6501 Progress Report Group 4

Improving Credit Card Fraud Detection using Generative Adversarial Networks

Group 4 Team Member: Hao Ning, Jun Ying

Working Schedule

Time	Milestone
09/21/2020	Exploratory Data Analysis (EDA): Jun Base Model: Hao
09/28/2020	Original data + GAN
10/05/2020	Network & Framework Development WGAN: Hao BAGAN: Jun
10/12/2020	WGAN & BAGAN Evaluation & Analysis
10/19/2020	Preliminary Presentation
10/26/2020	Network & Framework Development WGAN_GP: Hao BEGAN: Jun
11/02/2020	WGAN_GP, BEGAN Evaluation & Analysis
11/09/2020 & 11/16/2020	Summary of Results, Github
11/23/2020	Manuscript
11/30/2020 & 12/07/2020	Mock Presentation & Presentation and Journal Submission

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09/21/2020

EDA

```
Index(['Time', 'V1', 'V2', 'V3', 'V4', 'V5', 'V6', 'V7', 'V8', 'V9', 'V10',
       'V11', 'V12', 'V13', 'V14', 'V15', 'V16', 'V17', 'V18', 'V19', 'V20',
       'V21', 'V22', 'V23', 'V24', 'V25', 'V26', 'V27', 'V28', 'Amount',
       'Class'],
```

About the dataset, there are 30 features and 1 class (normal:0, fraud:1)

```
   Time        V1        V2        V3  ...       V27       V28  Amount  Class
0   0.0 -1.359807 -0.072781  2.536347  ...  0.133558 -0.021053  149.62      0
1   0.0  1.191857  0.266151  0.166480  ... -0.008983  0.014724    2.69      0
2   1.0 -1.358354 -1.340163  1.773209  ... -0.055353 -0.059752  378.66      0
3   1.0 -0.966272 -0.185226  1.792993  ...  0.062723  0.061458  123.50      0
4   2.0 -1.158233  0.877737  1.548718  ...  0.219422  0.215153   69.99      0
```

There is no null value in the dataset.

```
 Total null values in the dataset
0
```

As we know, the dataset is extremely imbalanced(0.173%).

```
The amounts of normal transactions (class 0) & fraud transactions (class 1)
0    284315
1       492
```

We have observed that there are some transactions which are 0.

```
                Time            V1  ...         Amount          Class
count  284807.000000  2.848070e+05  ...  284807.000000  284807.000000
mean       14.537951  3.919560e-15  ...      88.349619       0.001727
std         5.847061  1.958696e+00  ...     250.120109       0.041527
min         0.000000 -5.640751e+01  ...       0.000000       0.000000
25%        10.598194 -9.203734e-01  ...       5.600000       0.000000
50%        15.010833  1.810880e-02  ...      22.000000       0.000000
75%        19.329722  1.315642e+00  ...      77.165000       0.000000
max        23.999444  2.454930e+00  ...   25691.160000       1.000000
```

The total number of 0 amount: 1825 (1.479% fraud)

```
The null amounts of normal transactions (class 0) & fraud transactions (class 1)
0    1798
1      27
Name: Class, dtype: int64
```

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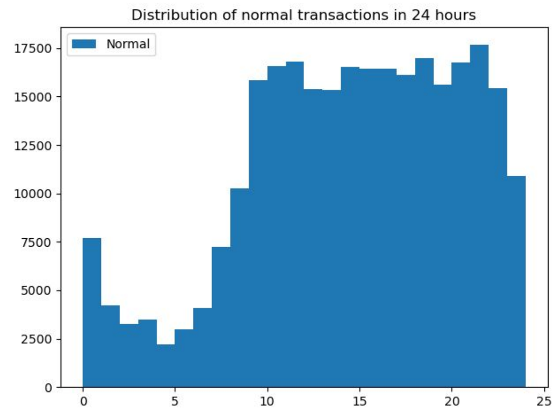
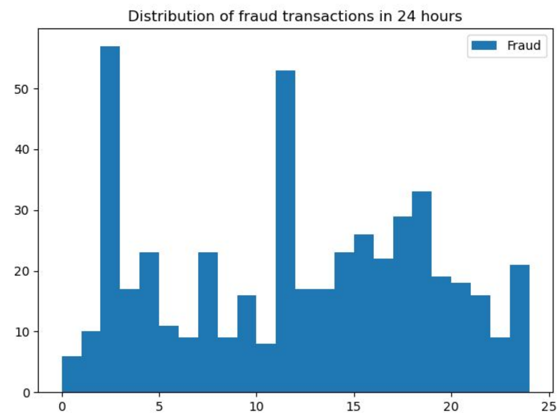
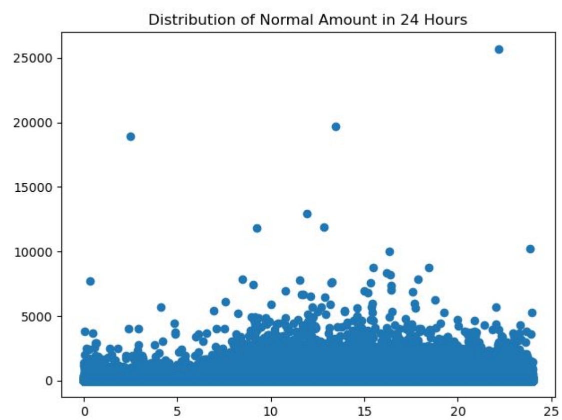
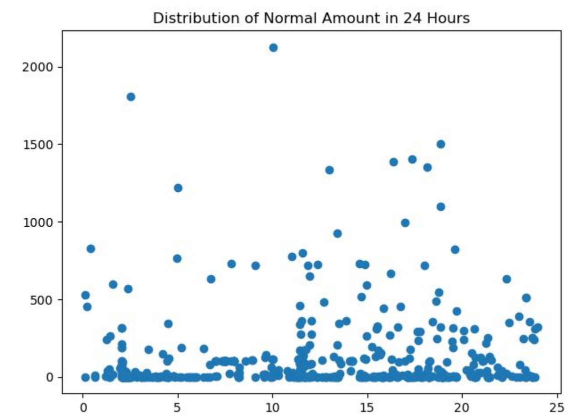


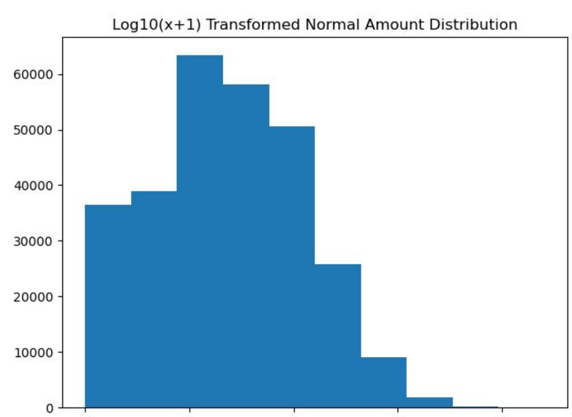


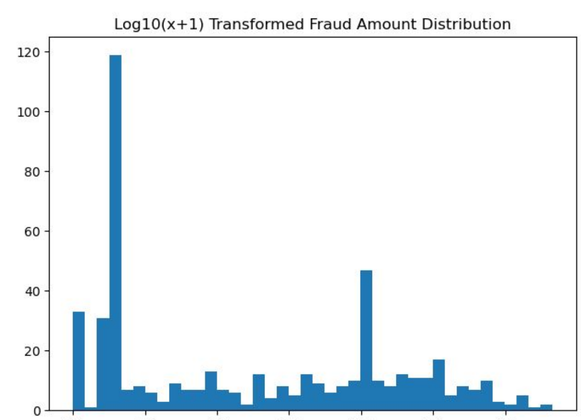
From the histogram, we can observe that normal transactions generally occur from 9 am to 0 am. However, the fraud transactions occur particularly frequently at 2 am and 12 pm.





We can find from this scatter plot that the number of super-large transactions is very small. In comparison, the largest amount of normal transactions is over €25,000. However, the largest amount of fraud transactions is only €2,000.





Normal amount was from ten to hundred. Fraud Amount distributed in less than €1.

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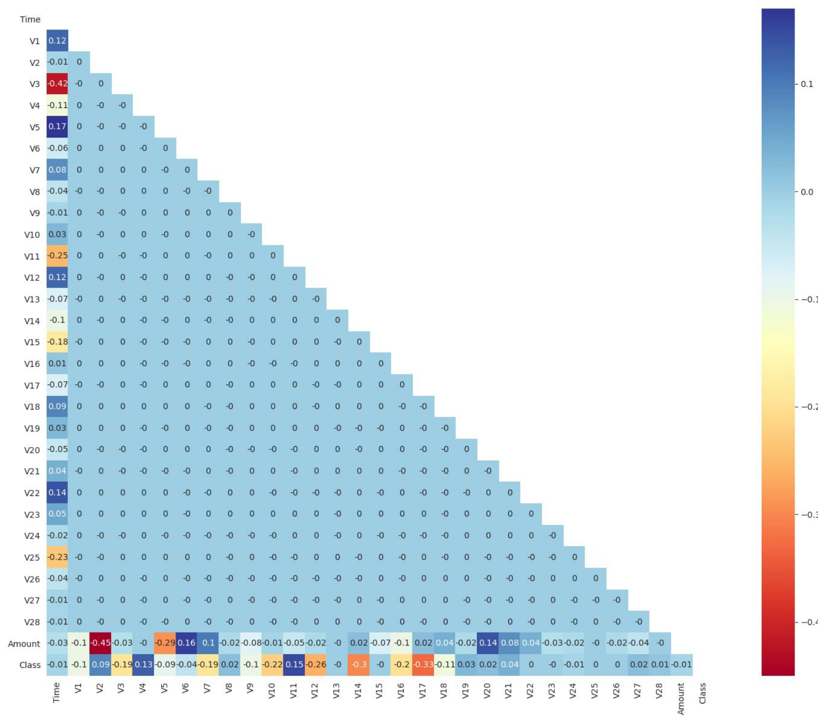

