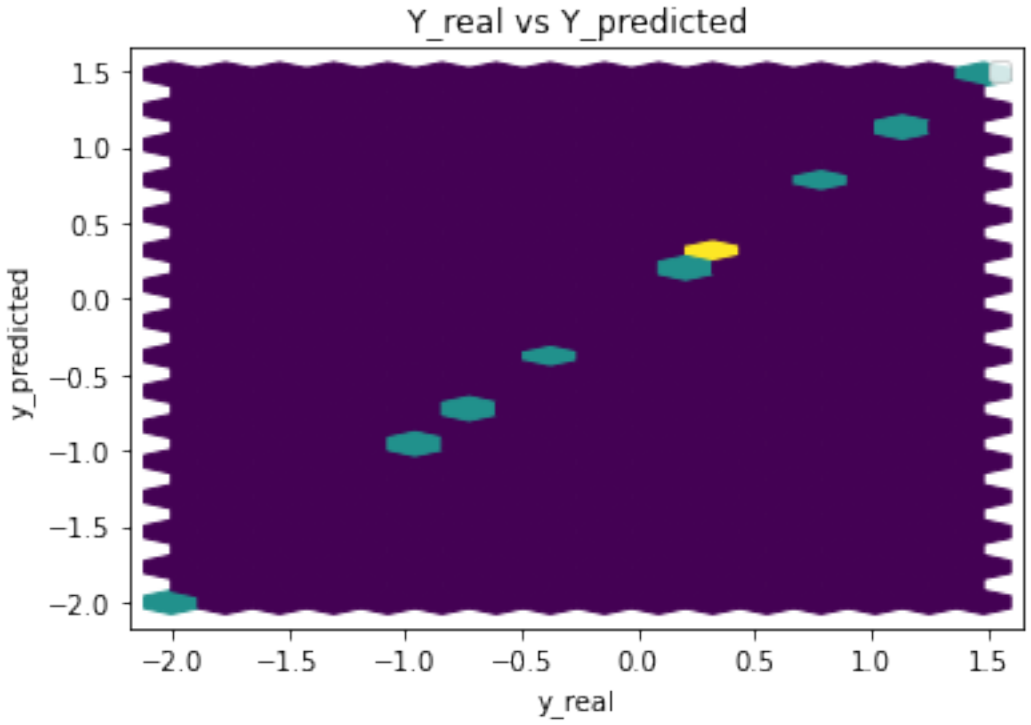
```
3  0.472821  0.948381  0.896898  0.968297  0.123775  0.322727  0.624299
4  0.145426  0.315487  0.690114  0.103206  0.009039  0.500428  0.583773

         X7        X8        X9          Y
0  0.642739  0.971524  0.210137  16.443805
1  0.333939  0.039234  0.321735  21.249520
2  0.579075  0.164716  0.278566  18.907658
3  0.731854  0.738494  0.225107  23.201949
4  0.337531  0.525335  0.651208   3.343592
```

1.5 Stats Model

[6]:
```
[coeff,y_pred] = statsModel.statsModel(X,Y)
```

```
No handles with labels found to put in legend.

                            OLS Regression Results
==============================================================================
Dep. Variable:                      Y   R-squared:                       1.000
Model:                            OLS   Adj. R-squared:                    nan
Method:                 Least Squares   F-statistic:                       nan
Date:                Wed, 20 Oct 2021   Prob (F-statistic):                nan
Time:                        20:05:04   Log-Likelihood:                325.96
No. Observations:                  10   AIC:                           -631.9
Df Residuals:                       0   BIC:                           -628.9
Df Model:                           9
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const        2.22e-16        inf          0        nan         nan         nan
x1             0.3402        inf          0        nan         nan         nan
x2             0.8040        inf          0        nan         nan         nan
x3             0.0220        inf          0        nan         nan         nan
x4             0.5338        inf          0        nan         nan         nan
x5             0.3440        inf          0        nan         nan         nan
x6            -0.1498        inf         -0        nan         nan         nan
x7            -0.3580        inf         -0        nan         nan         nan
x8            -0.2925        inf         -0        nan         nan         nan
x9             0.0163        inf          0        nan         nan         nan
x10           -0.1335        inf         -0        nan         nan         nan
==============================================================================
Omnibus:                        3.588   Durbin-Watson:                   2.073
Prob(Omnibus):                  0.166   Jarque-Bera (JB):                1.116
Skew:                          -0.245   Prob(JB):                        0.572
Kurtosis:                       1.439   Cond. No.                         25.0
==============================================================================

Notes:
```

```
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
[2] The input rank is higher than the number of observations.
Parameters:  const    2.220446e-16
x1         3.401771e-01
x2         8.040467e-01
x3         2.195216e-02
x4         5.337661e-01
x5         3.440083e-01
x6        -1.498168e-01
x7        -3.579580e-01
x8        -2.925108e-01
x9         1.631096e-02
x10       -1.335153e-01
dtype: float64
```




```
Performance Metrics
Mean Squared Error: 2.8482192761553952e-30
Mean Absolute Error: 1.4932499681208355e-15
Manhattan distance: 1.4932499681208355e-14
Euclidean distance: 5.336871064730153e-15
```

1.6 Common Training Parameters (GAN & ABC_GAN)

[7]:
```
n_epochs = 5000
error = 0.001
batch_size = n_samples//2
```

1.7 GAN Model

[8]:
```
real_dataset = dataset.CustomDataset(X,Y)
device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
```

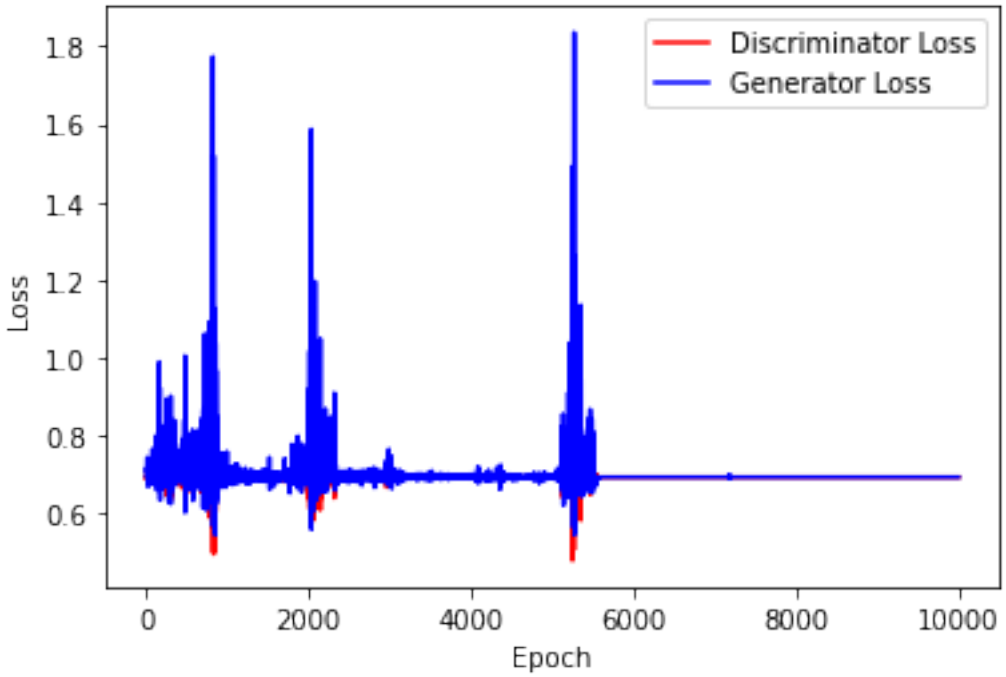
Training GAN for n_epochs number of epochs

[9]:
```
generator = network.Generator(n_features+2)
discriminator = network.Discriminator(n_features+2)

criterion = torch.nn.BCEWithLogitsLoss()
gen_opt = torch.optim.Adam(generator.parameters(), lr=0.01, betas=(0.5, 0.999))
disc_opt = torch.optim.Adam(discriminator.parameters(), lr=0.01, betas=(0.5, 0.
↪999))
```

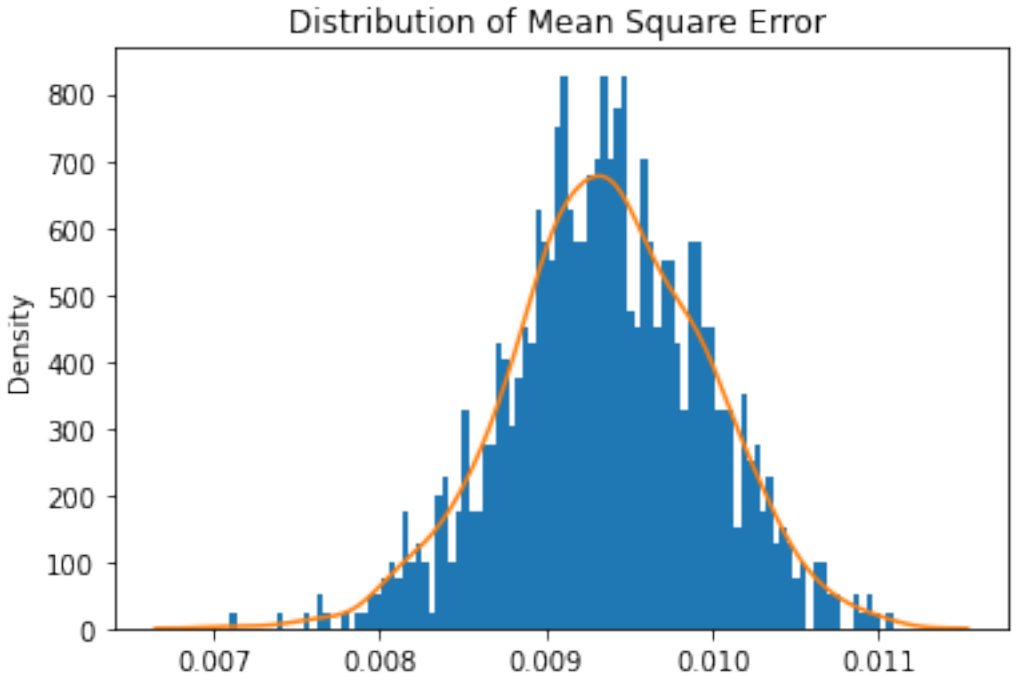
[10]:
```
print(generator)
print(discriminator)
```

```
Generator(
  (hidden1): Linear(in_features=12, out_features=100, bias=True)
  (hidden2): Linear(in_features=100, out_features=100, bias=True)
  (output): Linear(in_features=100, out_features=1, bias=True)
  (relu): ReLU()
)
Discriminator(
  (hidden1): Linear(in_features=12, out_features=25, bias=True)
  (hidden2): Linear(in_features=25, out_features=50, bias=True)
  (output): Linear(in_features=50, out_features=1, bias=True)
  (relu): ReLU()
)
```

