Cmpe 597 HW2

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1 Handwritten Digit Generation with VAE

1.1 Training

The model has been trained for 60 epochs. The behavior of KL divergence loss did not change much over the epochs. BCE converged in the 10th epoch. After the 10th epoch, model learning stopped. When we look at the images generated from random vectors in 2, the reason for this behavior in model losses can be explained. VAE has always generated the number 8. The reason why KL divergence remains stable and training does not progress after a point is due to underfit.

Note : The regularization term coefficient in KL divergence is 0.01.

1.2 Generation

As noted in the comments to the Loss functions, the VAE consistently produced the number 8 in random vectors. There is an underfitting here. The reasons for this may be that the size of the latent space is short and the encoder consists of a single layer LSTM module. The encoder can be made into a more complex model for better quality and diverse image production.

2 Handwritten Digit Generation with GAN

2.1 Loss function

From 3 to 8, the loss function of generator/discriminator of GAN and WGAN is shown.[lye19][Kha21]

- WGAN's loss plots are more stable than GAN.
- As expected, the loss values of the GAN were very sensitive to the complexity of the generator. As the generator complexity increased, the loss values behaved more stable and converged more quickly.
- WGAN is not affected by the complexity of the generator. Convergence was around the 25th epoch in all three experiments and loss values showed a stable behavior in all three experiments.

2.2 Generation

- Qualitative Performance : Qualitative analysis is a subjective analysis and is done with the help of human annotators.
  - The worst performing model is the GAN model. Except for the Weak GAN model, the images generated by other GAN models do not make any sense.
  - It can be understood that the images generated by the VAE model are 8, but the same image is always generated. For this reason, the VAE is the second best model.
  - The WGAN model is the best model for qualitative analysis. It is definitely better than VAE and GAN in terms of diversity and image quality in image generation. However, some generated numbers are difficult to understand.

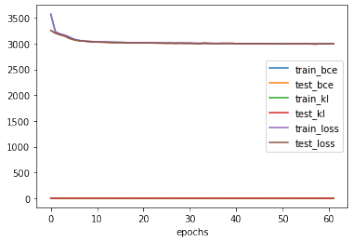

Figure 1: Line Plots of VAE model's Cross Entropy Loss and KL Divergence over Training Epoch

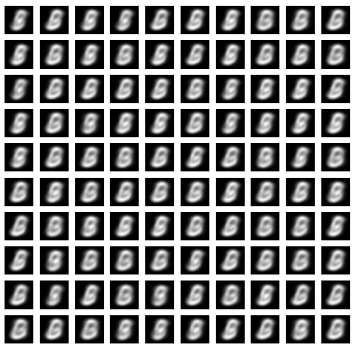

Figure 2: Generated Images from trained VAE model

- Quantitative Performance: Inception score was used in this analysis. The inception score tables of these models are as follows.
  - According to these results, the best model is the WGAN model, but there is not much difference between the GAN, WGAN and VAE results. As expected, the GAN received the worst possible inception score. VAE and WGAN beat this score with very small values of 0.14 and 0.16. This shows that different images are not produced for different distributions. Again, this problem can be solved by increasing the size of the latent space.[Bro21]

Table 1: Inception scores of models

Model	**Inception Score**
GAN	1.0
WGAN	1.165
VAE	1.146

Necessary codes/models/images can be found at https://github.com/noeldar/cmpe-597-HW2

References

[Bro21] Jason Brownlee. How to Evaluate Generative Adversarial Networks. https://machinelearningmastery.com/how-to-evaluate-generative-adversarial-networks/, 2021.

[Kha21] Renu Khandelwal. How to improve image generation using Wasserstein GAN. https://medium.com/mlearning-ai/how-to-improve-image-generation-using-wasserstein-gan-1297f449ca75, 2021.

[lye19] lyeoni. Pytorch implementation of GAN(Generative Adversarial Networks) on the MNIST data set. https://github.com/lyeoni/pytorch-mnist-GAN/blob/master/pytorch-mnist-GAN.ipynb, 2019.