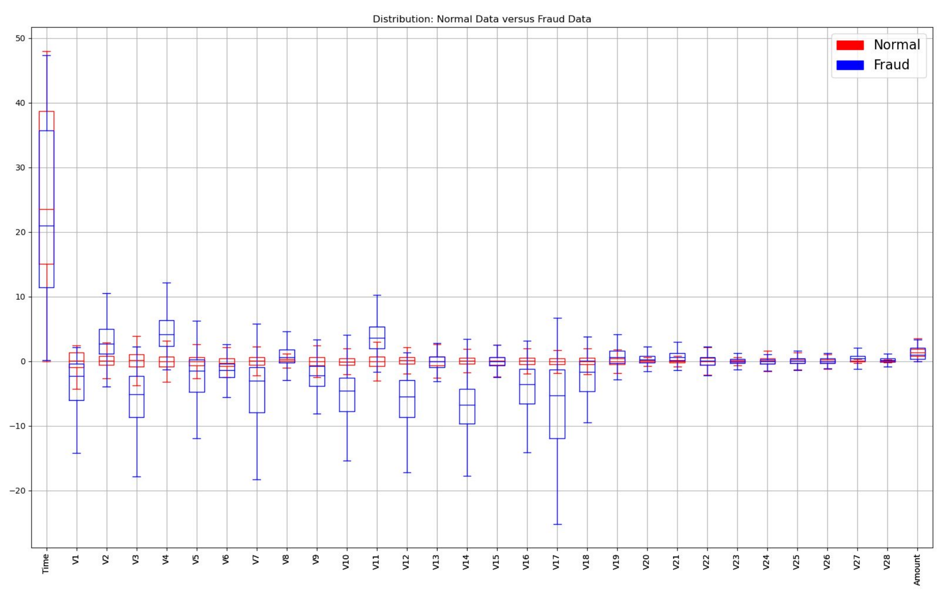

Base Model:

1. Split the data with train set 80% 227845 (394 fraud) and test set 20% 56962 (98 fraud), and labels are stratified
2. Perform Random Under Sampling (RUS) & Random Over Sampling (ROS) on train set
3. Use GridsearchCV to find the best parameters for XGBoostClassifier
4. Predict with best parameters
5. Test performance evaluation, shown below

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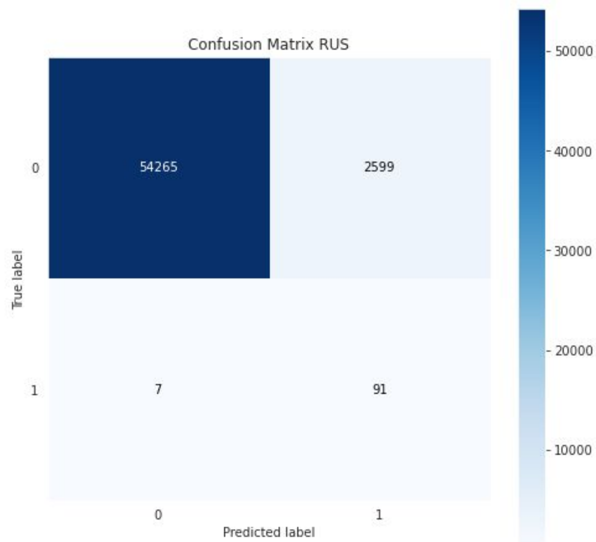
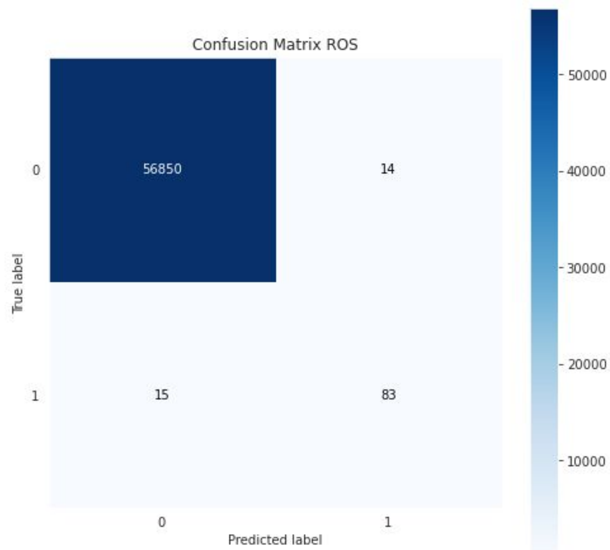
	RUS **1 394** **0 394**	**ROS** **1 227451** **0 227451**
Accuracy	0.954250	0.999491
Precision	0.033829	0.855670
Recall	0.928571	0.846939
F1 score	0.065280	0.851282
ROC AUC score	0.941433	0.923346





09/28/2020

Implemented with Keras

A bit change from from original gan:

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Vanilla gan deals with images, but we are dealing with tabular data, so tanh is removed.
Also, we removed batch normalization since the training results are bad.

Noise = 32
len(features) = 30

Generator

Input	Output size
(32, 1)	(64,1)
(64, 1)	(128, 1)
(128, 1)	(256, 1)
(256, 1)	(30, 1)

LeakyReLU(0.2)

Discriminator

Input	Output size
(30, 1)	(256,1)
(256, 1)	(128, 1)
(128, 1)	(64, 1)
(64, 1)	(1, 1)

LeakyReLU(0.2)

Train
epoch=10, batch_size=128, steps_per_epoch=100

```
EPOCH #  10 ------------------------------------------------
Steps (5 / 50): [Loss_D_real: 0.101874, Loss_D_fake: 0.804704, acc: 55.47%] [Loss_G: 0.577402]
Steps (10 / 50): [Loss_D_real: 0.034651, Loss_D_fake: 0.794337, acc: 58.59%] [Loss_G: 0.583686]
Steps (15 / 50): [Loss_D_real: 0.043936, Loss_D_fake: 0.802042, acc: 64.84%] [Loss_G: 0.606348]
Steps (20 / 50): [Loss_D_real: 0.034166, Loss_D_fake: 0.831742, acc: 57.81%] [Loss_G: 0.573465]
Steps (25 / 50): [Loss_D_real: 0.045282, Loss_D_fake: 0.852394, acc: 56.25%] [Loss_G: 0.597851]
Steps (30 / 50): [Loss_D_real: 0.072814, Loss_D_fake: 0.801378, acc: 60.94%] [Loss_G: 0.593632]
Steps (35 / 50): [Loss_D_real: 0.062091, Loss_D_fake: 0.837749, acc: 55.47%] [Loss_G: 0.597265]
Steps (40 / 50): [Loss_D_real: 0.099103, Loss_D_fake: 0.853835, acc: 54.69%] [Loss_G: 0.578026]
Steps (45 / 50): [Loss_D_real: 0.088608, Loss_D_fake: 0.799784, acc: 60.16%] [Loss_G: 0.573147]
Steps (50 / 50): [Loss_D_real: 0.043118, Loss_D_fake: 0.808880, acc: 61.72%] [Loss_G: 0.589081]
```