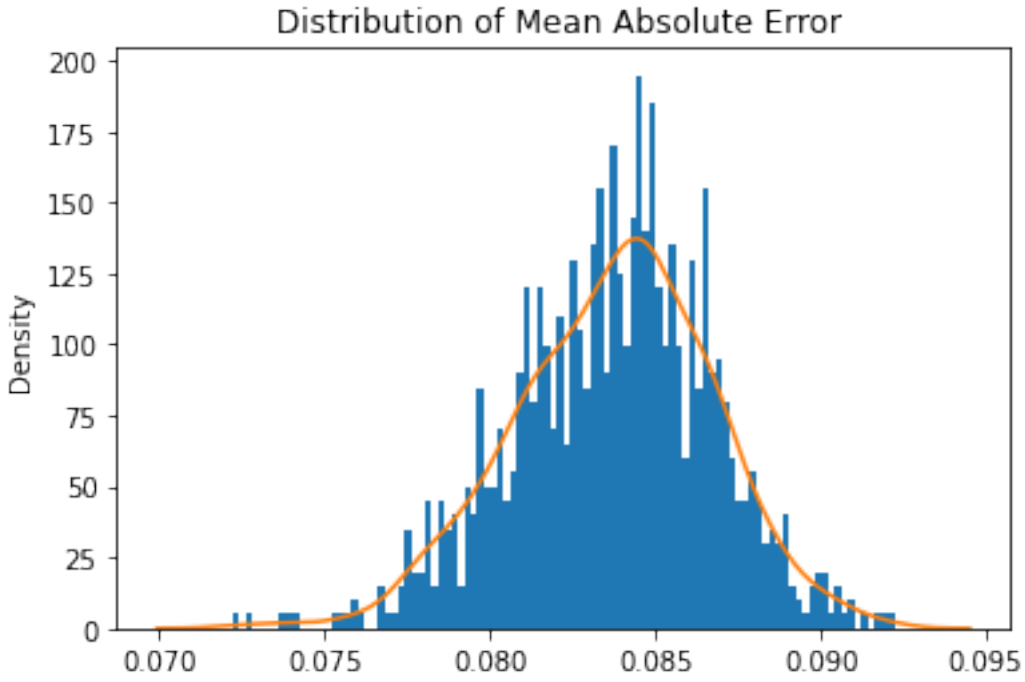
[11]:
```
train_test.
↪training_GAN(discriminator,generator,disc_opt,gen_opt,real_dataset,batch_size,␣
↪n_epochs,criterion,device)
```



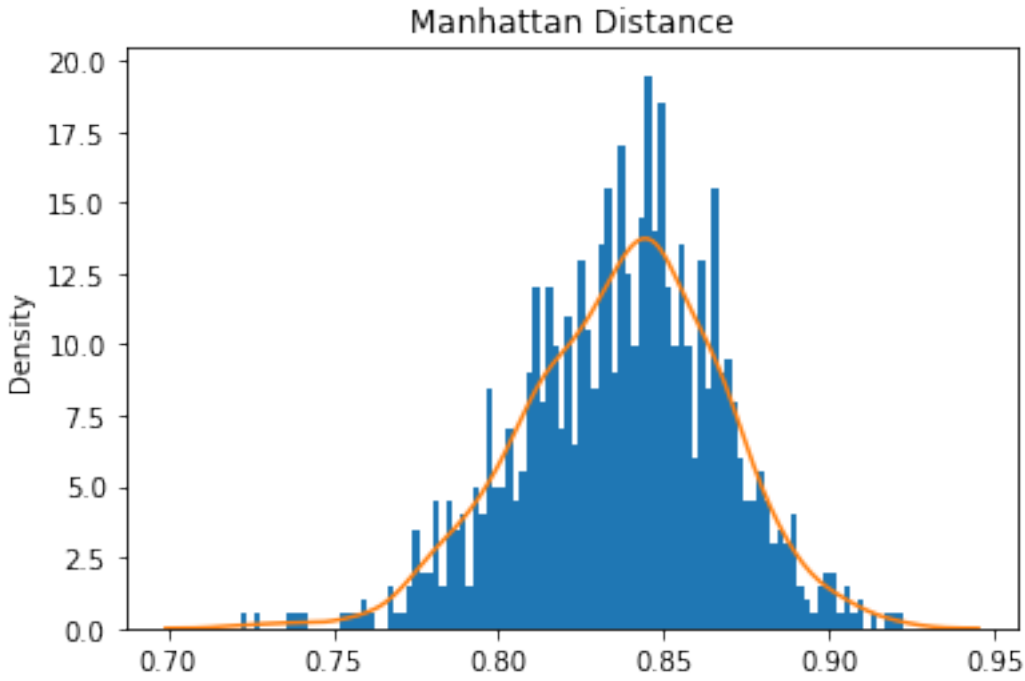
[12]:
```
train_test.test_generator(generator,real_dataset,device)
```



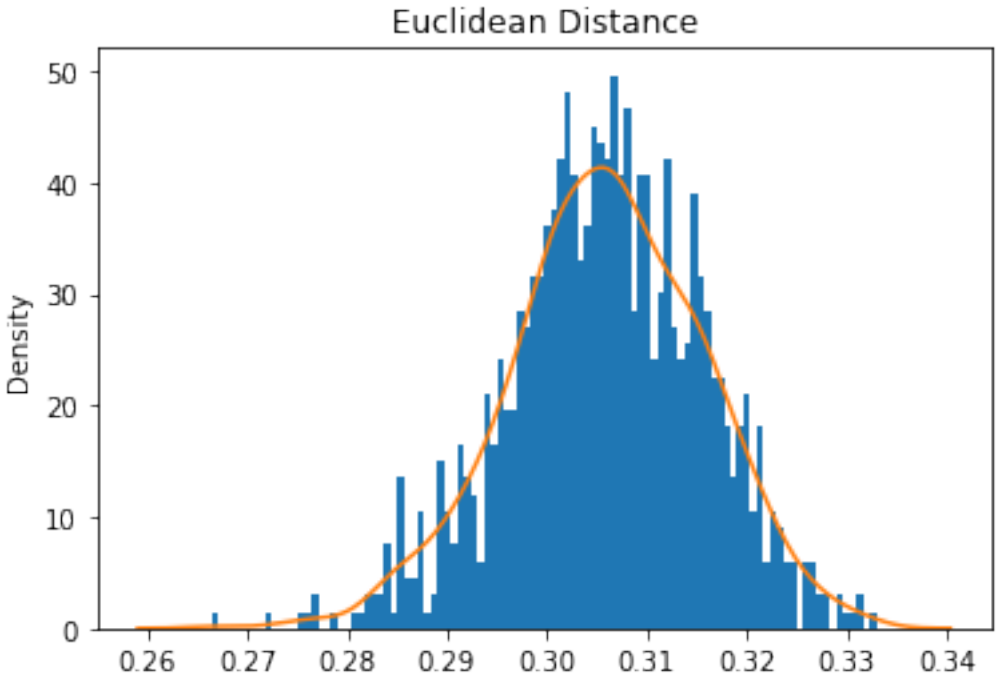
```
Mean Square Error: 0.009363350902948004
```




```
Mean Absolute Error: 0.08371758110150695
```

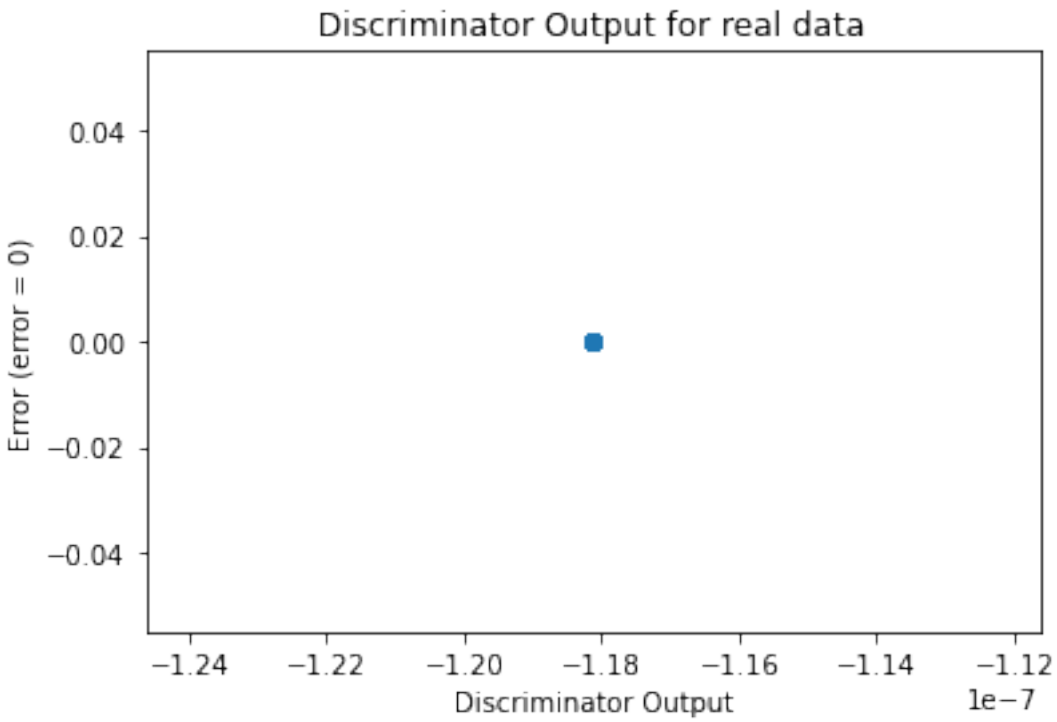


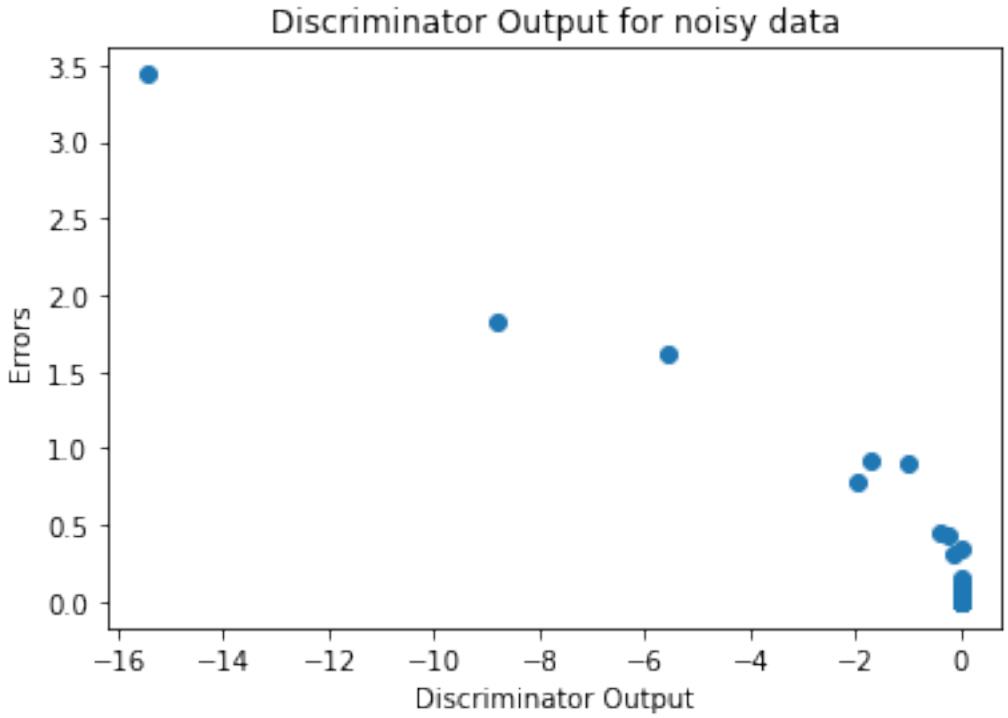
```
Mean Manhattan Distance: 0.8371758110150694
```




```
Mean Euclidean Distance: 0.30583998132636514
```