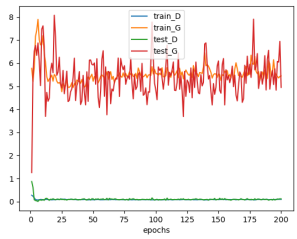

Figure 3: Line Plots of GAN model's loss of which generator has two layers

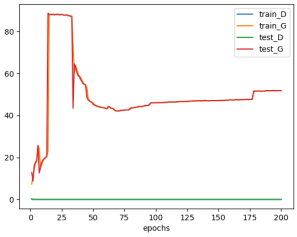

Figure 4: Line Plots of GAN model's loss of which generator has four layers

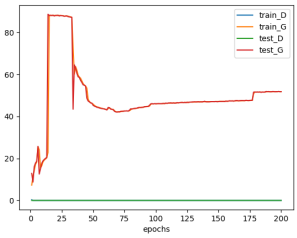

Figure 5: Line Plots of GAN model's loss of which generator has six layers

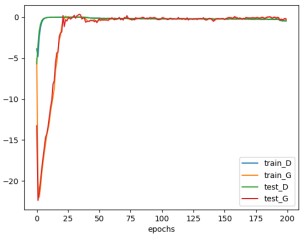

Figure 6: Line Plots of WGAN model's loss of which generator has two layers

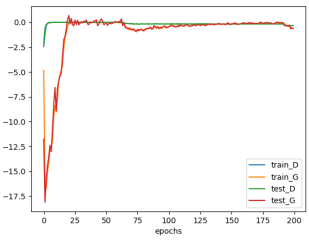

Figure 7: Line Plots of WGAN model's loss of which generator has two layers

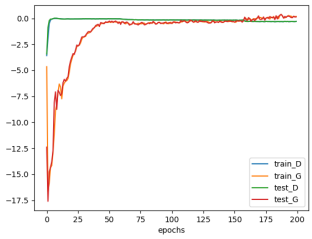

Figure 8: Line Plots of WGAN model's loss of which generator has two layers

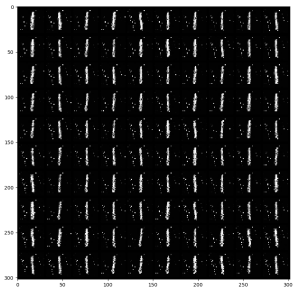

Figure 9: Generated Images of GAN model of which generator has two layers

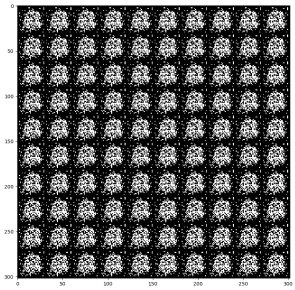

Figure 10: Generated Images of GAN model of which generator has four layers

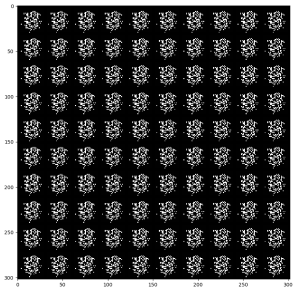

Figure 11: Generated Images of GAN model of which generator has six layers

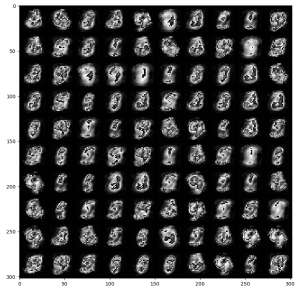

Figure 12: Generated Images of WGAN model of which generator has two layers

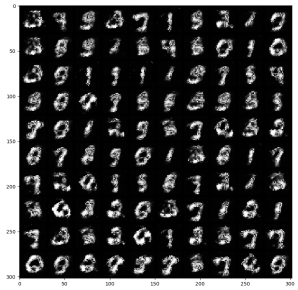

Figure 13: Generated Images of WGAN model of which generator has two layers

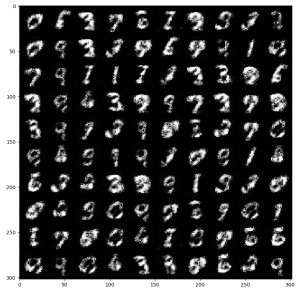

Figure 14: Generated Images of WGAN model of which generator has two layers