epoch=20, batch_size=128, steps_per_epoch=100

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```
EPOCH #  20 ------------------------------------------------
Steps (10 / 100): [Loss_D_real: 0.041530, Loss_D_fake: 0.459832, acc: 100.00%] [Loss_G: 1.017299]
Steps (20 / 100): [Loss_D_real: 0.049112, Loss_D_fake: 0.453462, acc: 100.00%] [Loss_G: 1.008852]
Steps (30 / 100): [Loss_D_real: 0.065196, Loss_D_fake: 0.458509, acc: 100.00%] [Loss_G: 1.018385]
Steps (40 / 100): [Loss_D_real: 0.061704, Loss_D_fake: 0.459229, acc: 100.00%] [Loss_G: 1.009706]
Steps (50 / 100): [Loss_D_real: 0.051204, Loss_D_fake: 0.460033, acc: 100.00%] [Loss_G: 1.005355]
Steps (60 / 100): [Loss_D_real: 0.059828, Loss_D_fake: 0.457545, acc: 100.00%] [Loss_G: 1.008903]
Steps (70 / 100): [Loss_D_real: 0.056420, Loss_D_fake: 0.468705, acc: 100.00%] [Loss_G: 1.013539]
Steps (80 / 100): [Loss_D_real: 0.052308, Loss_D_fake: 0.452640, acc: 100.00%] [Loss_G: 1.017379]
Steps (90 / 100): [Loss_D_real: 0.053092, Loss_D_fake: 0.457065, acc: 100.00%] [Loss_G: 0.990622]
Steps (100 / 100): [Loss_D_real: 0.052301, Loss_D_fake: 0.467294, acc: 100.00%] [Loss_G: 1.017609]
```

Original data + GAN

Original x_train has total of 227451 transactions, 227451 normal & 394 Fraud

1000

	Time	V1	V2	V3	V4	V5	V6	V7
count	1000.000000	1000.000000	1000.000000	1000.000000	1000.000000	1000.000000	1000.000000	1000.000000
mean	3.198658	-0.762727	0.550367	-0.873793	1.195856	-0.272612	-0.130996	-0.884949
std	0.809518	0.242217	0.253704	0.331019	0.368733	0.255425	0.269881	0.360904
min	1.008744	-1.553868	-0.155640	-2.179475	0.302933	-1.204325	-1.027105	-2.258104
25%	2.607475	-0.912981	0.371793	-1.077172	0.923517	-0.423956	-0.310939	-1.102170
50%	3.141616	-0.749497	0.537789	-0.843910	1.163639	-0.256563	-0.115827	-0.863040
75%	3.701715	-0.591140	0.721689	-0.630434	1.437751	-0.110544	0.049115	-0.619941
max	6.568467	-0.130614	1.558176	-0.094866	2.794897	0.407353	0.780389	-0.010803

227451

	Time	V1	V2	V3	V4	V5	V6	V7
count	227057.000000	227057.000000	227057.000000	227057.000000	227057.000000	227057.000000	227057.000000	227057.000000
mean	3.218182	-0.756782	0.545352	-0.866097	1.202468	-0.291984	-0.135337	-0.896145
std	0.811016	0.237066	0.248467	0.324762	0.375655	0.256962	0.262601	0.354981
min	0.864484	-2.054668	-0.467559	-3.083328	-0.161810	-1.679709	-1.472434	-2.770730
25%	2.637128	-0.907640	0.373894	-1.067587	0.936952	-0.454703	-0.305321	-1.119700
50%	3.155144	-0.741693	0.535582	-0.835388	1.177741	-0.278191	-0.129604	-0.866557
75%	3.728471	-0.590163	0.706314	-0.633782	1.443069	-0.115094	0.040692	-0.641359
max	8.098510	0.093333	1.781384	0.096544	3.173466	0.693545	1.145589	0.370842

The fraud in x_train

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	Time	V1	V2	V3	V4	V5	V6	V7
count	394.000000	394.000000	394.000000	394.000000	394.000000	394.000000	394.000000	394.000000
mean	23.008938	-4.707808	3.588729	-7.068378	4.592975	-3.101629	-1.387192	-5.539909
std	13.347935	6.841390	4.309436	7.166449	2.883467	5.406586	1.864770	7.316745
min	1.239444	-30.552380	-8.402154	-31.103685	-1.313275	-22.105532	-5.773192	-43.557242
25%	11.500278	-5.996596	1.229209	-8.436924	2.419178	-4.741036	-2.504633	-7.765017
50%	21.393056	-2.272114	2.662472	-5.133485	4.258196	-1.522962	-1.421577	-2.926216
75%	35.912917	-0.410418	4.737900	-2.302626	6.390866	0.240184	-0.361122	-0.900824