[13]:
```
sanityChecks.discProbVsError(real_dataset,discriminator,device)
```


Discriminator Output for real data
0.04
0.02
0.00
−0.02
−0.04
Error (error = 0)
−1.24
−1.22
−1.20
−1.18
−1.16
−1.14
−1.12
1e−7
Discriminator Output

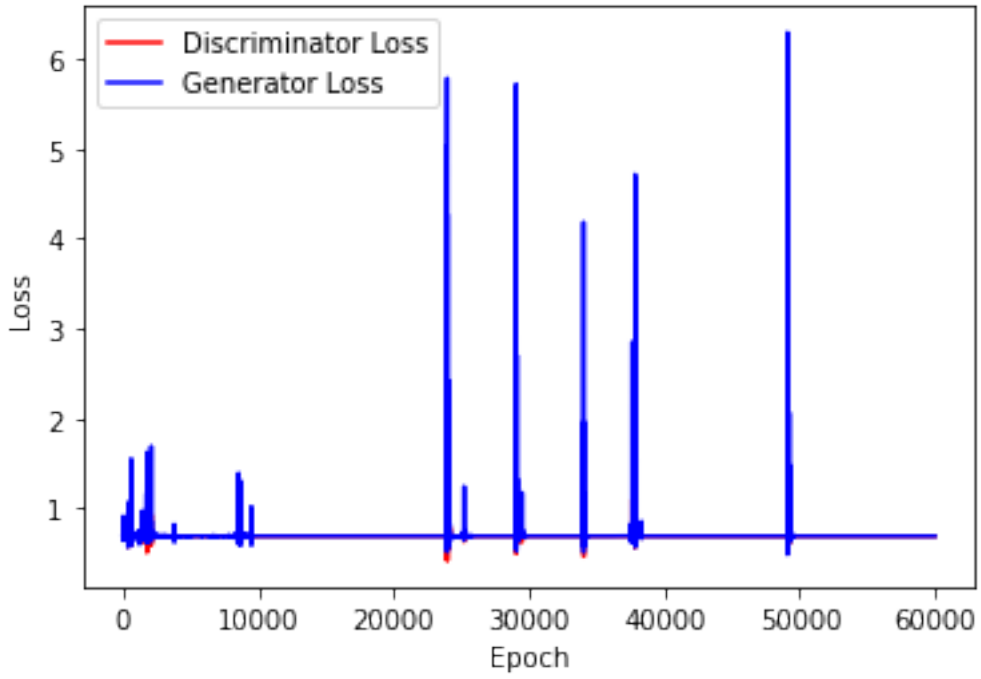

Discriminator Output for noisy data
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Errors
−16
−14
−12
−10
−8
−6
−4
−2
0
Discriminator Output

Training GAN until mse of y_pred is > 0.1 or n_epochs < 30000

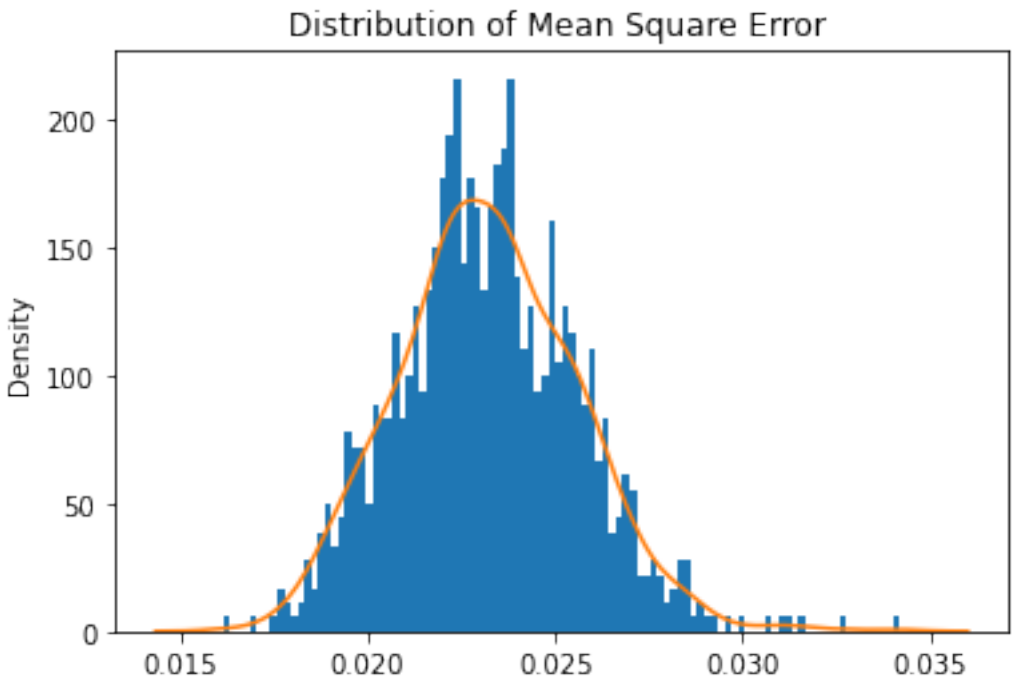
[14]:
```
generator = network.Generator(n_features+2)
discriminator = network.Discriminator(n_features+2)
criterion = torch.nn.BCEWithLogitsLoss()
gen_opt = torch.optim.Adam(generator.parameters(), lr=0.01, betas=(0.5, 0.999))
disc_opt = torch.optim.Adam(discriminator.parameters(), lr=0.01, betas=(0.5, 0.
↪999))
```

[15]:
```
train_test.
↪training_GAN_2(discriminator,generator,disc_opt,gen_opt,real_dataset,batch_size,error,crite
```

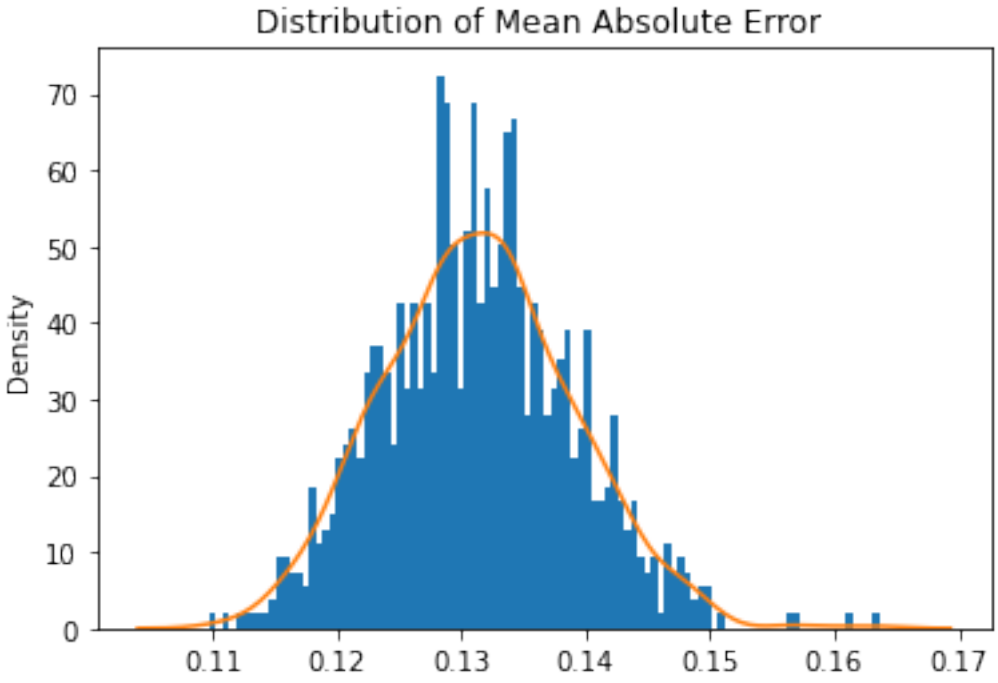
```
Number of epochs needed 30000
```



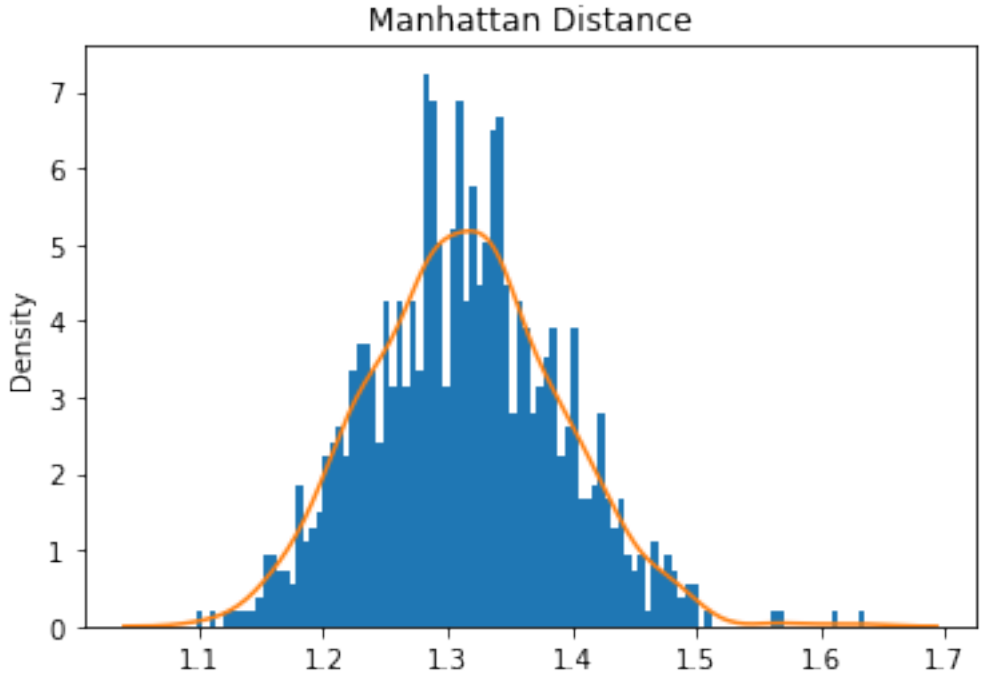
[16]:
```
train_test.test_generator(generator,real_dataset,device)
```