max	47.318889	2.132386	22.057729	2.250210	12.114672	11.095089	6.474115	5.802537

The little std observed in the GAN generated data indicates **mode collapse** in vanilla gan

Base ROS from Original data Normal: 227451 Fraud: 227451	Add GAN 1000 then ros.fit Normal: 227451 Fraud: 227451	GAN 227057 Normal: 227451 Fraud: 227451
Accuracy: 0.9994908886626171 Precision: 0.8556701030927835 Recall: 0.8469387755102041 F1 score: 0.8512820512820514 ROC AUC score: 0.923346287023532	Accuracy: 0.9995084442259752 Precision: **0.8645833333333334** Recall: 0.8469387755102041 F1 score: 0.8556701030927835 ROC AUC score: 0.9233550799329299	Accuracy: 0.9995435553526912 Precision: 0.9 Recall: 0.826530612244898 F1 score: 0.8617021276595744 ROC AUC score: 0.9131861699378682

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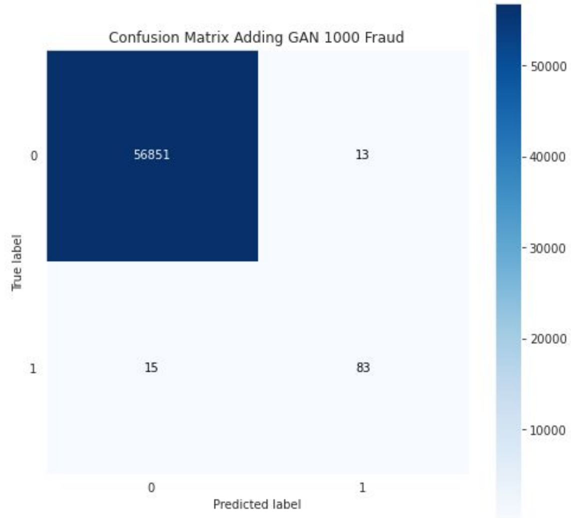

GAN didn't really improve much of the performance of the classification model for now, we think this is because the generator is only producing low spectrum data. We will work on a few improved GAN algorithms to see if the problems are resolved.

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10/05/2020

WGAN development: Hao

Why WGAN:

- Prevent mode collapse and gradient vanishing in vanilla GAN.
- Evaluate the difference between real and generated samples with wasserstein distance, using a score rather than label.

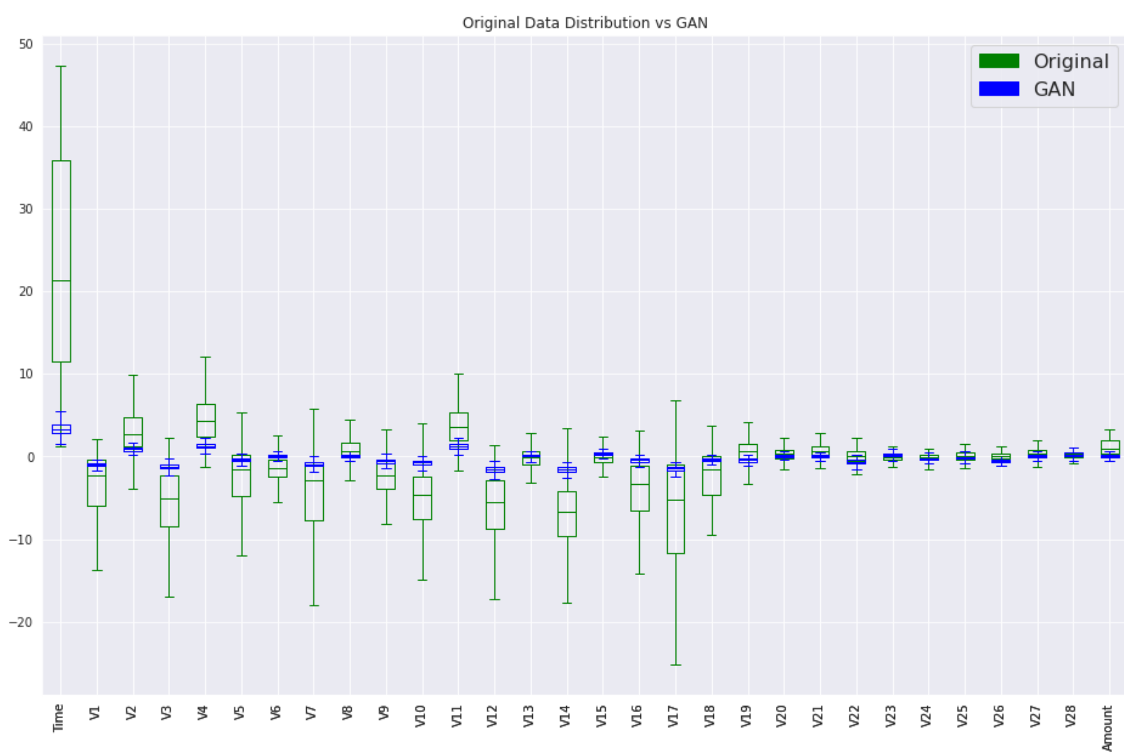
Implementation in Keras, compared to vanilla GAN:

- Loss function, no log
- D: no sigmoid
- Clip the weight of D (-c,c), if w>c, w=c, if w<-c, w=-c
- Use RMSProp
- Train D more than G

Training Parameters: RMSprop(lr=0.00001), batch_size=128, train D twice

Generate 1000 'Fraud', visually compare the data distribution using boxplot:

- GAN has very narrow spectrum of data distribution
- WGAN shows a wider distribution and close to the original data distribution
    - Good overlapping with the original distribution



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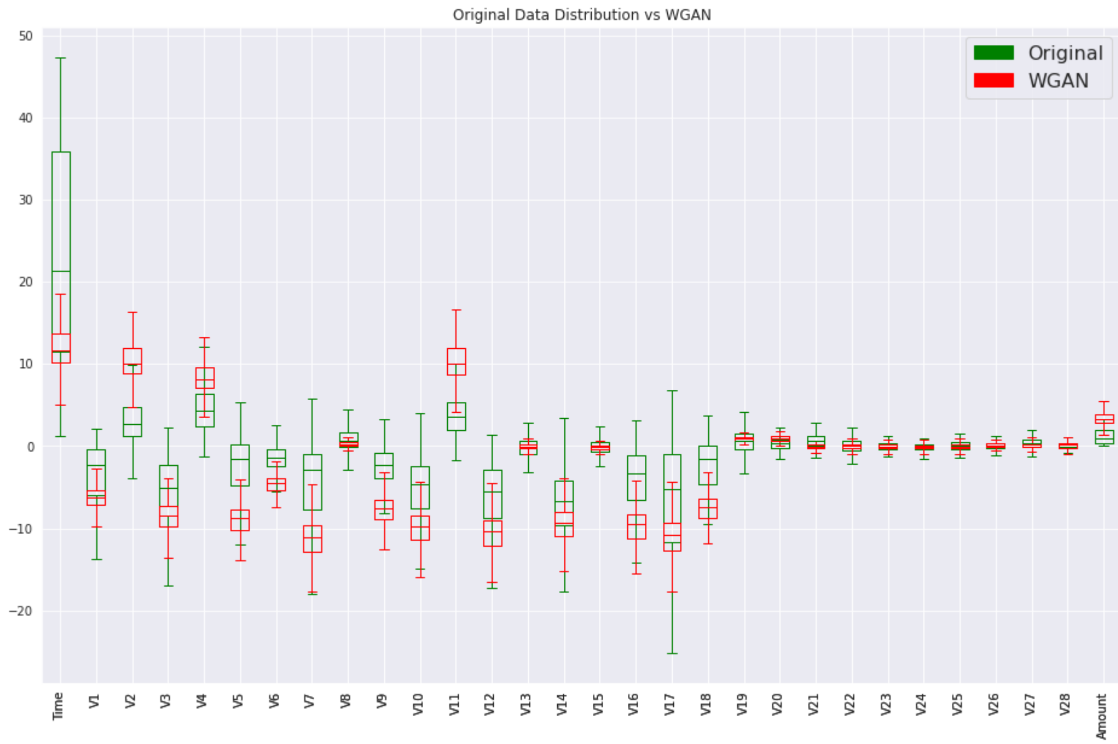


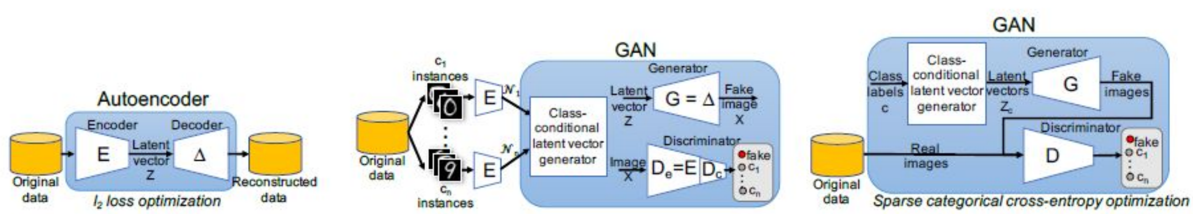
BAGAN development: JUN

Why BAGAN:

- It is an augmentation tool to restore the dataset balance by generating new minority-class data.
- It can learn the underlying features of the specific classification problem starting from all data and then to apply these features for the generation of new minority-class data.

Compared to original GAN:

- Discriminator has a single output that returns either a problem-specific class label c or the label fake.
- Coupling GAN and autoencoding techniques to provide a precise selection of the class conditioning and to better avoid mode collapse.



(a) Autoencoder training. (b) GAN initialization. (c) GAN training.

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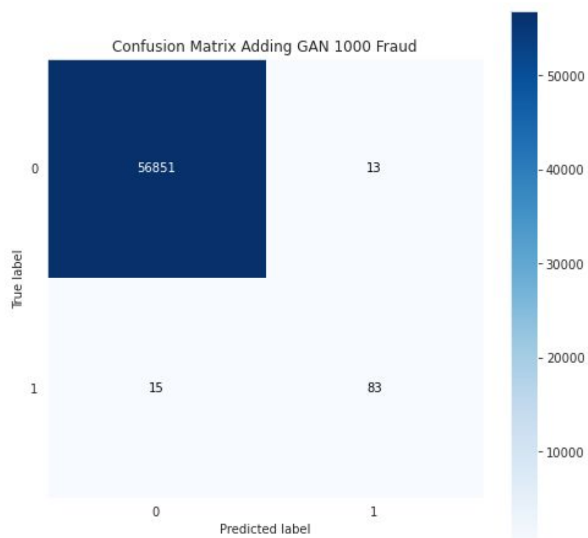
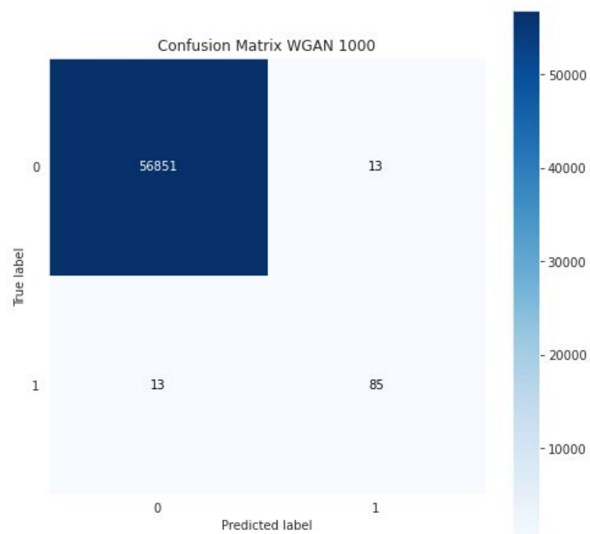
10/12/2020

WGAN performance evaluation: Hao

Obvious improvement on model performance

Base ROS from Original data Normal: 227451 Fraud: 227451	Add GAN 1000 then ros.fit Normal: 227451 Fraud: 227451	Add WGAN 1000 then ros.fit Normal: 227451 Fraud: 227451
Accuracy: 0.9994908886626171 Precision: 0.8556701030927835 Recall: 0.8469387755102041 F1 score: 0.8512820512820514 ROC AUC score: 0.923346287023532	Accuracy: 0.9995084442259752 Precision: 0.8645833333333334 Recall: 0.8469387755102041 F1 score: 0.8556701030927835 ROC AUC score: 0.9233550799329299	**Accuracy:** **0.9995435553526912** **Precision:** **0.8673469387755102** **Recall:** **0.8673469387755102** **F1 score:** **0.8673469387755102** **ROC AUC score:** **0.9335591615655828**





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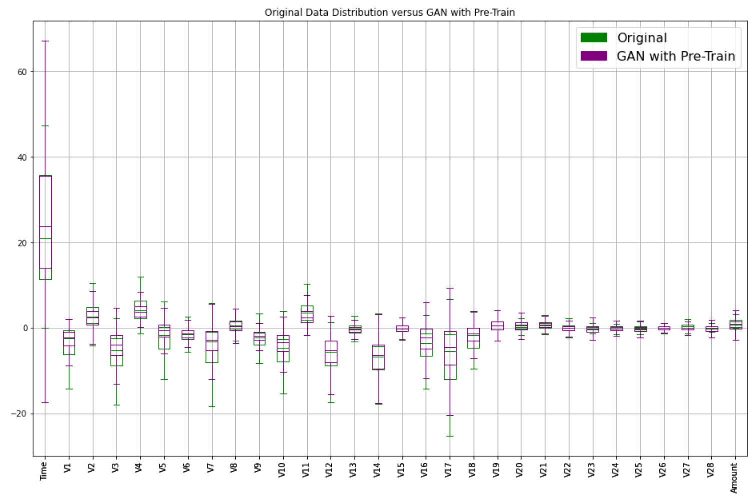
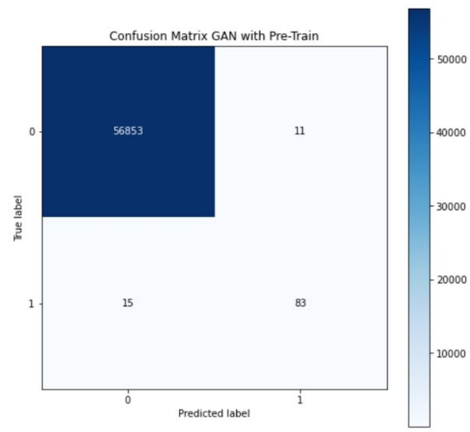
GAN with Pre-Train Performance : JUN

Better than Original GAN, slightly worse than WGAN, adding 1000 generated fraud
Wider spectrum of data & Overlap well with the original data





	GAN	GAN + AE
Accuracy	**0.999508**	**0.999544**
Precision	**0.864583**	**0.882979**
Recall	**0.846939**	**0.846939**
F1 score	**0.855670**	**0.864583**
ROC AUC score	**0.923355**	**0.923373**

Preliminary Presentation

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10/19/2020

WGAN_GP development: Hao

Why WGAN_GP:

- WGAN weight clipping does not strictly fullil the 1-Lipschitz function requirement
  $$|f(x_1) - f(x_2)| \leq K|x_1 - x_2|.$$
  K =1, is 1-Lipschitz function, it has strong uniform continuity
- A differentiable function is 1-Lipschitz if and only if it has gradients with **norm at most 1 everywhere**
- WGAN_GP constrain the weight more effectively

Note: batch normalization is already removed, so we don’t need to do anything here

Changes compared to WGAN

- Gradient penalty
  $$\underbrace{\lambda \underset{\hat{\boldsymbol{x}} \sim \mathbb{P}_{\hat{\boldsymbol{x}}}}{\mathbb{E}} \left[(\|\nabla_{\hat{\boldsymbol{x}}} D(\hat{\boldsymbol{x}})\|_2 - 1)^2 \right].}_{\text{Our gradient penalty}}$$
- Adam optimizer

Training Parameters: ADAM(lr=0.00001), batch_size=128, gp_lambda=5

Generate 1000 ‘Fraud’, visually compare the data distribution using boxplot:

- Wider range and better overlaps with original data compared to WGAN

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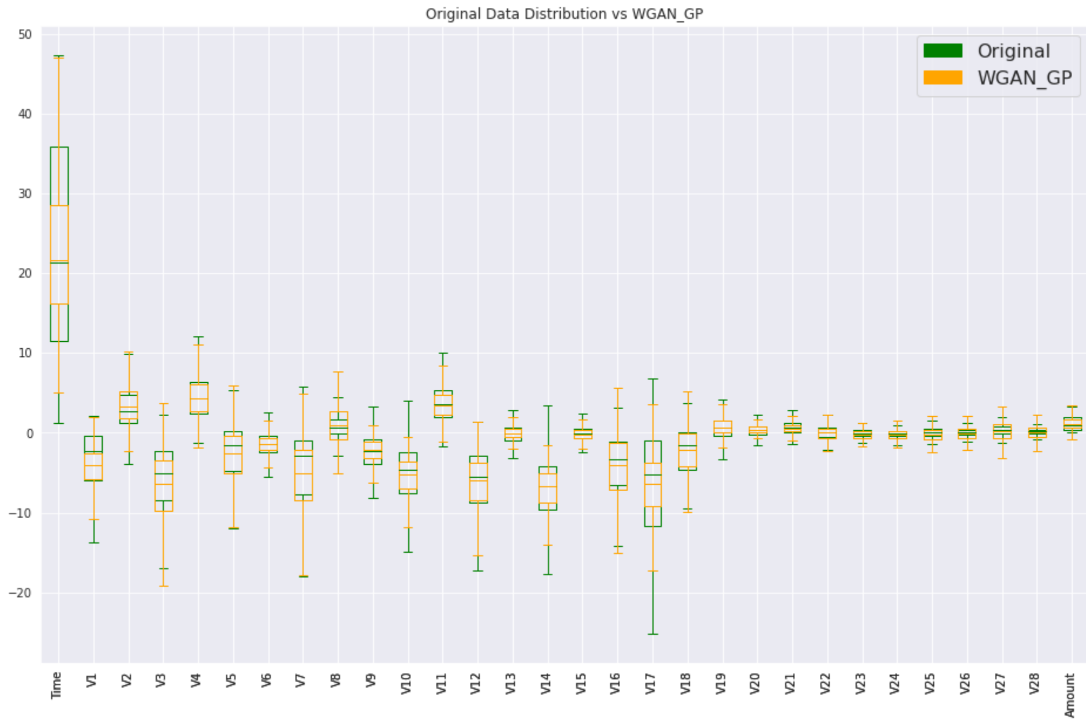

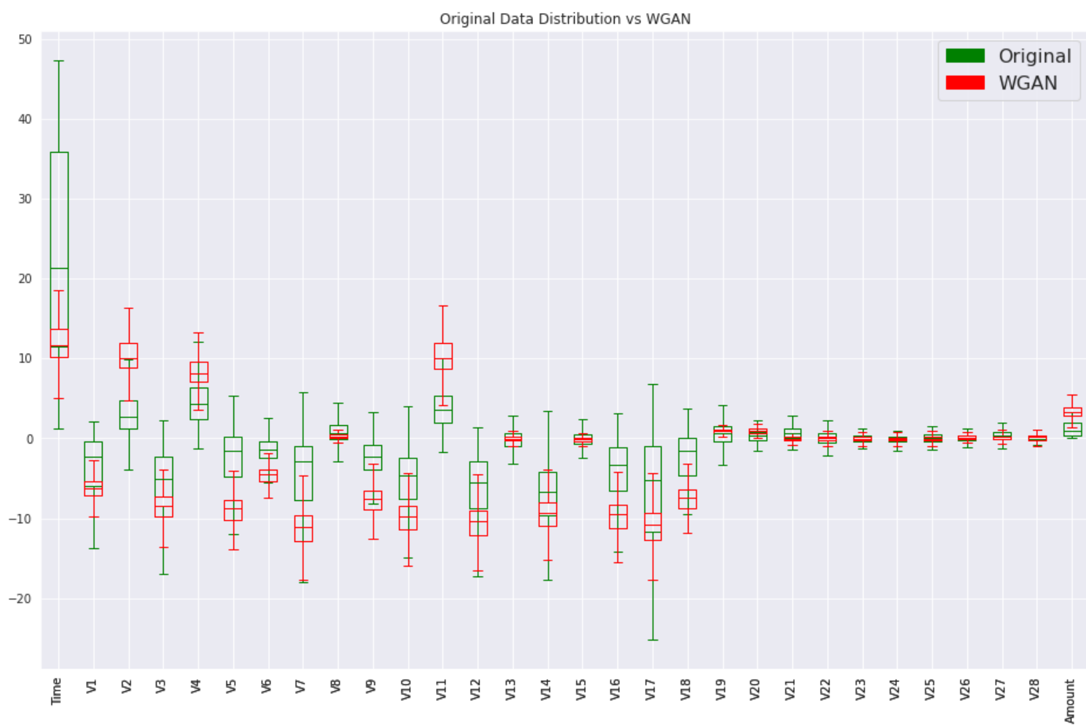

BEGAN development: Jun

Why BEGAN:

- a novel equilibrium method for balancing adversarial networks
- using an autoencoder as the discriminator
- using a variable kt∈ [0, 1] to control equilibrium(kt is adjusted at each step)

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$$\begin{cases} \mathcal{L}_D = \mathcal{L}(x) - k_t.\mathcal{L}(G(z_D)) & \text{for } \theta_D \\ \mathcal{L}_G = \mathcal{L}(G(z_G)) & \text{for } \theta_G \\ k_{t+1} = k_t + \lambda_k(\gamma\mathcal{L}(x) - \mathcal{L}(G(z_G))) & \text{for each training step } t \end{cases}$$

Derive a global measure of convergence by using the equilibrium concept:

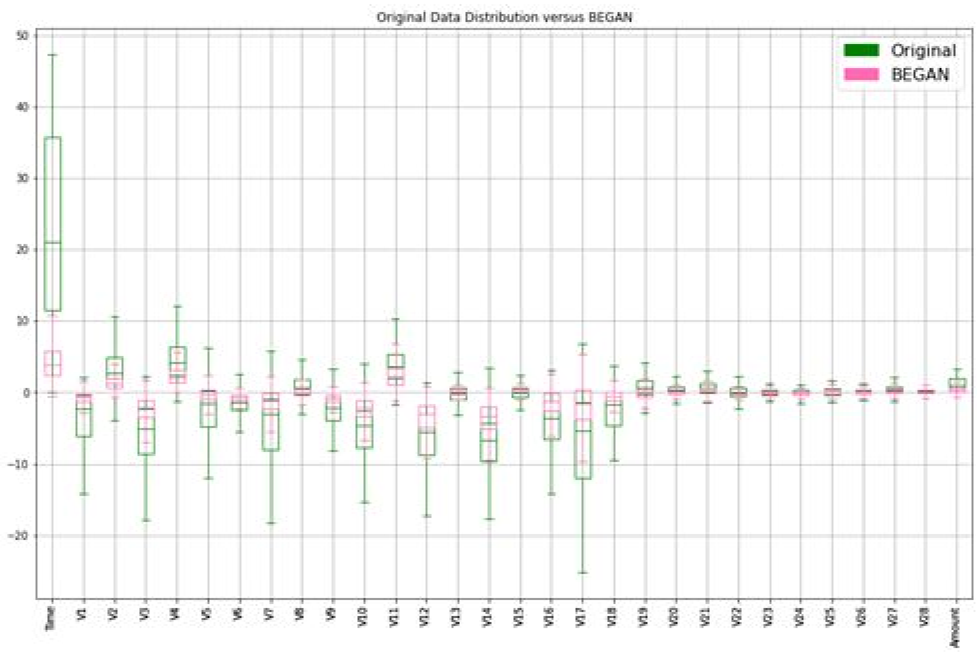
$$\mathcal{M}_{global} = \mathcal{L}(x) + |\gamma\mathcal{L}(x) - \mathcal{L}(G(z_G))|$$

This measure can be used to determine when the network has reached its final state or if the model has collapsed.

Training Parameters: ADAM(lr=0.0001), batch_size=128, gp_lambda=5

Generate 1000 'Fraud', visually compare the data distribution using boxplot:

- Although better than the basic GAN, it does not overlap with the dataset well.
- There are cases where Time or Amount is less than 0.



Future work

- Fix and improve the loss function
- Adjustment parameters

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10/26/2020

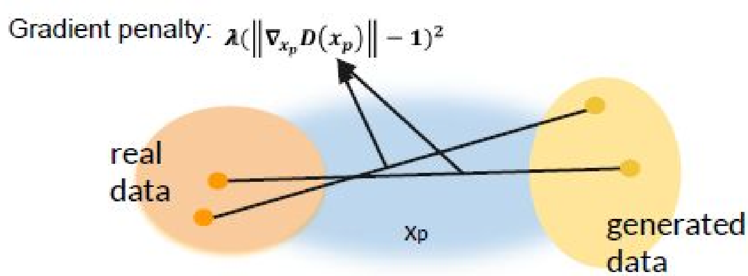
WGAN_GP performance evaluation: Hao

Interpolated part explanation