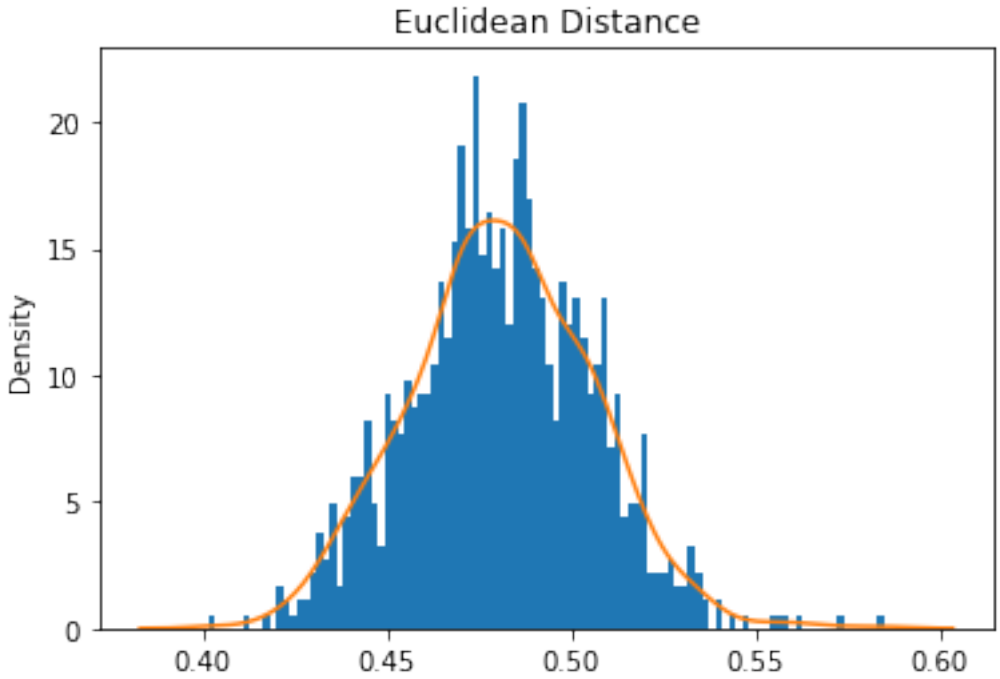

```
Mean Square Error: 0.023195370538341045
```



```
Mean Absolute Error: 0.1313441815651953
```




```
Mean Manhattan Distance: 1.3134418156519532
```



```
Mean Euclidean Distance: 0.48097909851401455
```

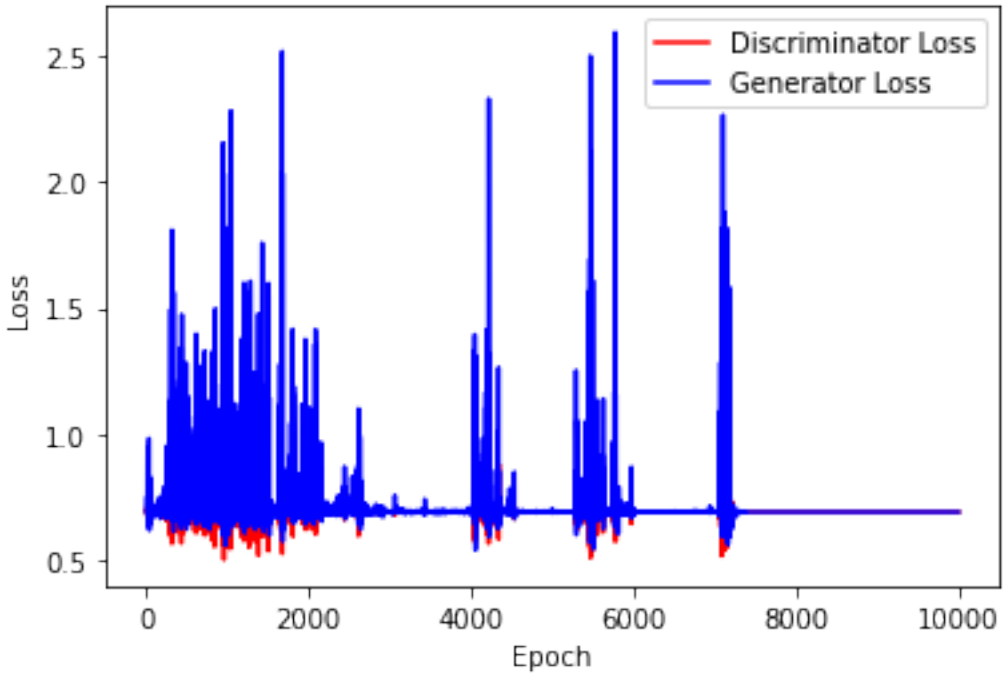
2 ABC GAN Model

2.0.1 Training the network

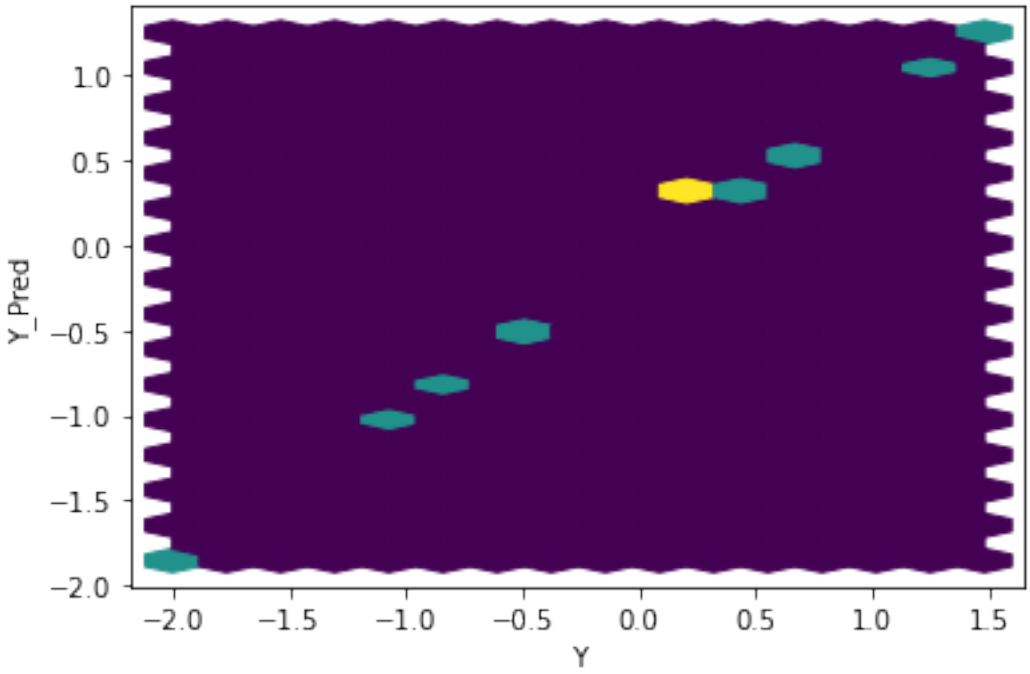
Training ABC-GAN for n_epochs number of epochs

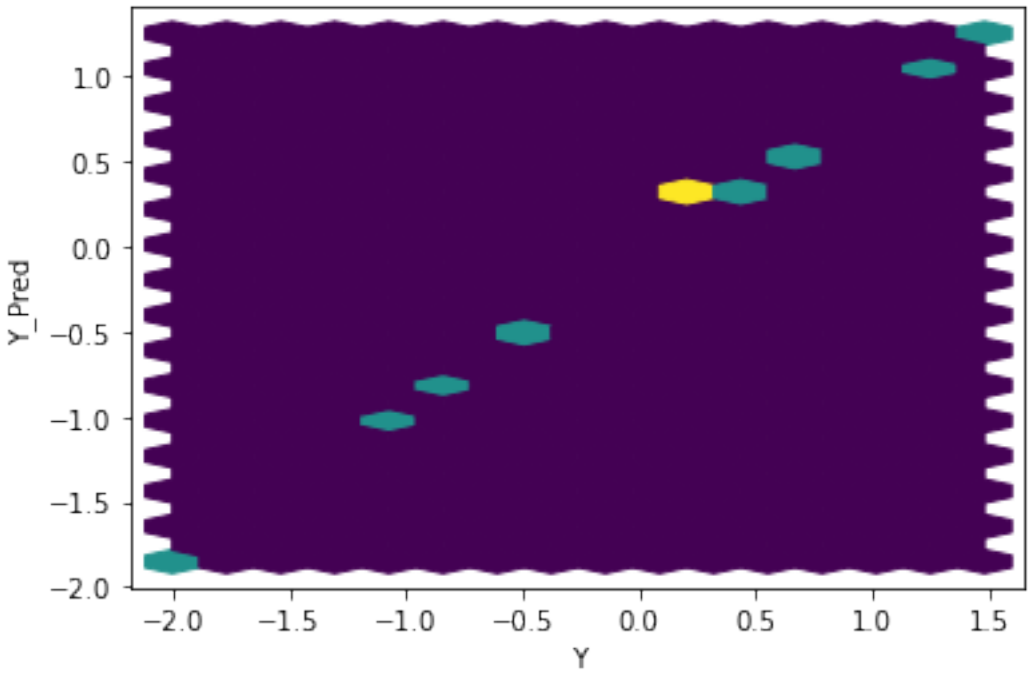
[17]:
```
gen = network.Generator(n_features+2)
disc = network.Discriminator(n_features+2)

criterion = torch.nn.BCEWithLogitsLoss()
gen_opt = torch.optim.Adam(gen.parameters(), lr=0.01, betas=(0.5, 0.999))
disc_opt = torch.optim.Adam(disc.parameters(), lr=0.01, betas=(0.5, 0.999))
```

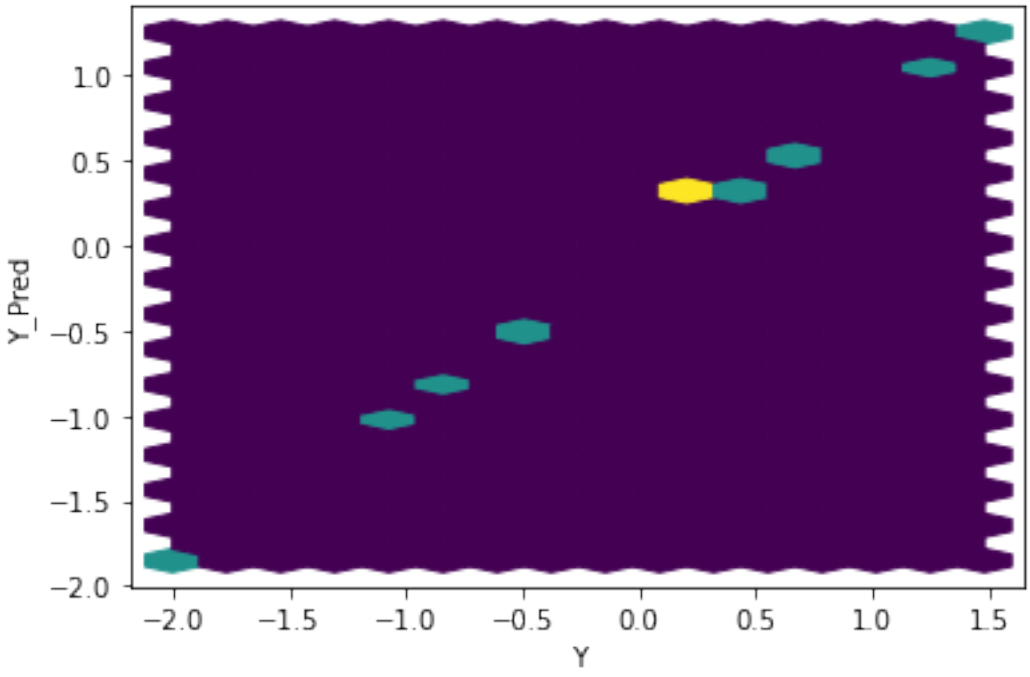
[18]:
```
ABC_train_test.training_GAN(disc, gen,disc_opt,gen_opt,real_dataset,␣
↪batch_size, n_epochs,criterion,coeff,mean,variance,device)
```