```
def gradient_penalty(self, batch_size, real_data, fake_data):
    """ Calculates the gradient penalty.
    This loss is calculated on an interpolated data
    and added to the discriminator loss.
    """
    # get the interplated image
    alpha = tf.random.normal([batch_size, 1, 1, 1], 0.0, 1.0)
    diff = fake_data - real_data
    interpolated = real_data + alpha * diff
```

The points interpolated between real and generated data should have a gradient norm of 1.

It's hard to get gradients with norm at most 1 everywhere, so we interpolate between real and generated samples. Instead of applying clipping, WGAN-GP applies a penalty if the gradient norm moves away from its target norm value 1.



Obvious further improvement on model performance with WGAN_GP, best model

	Base	GAN	WGAN	WGAN_GP
Accuracy	0.999491	0.999491	0.999544	**0.999596**
Precision	0.855670	0.864583	0.867347	**0.894737**
Recall	0.846939	0.846939	0.867347	**0.867347**
F1 score	0.851282	0.855670	0.867347	**0.880829**
ROC AUC score	0.923346	0.923355	0.933559	**0.933586**

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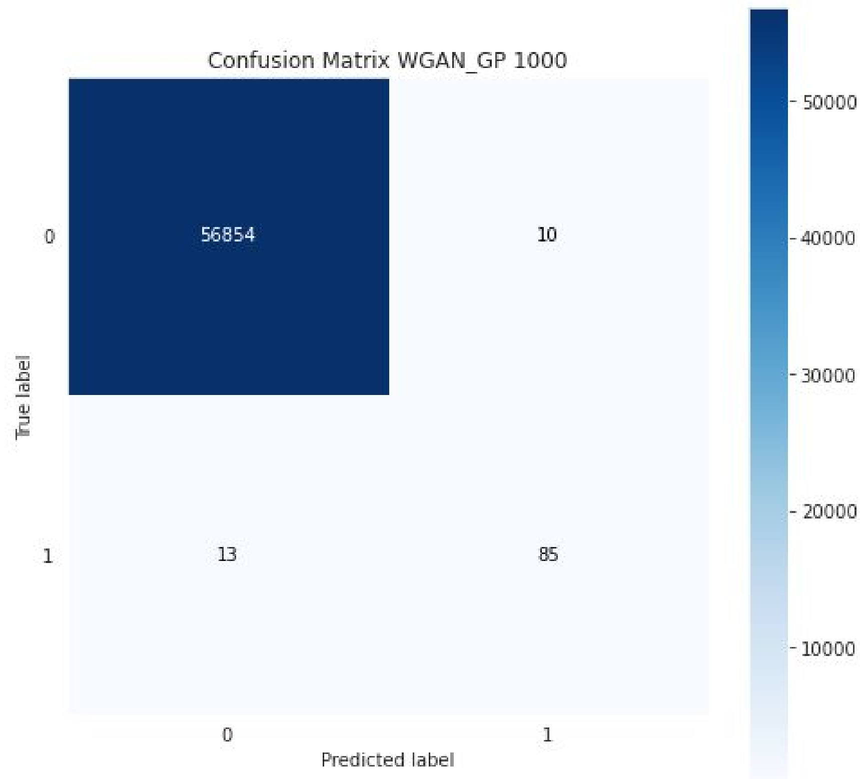

BEGAN performance evaluation: Jun

Discriminator: Autoencoder (Encoder + Decoder)
Generator: Decoder
Loss Function:

$$\begin{cases} \mathcal{L}_D = \mathcal{L}(x) - k_t.\mathcal{L}(G(z_D)) & \text{for } \theta_D \\ \mathcal{L}_G = \mathcal{L}(G(z_G)) & \text{for } \theta_G \\ k_{t+1} = k_t + \lambda_k(\gamma\mathcal{L}(x) - \mathcal{L}(G(z_G))) & \text{for each training step } t \end{cases}$$

$$\mathcal{M}_{global} = \mathcal{L}(x) + |\gamma\mathcal{L}(x) - \mathcal{L}(G(z_G))|$$

This measure can be used to determine when the network has reached its final state or if the model has collapsed.

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K∈[0,1]

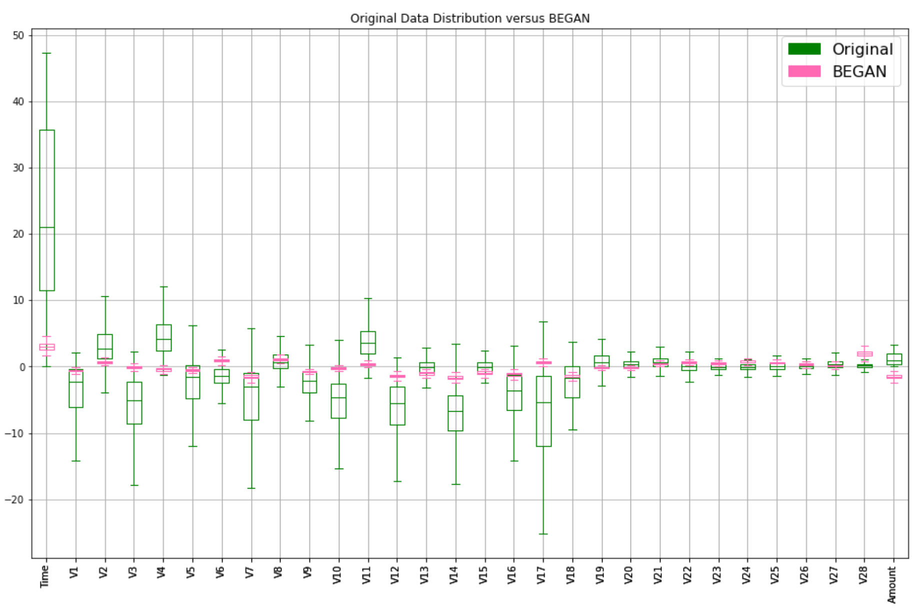
k=1e-05