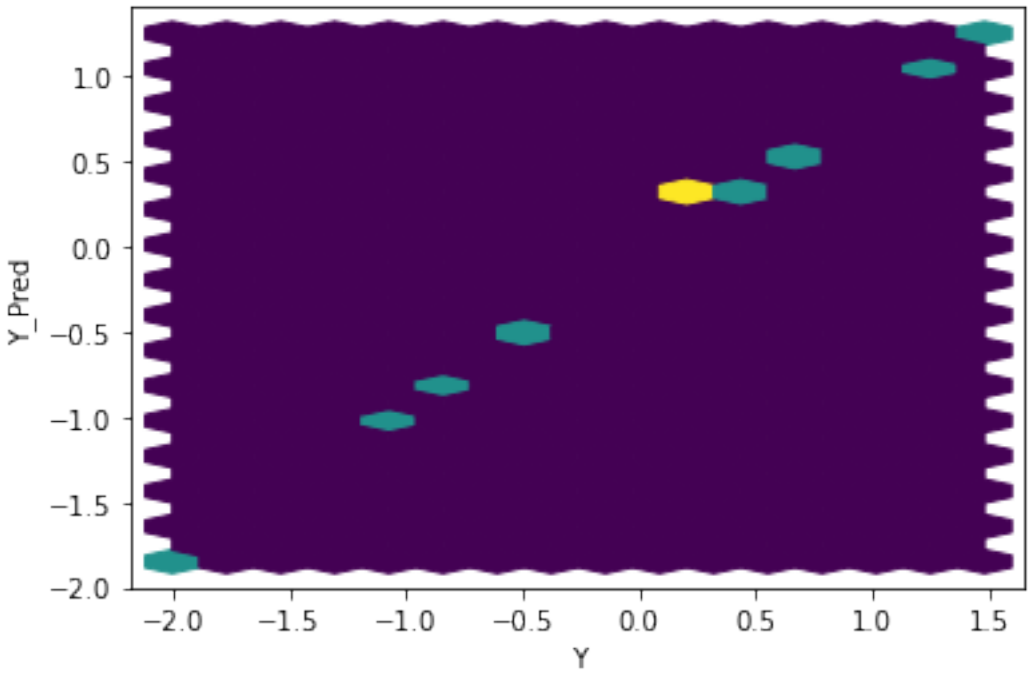


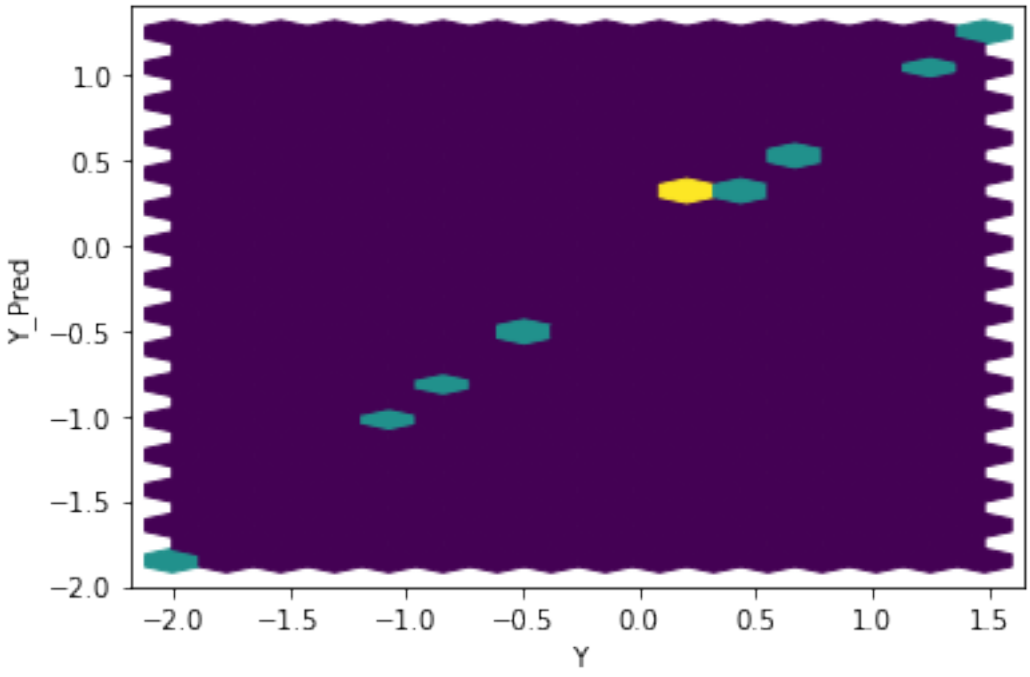
[19]:
```
ABC_train_test.test_generator(gen,real_dataset,coeff,mean,variance,device)
```