```
EPOCH #  20 ---------------------------------------------------
Steps (10 / 100): [loss_D: 23.763582] [Loss_G: 5191.047363] [M_global: 5191.140451]
Steps (20 / 100): [loss_D: 23.283887] [Loss_G: 5037.947266] [M_global: 5038.038371]
Steps (30 / 100): [loss_D: 20.021150] [Loss_G: 5360.807129] [M_global: 5360.880726]
Steps (40 / 100): [loss_D: 19.312572] [Loss_G: 5416.488770] [M_global: 5416.558218]
Steps (50 / 100): [loss_D: 21.133590] [Loss_G: 5494.187012] [M_global: 5494.264138]
Steps (60 / 100): [loss_D: 21.643043] [Loss_G: 5638.911621] [M_global: 5638.991511]
Steps (70 / 100): [loss_D: 20.518601] [Loss_G: 5681.296387] [M_global: 5681.370212]
Steps (80 / 100): [loss_D: 19.534069] [Loss_G: 5762.511230] [M_global: 5762.579990]
Steps (90 / 100): [loss_D: 21.824670] [Loss_G: 5780.583496] [M_global: 5780.663860]
Steps (100 / 100): [loss_D: 19.115582] [Loss_G: 6058.291992] [M_global: 6058.358950]
```

	Time
count	1000.000000
mean	45316.074219
std	9665.684570
min	18976.361328
25%	38610.062500
50%	45014.445312
75%	51699.350586
max	78984.054688

k=1

	Time
count	1000.000000
mean	2.994987
std	0.581427
min	1.631465
25%	2.582442
50%	2.933775
75%	3.378483
max	5.222883



k=0.08

```
EPOCH #  20 ---------------------------------------------------
Steps (10 / 100): [loss_D: 23.402295] [Loss_G: 0.590853] [M_global: 0.687436]
Steps (20 / 100): [loss_D: 22.523965] [Loss_G: 0.568527] [M_global: 0.661421]
Steps (30 / 100): [loss_D: 22.351444] [Loss_G: 0.538081] [M_global: 0.631413]
Steps (40 / 100): [loss_D: 21.146445] [Loss_G: 0.510166] [M_global: 0.598388]
Steps (50 / 100): [loss_D: 22.483769] [Loss_G: 0.456806] [M_global: 0.552923]

Steps (60 / 100): [loss_D: 22.652090] [Loss_G: 0.423857] [M_global: 0.522124]
Steps (70 / 100): [loss_D: 24.288411] [Loss_G: 0.413211] [M_global: 0.520235]
Steps (80 / 100): [loss_D: 24.751768] [Loss_G: 0.415951] [M_global: 0.524934]
Steps (90 / 100): [loss_D: 22.647221] [Loss_G: 0.456992] [M_global: 0.554145]
Steps (100 / 100): [loss_D: 23.766275] [Loss_G: 0.482337] [M_global: 0.584548]
```

	Time
count	1000.000000
mean	5.871967
std	1.094325
min	3.122333
25%	5.059084
50%	5.770874
75%	6.568066
max	9.851136

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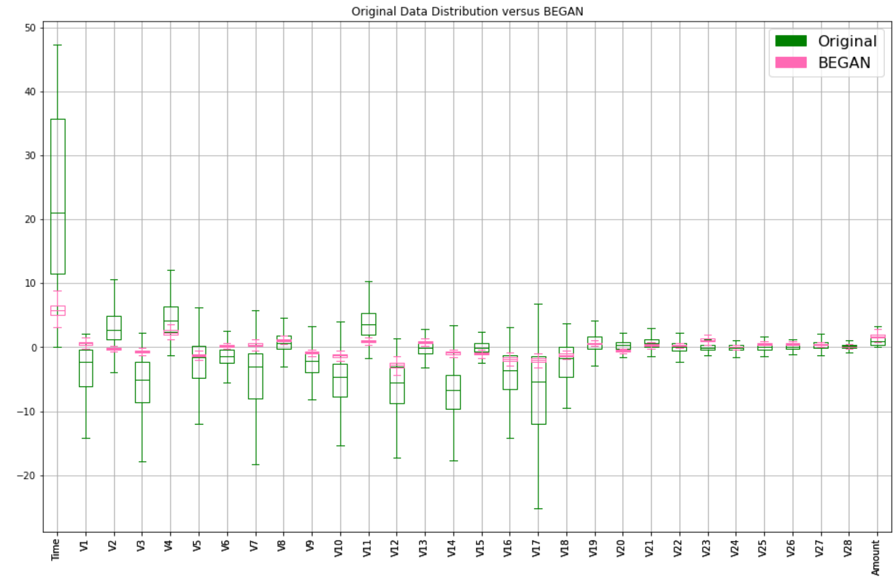
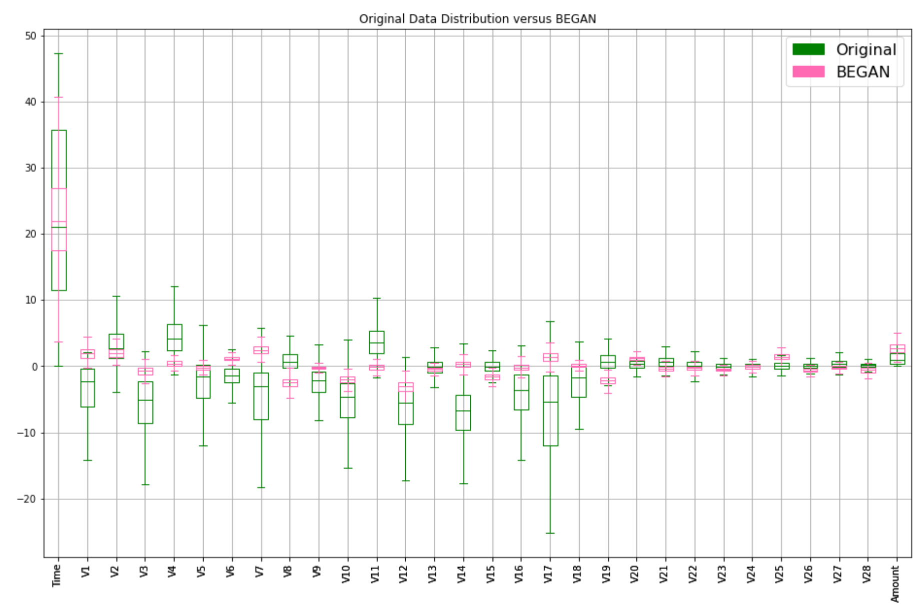


k=0.06, batch_size=64 (previous batch_size=128)

```
EPOCH #  20 -------------------------------------------------
Steps (10 / 100): [loss_D: 32.496956] [Loss_G: 0.655205] [M_global: 0.800755]
Steps (20 / 100): [loss_D: 34.503347] [Loss_G: 0.678137] [M_global: 0.832440]
Steps (30 / 100): [loss_D: 33.328989] [Loss_G: 0.632807] [M_global: 0.782633]
Steps (40 / 100): [loss_D: 29.965913] [Loss_G: 0.706928] [M_global: 0.838931]
Steps (50 / 100): [loss_D: 34.334496] [Loss_G: 0.707514] [M_global: 0.860885]