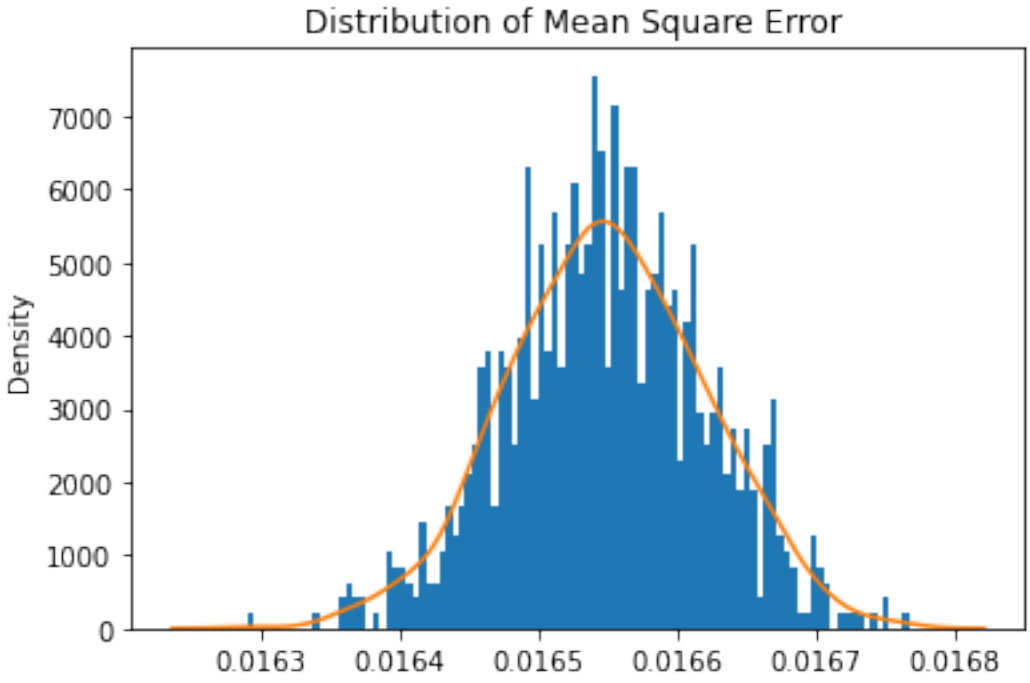

Y_Pred
Y
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5


Y_Pred
Y
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5

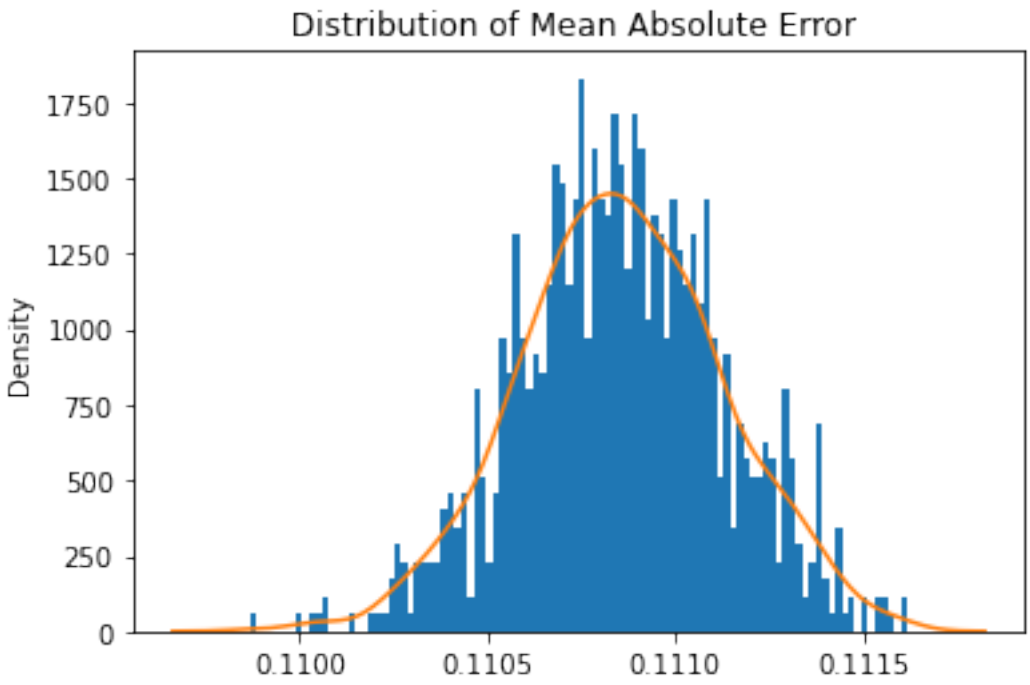

Y_Pred
Y
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5


Y_Pred
Y
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5

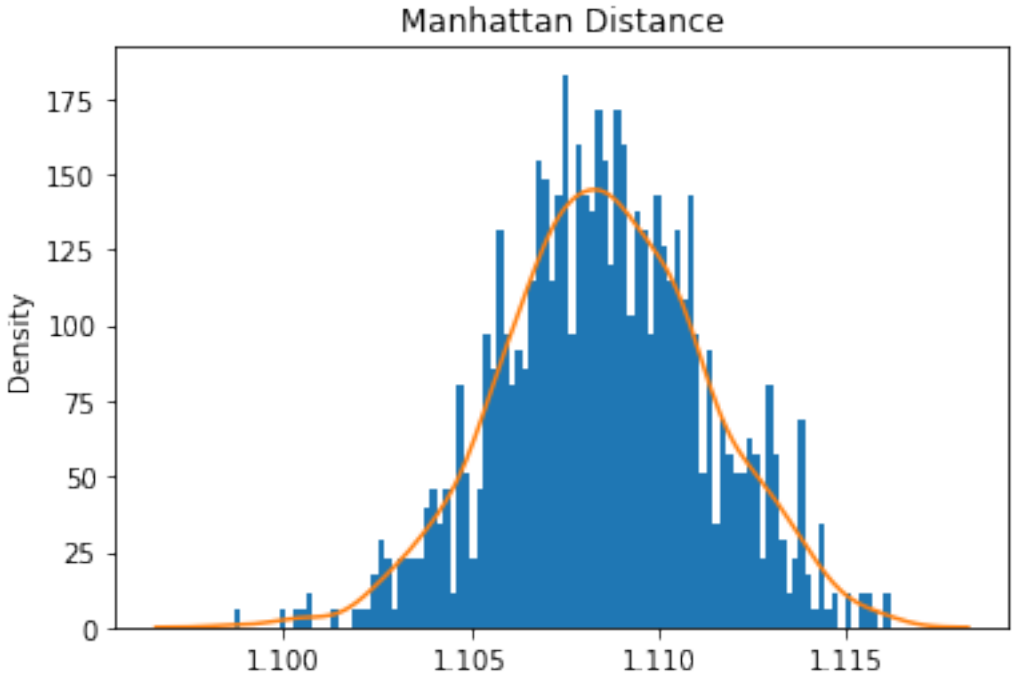




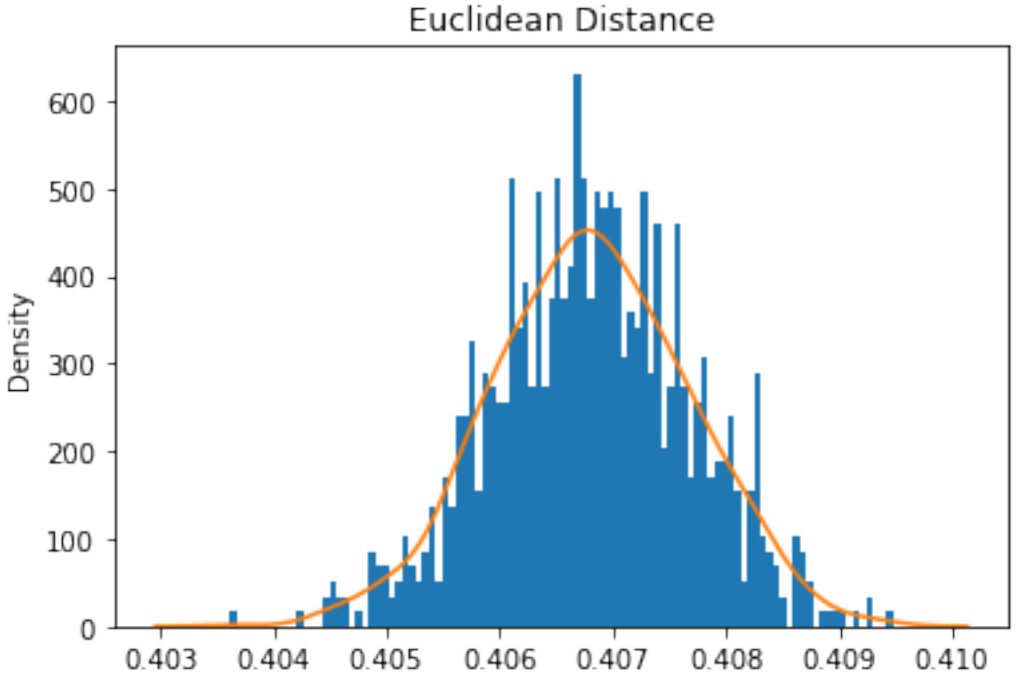

```
Mean Square Error: 0.016549121208843404
```




```
Mean Absolute Error: 0.1108549439251423
Mean Manhattan Distance: 1.1085494392514228
```

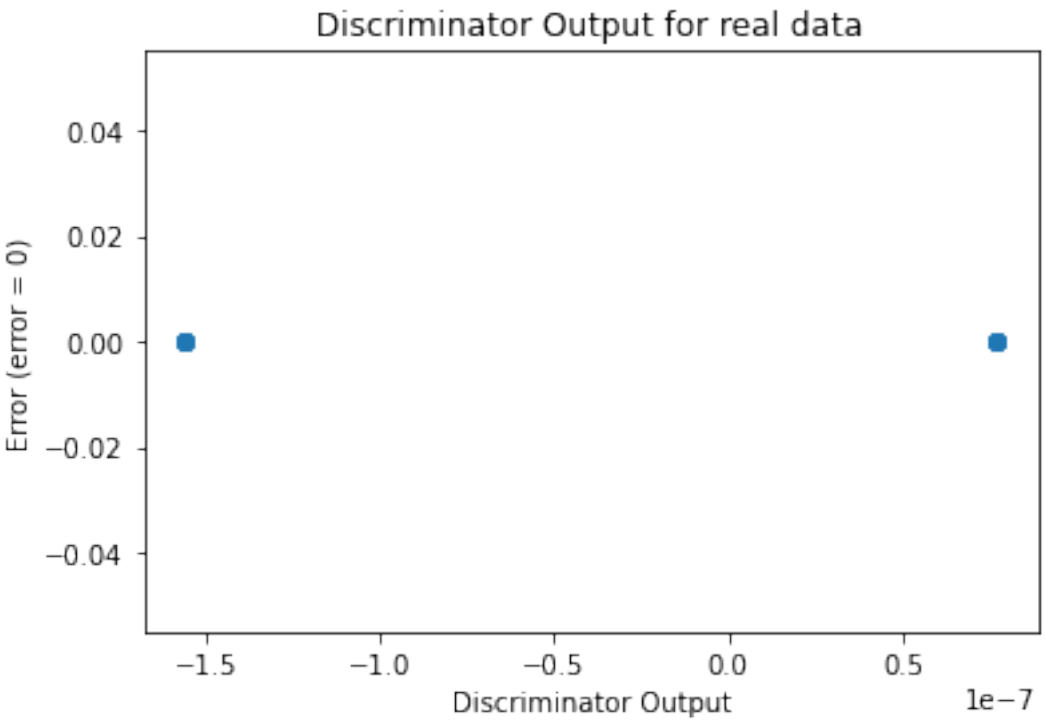


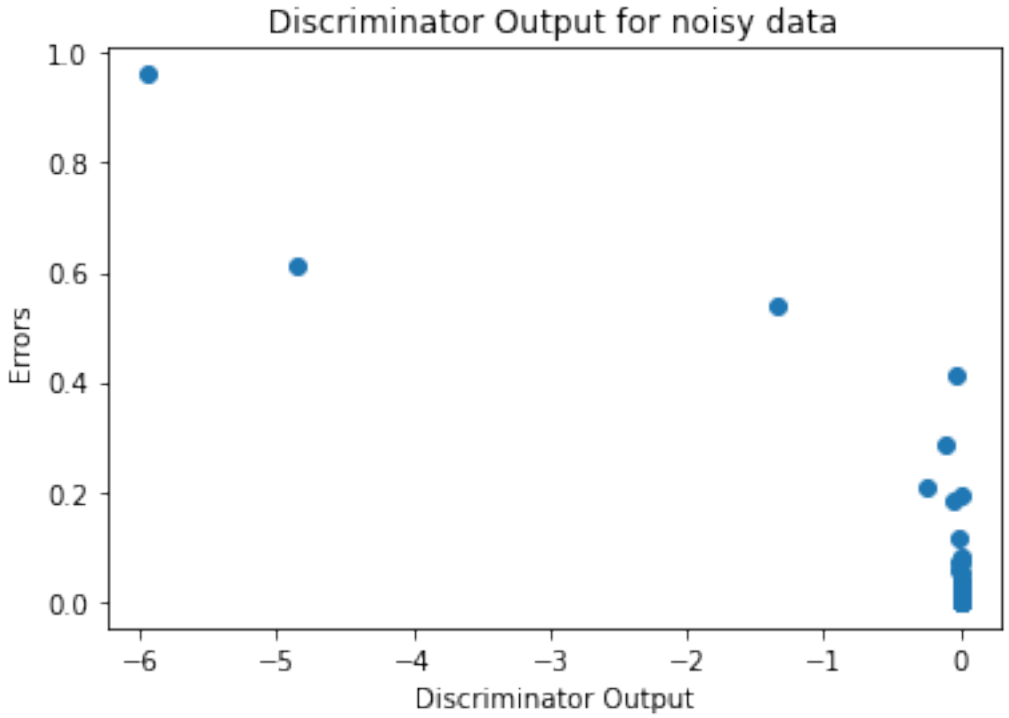
```
Mean Euclidean Distance: 0.40680517100364105
```



Sanity Checks

[20]:
```
sanityChecks.discProbVsError(real_dataset,disc,device)
```


Discriminator Output for real data
Error (error = 0)
0.04
0.02
0.00
−0.02
−0.04
−1.5
−1.0
−0.5
0.0
0.5
Discriminator Output
1e−7

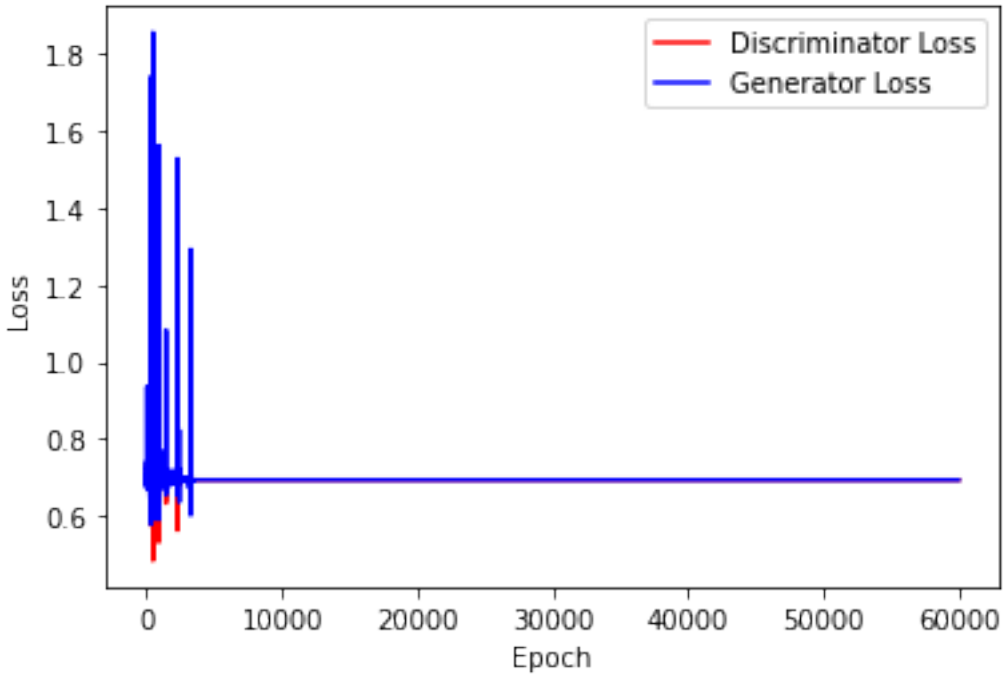

Discriminator Output for noisy data
Errors
1.0
0.8
0.6
0.4
0.2
0.0
−6
−5
−4
−3
−2
−1
0
Discriminator Output

Training GAN until mse of y_pred is > 0.1 or n_epochs < 30000

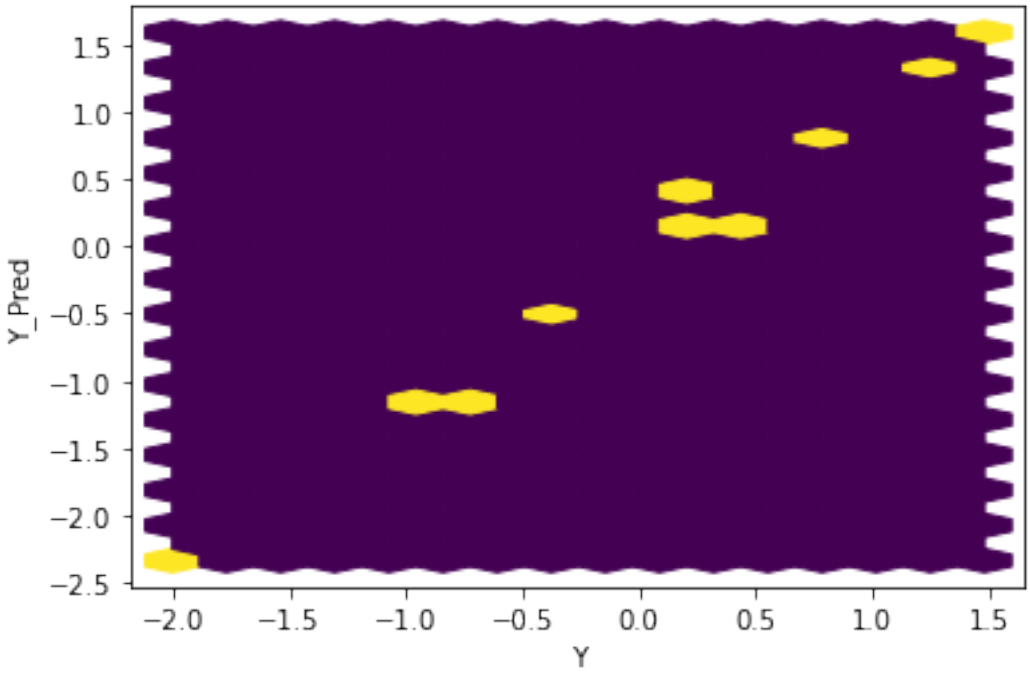
[21]:
```
gen = network.Generator(n_features+2)
disc = network.Discriminator(n_features+2)

criterion = torch.nn.BCEWithLogitsLoss()
gen_opt = torch.optim.Adam(gen.parameters(), lr=0.01, betas=(0.5, 0.999))
disc_opt = torch.optim.Adam(disc.parameters(), lr=0.01, betas=(0.5, 0.999))
```

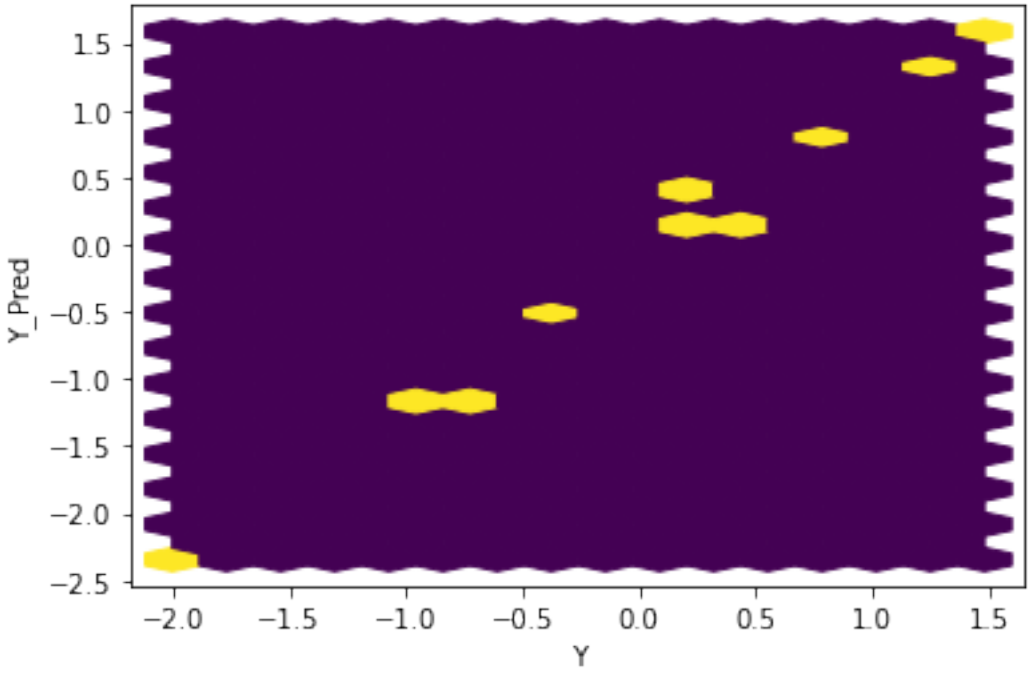
[22]:
```
ABC_train_test.
↪training_GAN_2(disc,gen,disc_opt,gen_opt,real_dataset,batch_size,␣
↪error,criterion,coeff,mean,variance,device)
```