Steps (60 / 100): [loss_D: 35.896397] [Loss_G: 0.728146] [M_global: 0.888655]
Steps (70 / 100): [loss_D: 34.635094] [Loss_G: 0.777039] [M_global: 0.930192]
Steps (80 / 100): [loss_D: 31.677556] [Loss_G: 0.797459] [M_global: 0.935513]
Steps (90 / 100): [loss_D: 32.950023] [Loss_G: 0.815464] [M_global: 0.959829]
Steps (100 / 100): [loss_D: 33.079243] [Loss_G: 0.865222] [M_global: 1.008930]
```

	Time
count	1000.000000
mean	22.586197
std	7.067127
min	3.769392
25%	17.571802
50%	21.885234
75%	26.850739
max	52.663231



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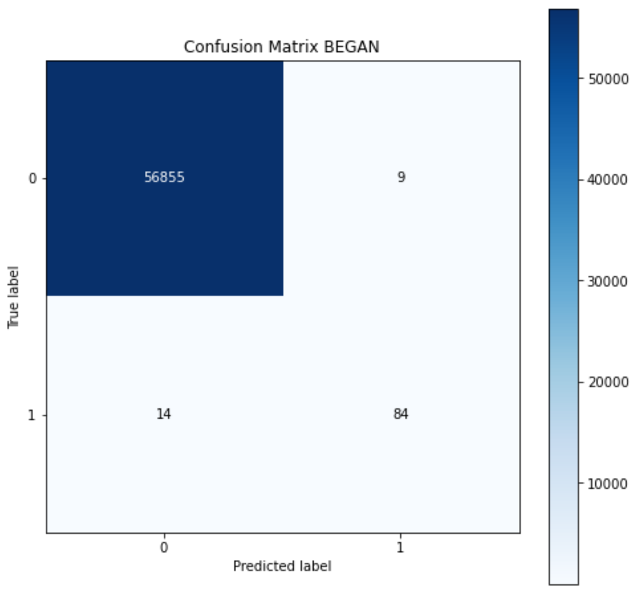
	Base	GAN	BEGAN
Accuracy	0.999491	0.999491	**0.999596**
Precision	0.855670	0.864583	**0.903226**
Recall	0.846939	0.846939	**0.857143**
F1 score	0.851282	0.855670	**0.879581**
ROC AUC score	0.923346	0.923355	**0.928492**



6501 Progress Report Group 4

11/02/2020

Final Report in progress
Github in progress

Result Summary

	Base	GAN	WGAN	WGAN_GP	GAN + AE	BEGAN
Accuracy	0.999491	0.999491	0.999544	**0.999596**	0.999544	**0.999596**
Precision	0.855670	0.864583	0.867347	**0.894737**	0.882979	**0.903226**
Recall	0.846939	0.846939	**0.867347**	**0.867347**	0.846939	**0.857143**
F1 score	0.851282	0.855670	0.867347	**0.880829**	0.864583	**0.879581**
ROC AUC score	0.923346	0.923355	0.933559	**0.933586**	0.923373	**0.928492**

Best Model for credit card fraud detection:
We can't only look at numbers for real world problems.

WGAN_GP vs BEGAN

- Both around 0.88 F1 score, WGAN_GP slightly higher F1
- WGAN_GP high recall (low FN), BEGAN high precision (low FP)
- In fraud detection(similarly sick patient detection, risk detection etc.), the cost of FN vs FP will help us understand the model performance in real life.

Is time biased? PCA time

6501 Progress Report Group 4

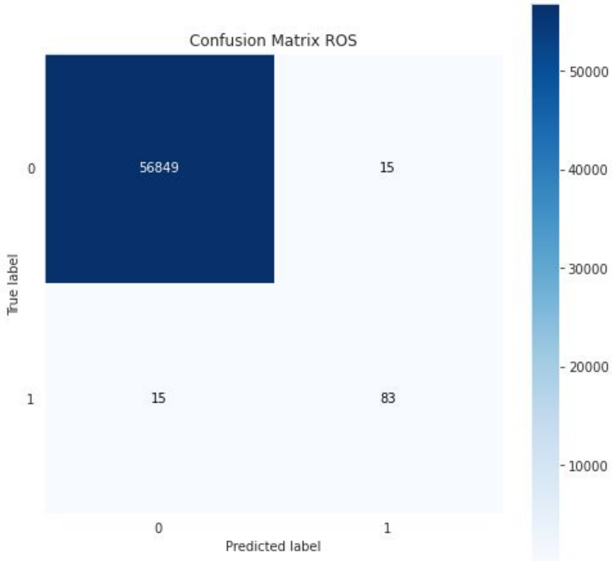
11/09/2020

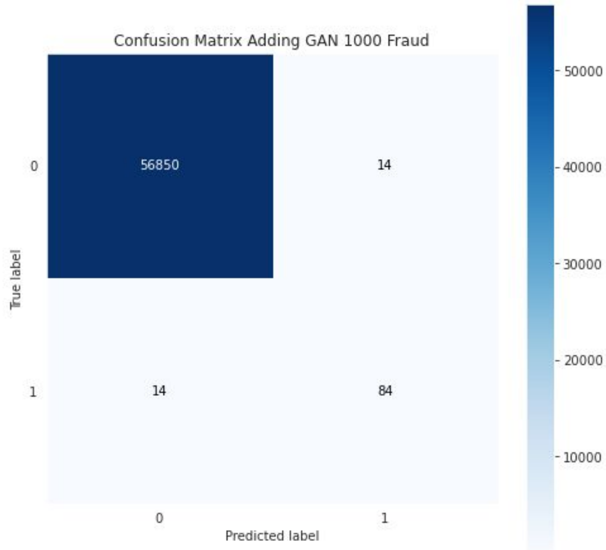
Hao:
Perform PCA for time, then train all models
Same trend as keep time as original, increasingly better performance with improved GANs
Original:

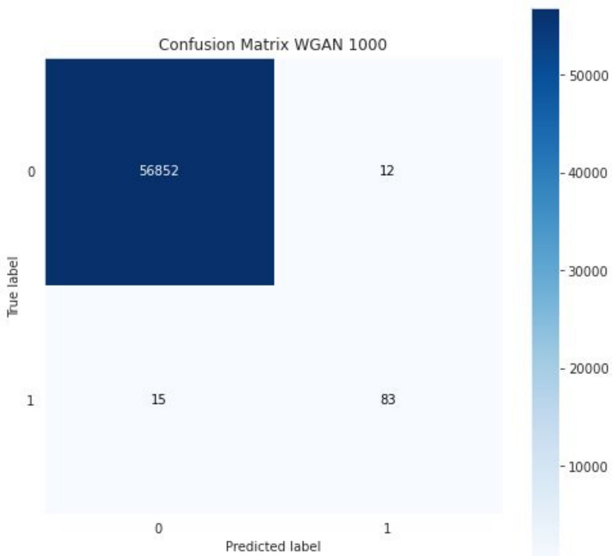
	Base	GAN	WGAN	WGAN_GP
Accuracy	0.999491	0.999491	0.999544	**0.999596**
Precision	0.855670	0.864583	0.867347	**0.894737**
Recall	0.846939	0.846939	0.867347	**0.867347**
F1 score	0.851282	0.855670	0.867347	**0.880829**
ROC AUC score	0.923346	0.923355	0.933559	**0.933586**

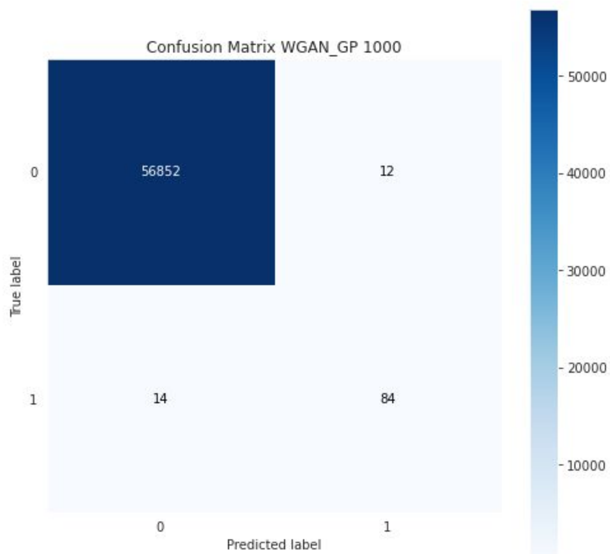
Time PCA

	Base	GAN	WGAN	WGAN_GP
Accuracy	0.999473	0.999508	0.999526	**0.999544**
Precision	0.846939	0.857143	0.873684	**0.875000**
Recall	0.846939	0.857143	0.846939	**0.857143**
F1 score	0.846939	0.857143	0.860104	**0.865979**
ROC AUC score	0.923337	0.928448	0.923364	**0.928466**


Confusion Matrix ROS
56849
15
15
83
True label
Predicted label
0
1
0
1
50000
40000
30000
20000
10000

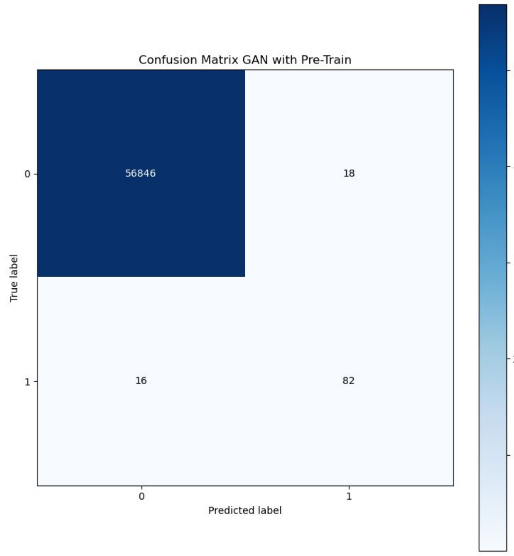

Confusion Matrix Adding GAN 1000 Fraud
56850
14
14
84
True label
Predicted label
0
1
0
1
50000
40000
30000
20000
10000

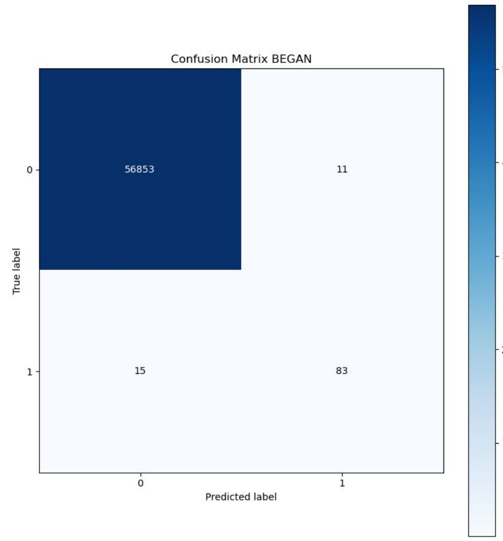

Confusion Matrix WGAN 1000
56852
12
15
83
True label
Predicted label
0
1
0
1
50000
40000
30000
20000
10000


Confusion Matrix WGAN_GP 1000
56852
12
14
84
True label
Predicted label
0
1
0
1
50000
40000
30000
20000
10000

6501 Progress Report Group 4

Jun:
Using the previous model, only use PCA at the classification part.

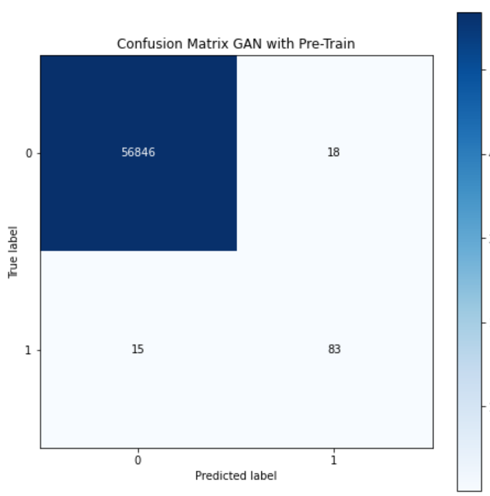


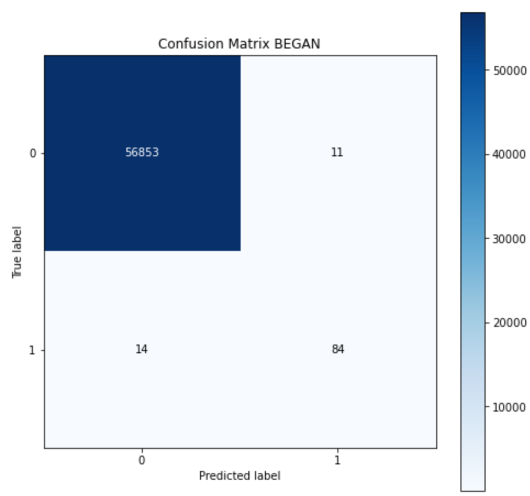


Accuracy: 0.999403110845827
Precision: 0.82
Recall: 0.8367346938775511
F1 score: 0.8282828282828283
ROC AUC score: 0.9182090745696141

Accuracy: 0.9995435553526912
Precision: 0.8829787234042553
Recall: 0.8469387755102041
F1 score: 0.8645833333333334
ROC AUC score: 0.9233726657517257

Using PCA transform the dataset, then train GAN and classification.





6501 Progress Report Group 4

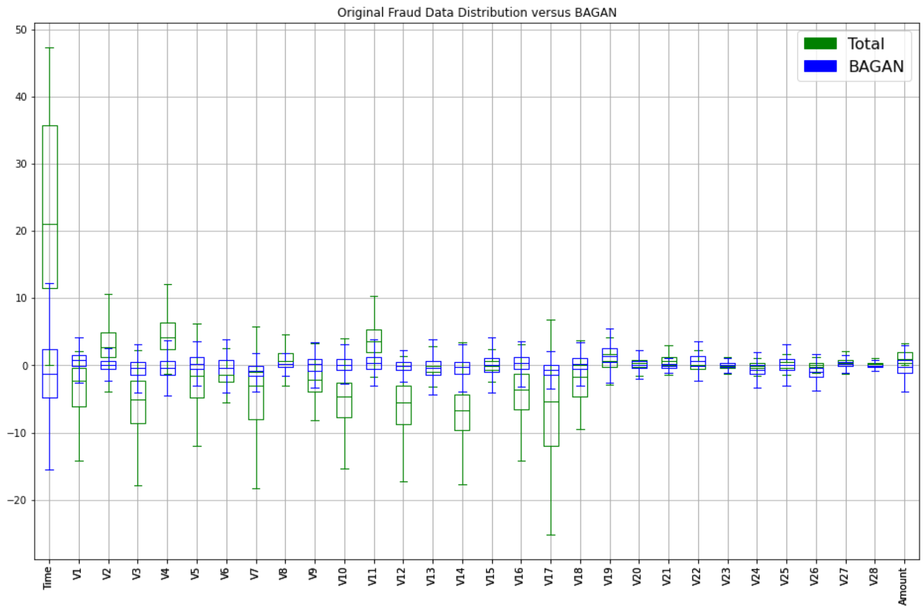
	GAN + AE PCA	GAN + AE	BEGAN PCA	BEGAN
Accuracy	0.999421	0.999544	0.999561	**0.999596**
Precision	0.821782	0.882979	0.884211	**0.903226**
Recall	0.846939	0.846939	0.857143	0.857143
F1 score	0.834171	0.864583	0.870466	**0.879581**
ROC AUC score	0.923311	0.923373	0.928475	**0.928492**

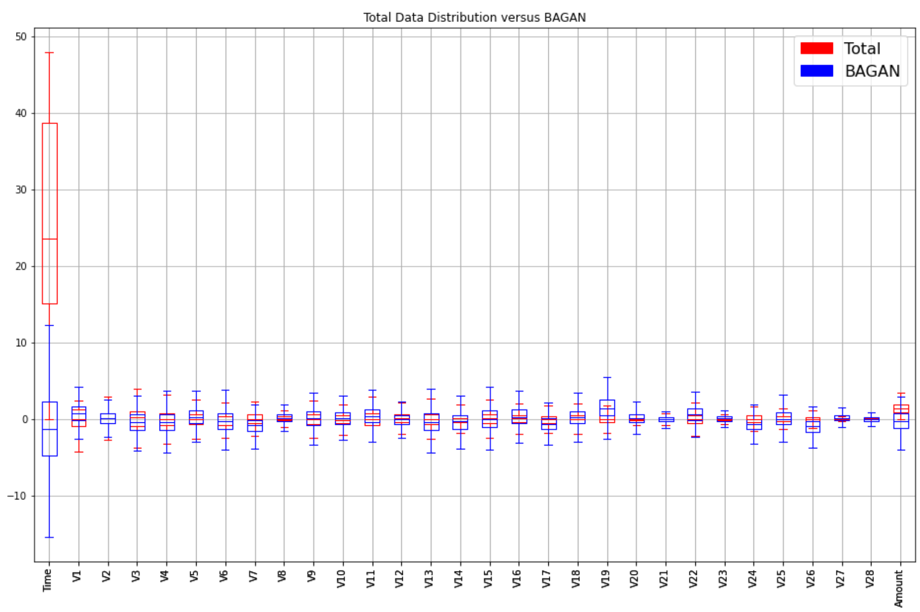
Conclusion:
No need to worry about the time feature, so we will keep it the way before.

6501 Progress Report Group 4

11/16/2020

About BAGAN:





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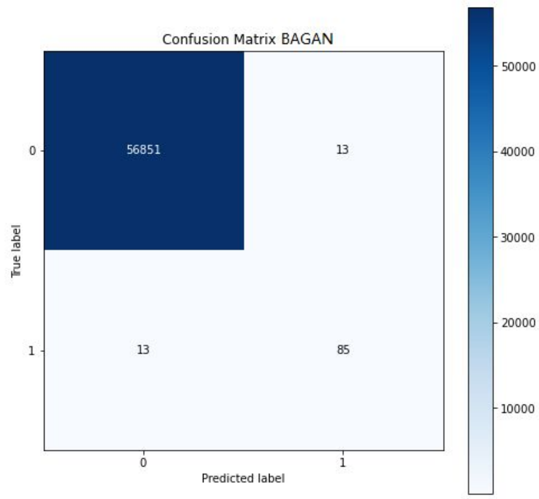

	Base	GAN	WGAN	WGAN_GP	GAN + AE	BEGAN	BAGAN
Accuracy	0.999491	0.999491	0.999544	**0.999596**	0.999544	**0.999596**	0.999544
Precision	0.855670	0.864583	0.867347	**0.894737**	0.882979	**0.903226**	0.867347
Recall	0.846939	0.846939	0.867347	**0.867347**	0.846939	**0.857143**	0.867347
F1 score	0.851282	0.855670	0.867347	**0.880829**	0.864583	**0.879581**	0.867347
ROC AUC score	0.923346	0.923355	0.933559	**0.933586**	0.923373	**0.928492**	0.933559

Final report
Paper script in progress

Financial knowledge research:
Different misclassification importance:
In fraud detection task, different misclassification
Misclassification of a normal transaction (FP) as fraud is not as harmful as detecting a fraud transaction as normal (FN). Because in the first case the mistake in classification will be identified in further investigations.

FN: direct loss
FP: customer volume & reputational damage, revenue losses

Fraud detection cost:
The system should take into account both the cost of fraudulent behavior that is detected and the cost of preventing it.

6501 Progress Report Group 4

11/23/2020-

Recording
Finalize paper draft & submission
Final representation