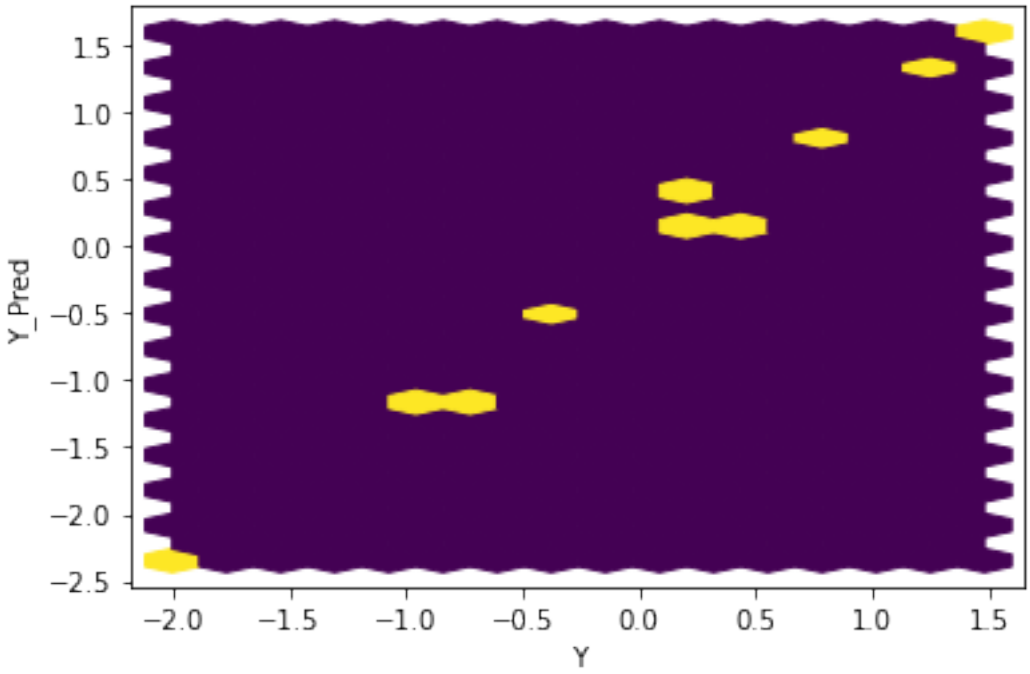
```
Number of epochs 30000
```

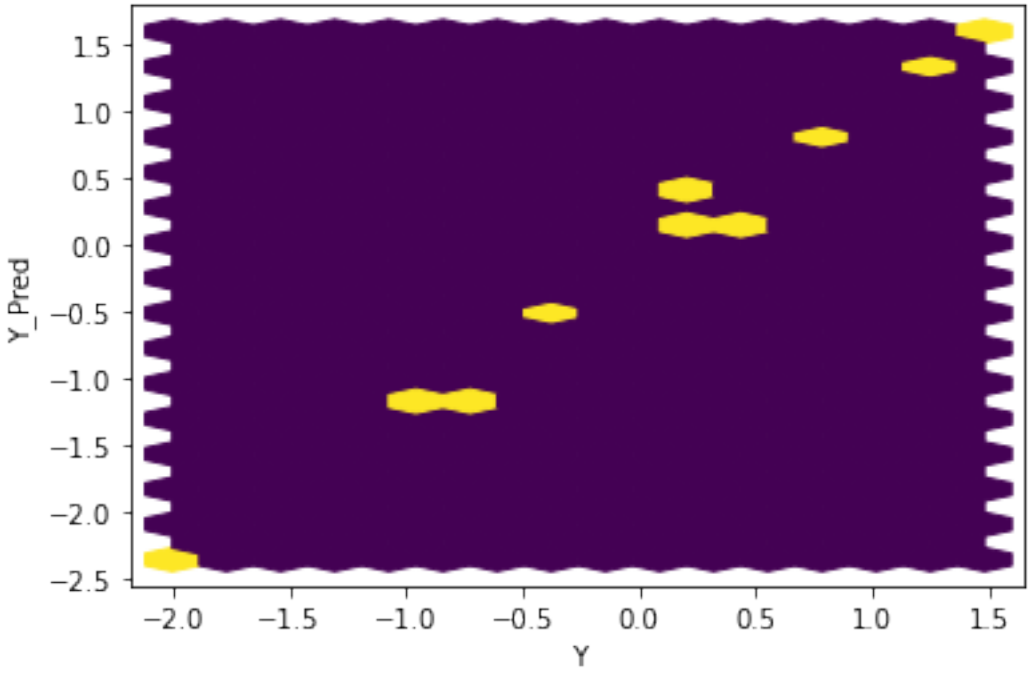


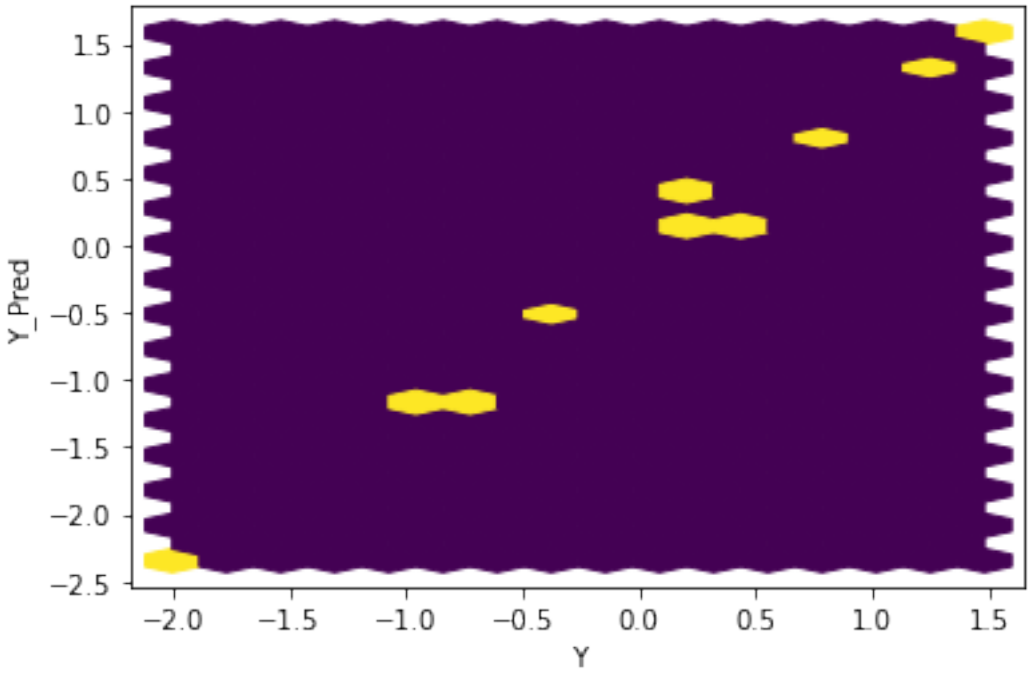
[23]:
```
ABC_train_test.test_generator(gen,real_dataset,coeff,mean,variance,device)
```

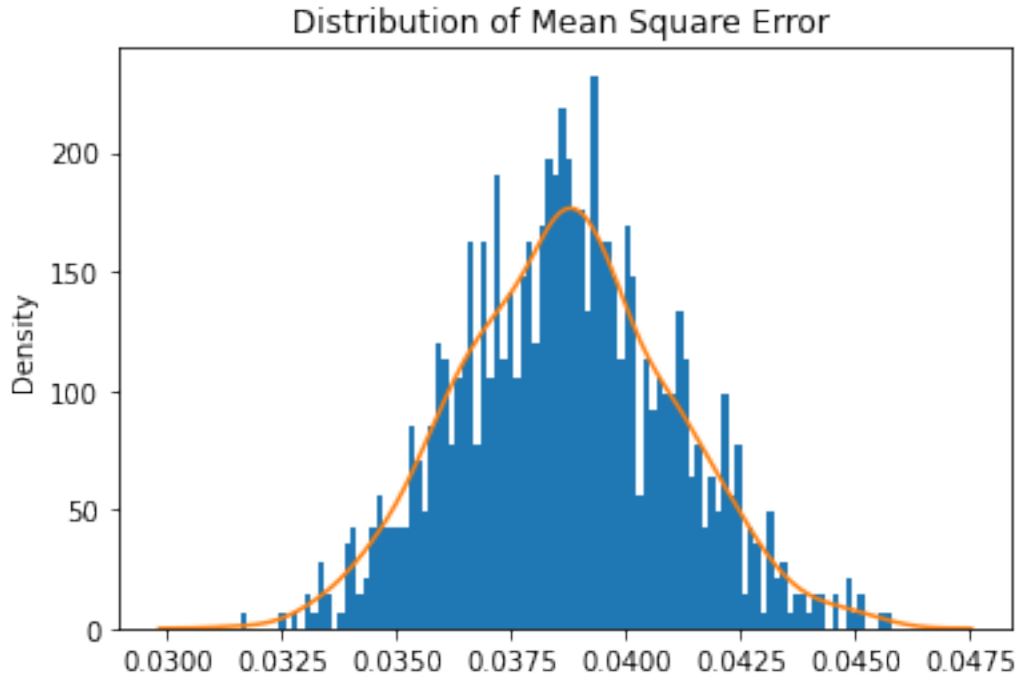

Y_Pred
Y
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5


Y_Pred
Y
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5

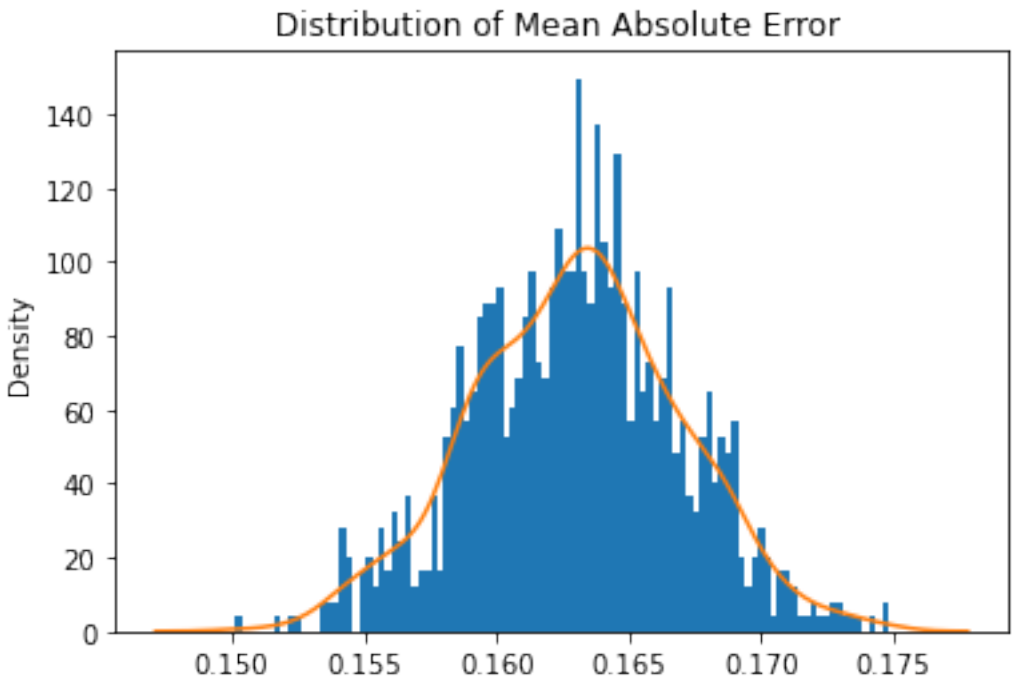

Y_Pred
Y
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5


Y_Pred
Y
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5

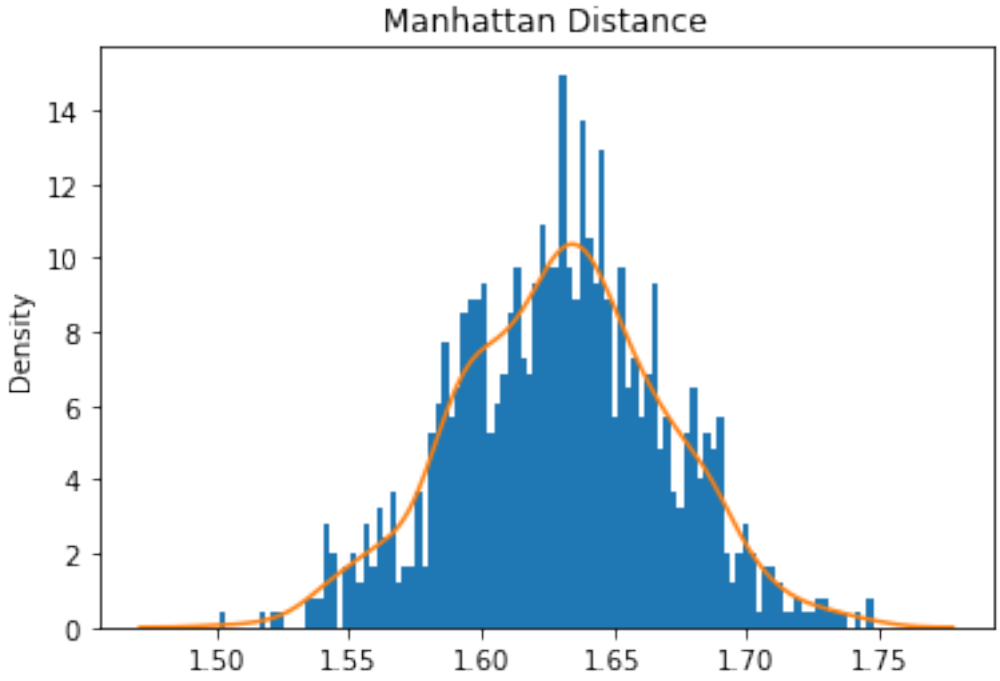




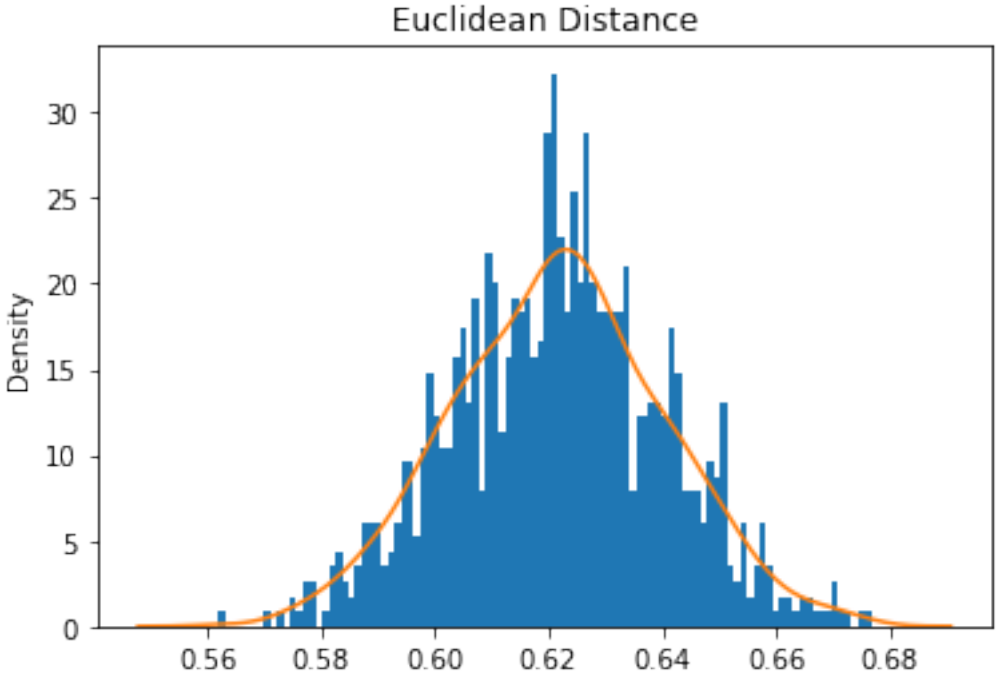

```
Mean Square Error: 0.038680920402443836
```




```
Mean Absolute Error: 0.1630047065794468
Mean Manhattan Distance: 1.630047065794468
```



```
Mean Euclidean Distance: 0.6216597382299895
```



[ ]: