Capsule Networks as Discriminator and as Generator in Generative Adversarial Networks

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Abstract

We consider Generative Adversarial Networks that use capsule networks (CapsNets) as a discriminator, or as a generator or both as a generator and as a discriminator. We propose three differnt architecture of the CapGAN and empirically show that CapsuleGAN outperforms convolutional-GAN at modeling image data distribution on MNIST and CIFAR-10 datasets, evaluated at semi-supervised image classification

1 Introduction

Generative Adversarial Networks(GANs) [1] are a recent novel class of deep generative models which have received tremendous interest in recent times. GANs consist of two neural networks, generator and discriminator. The generator aims to generate samples that are close to real data, i.e., training samples while the discriminator tries to distinguish between real and generated samples. In the whole adversarial training process, the generator is expected to learn the distribution of data and be able to generate data as good as the real data. Among all the generative models, GANs generate he sharpest images. These GANs are based on the convolutonal neural networks. Convolutional neural networks(CNN) are the most popular neural networks when it comes to image data. Recently, authors in [2] emphasized some of the inherent flaws of CNNs, like CNN completely loses pose information of images, and proposed a new nerual network architecture called capsule networks to solve these issues. Empirically, they have shown that the capsule networks learns better than CNN with less amount of training samples.

In this work, we consider to combine these two approaches. We aim to improve the generative performance of a GAN network by using Capsule networks. We conduct extensive study on GAN architecture with capsule networks. Here, we consider three different architecture: 1. Capsule network as a discriminator, 2. Capsule network as a generator, 3. Capsule Networks as both generator and discriminator. We consider performance of convolutional neural network based GAN, which we call as convGAN[3] as the bench-mark performance and show that the GAN with capsule networks outperforms convGAN at modeling image data distribution on MNIST and CIFAR-10 datasets at semi-supervised image classification.

2 GAN architecture

In this section, we first present the convGAN network which we considered as the benchmark for performance comparison with the proposed capsule based GAN(capsGAN). We then present three different architectures of the capGANs that we considered in this work.

2.1 Convolutional GAN

Convolutional GAN is one of the most popular GAN which uses CNN as both generative and discriminative networks. We see in the Figure 1 that this GAN has two loss function. Loss function, L_S defines the adversarial training process while the loss function L_C defines the misclassification error. Mathematically,

$$L_S = \mathbb{E}[logP(S = real|X_{real})] + \mathbb{E}[logP(S = fake|X_{fake})]$$
$$L_C = \mathbb{E}[logP(C = c|X_{real})] + \mathbb{E}[logP(C = c|X_{fake})]$$

The authors in [3] claim that generator learns distribution of data better when classification loss is also taken into account.

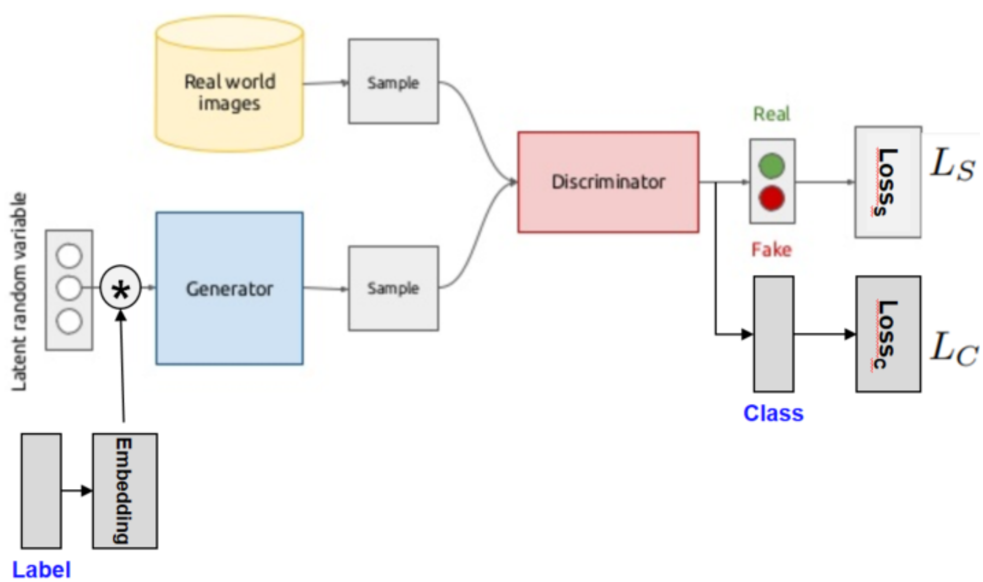


Figure 1: ConvGAN

2.2 GAN with capsule network as a discriminator

As shown in Figure 2, we use CNN as a generative network and a capsule network as the discriminative network. We also take account of classification loss as seen in the figure. We also take account of the classification loss in all of the capsGAN considered. If capsule network has better discriminative performance, then the generative performance should improve in the adverserial training process.

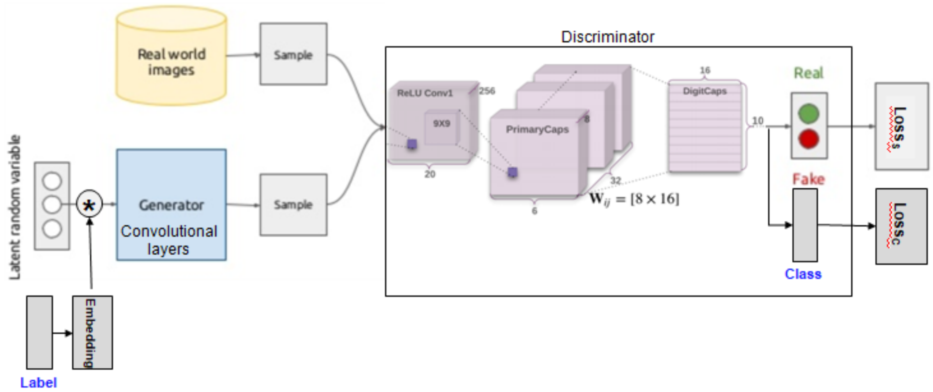


Figure 2: CapsNet as a discriminator

2.3 GAN with capsule network as a generator

As shown in Figure 3, we use capsule network as a generative network and a CNN as the discriminative network.

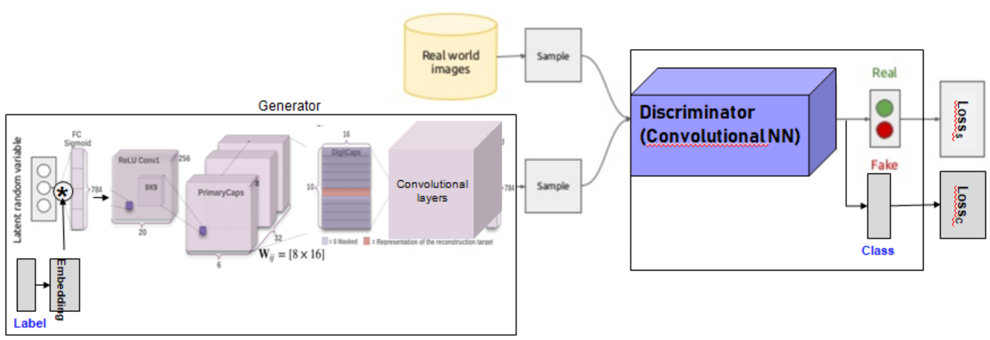


Figure 3: CapsNet as a discriminator

2.4 GAN with capsule network as a generator and a discriminator

As shown in Figure 4, we use capsule network in both generative network and discriminative network. This network should have better performance than convolutional GAN if the capsule network has better discriminative and generative performance.

3 Improving GAN performance

Initial performance results with capsule based GANs were not good. So we used some tricks to improve the performance of the CapsGAN.

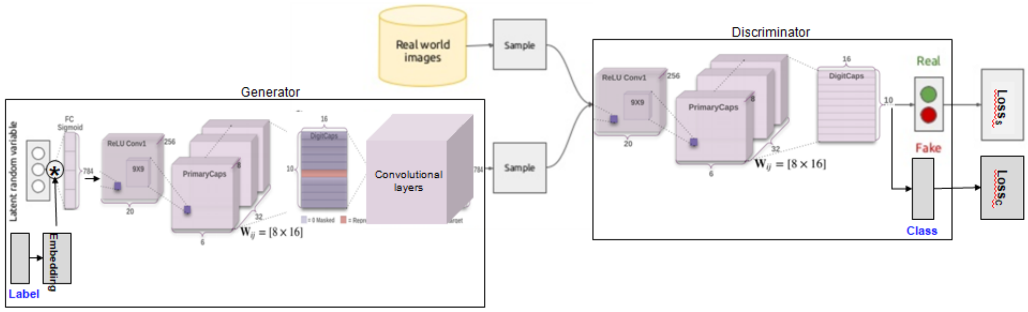


Figure 4: CapsNet as a discriminator

- Normalizing the inputs between -1 and 1.
- Avoiding Sparse Gradients.
- Using Soft and noisy labels.
- Pre-training the discriminator.

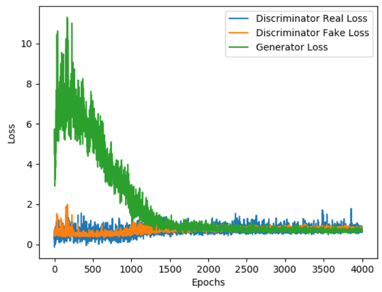
4 Experimental Results

In this section, we show experimental evaluation of the proposed capsGAN with convolutional GAN. We evaluate the performance in two datasets namely MNIST and CFAR10. In our first experiment, we compare generator loss, discriminator real loss and discriminator fake loss of convolutional GAN and all the capsGAN considered in this network. Figure 5 shows the experimental results for MNIST data set while Figure 6 shows results for CFAR10. We note that discriminator loss is small from the beginning. This is because of the fact that we pre-trained generator before using it in GAN.

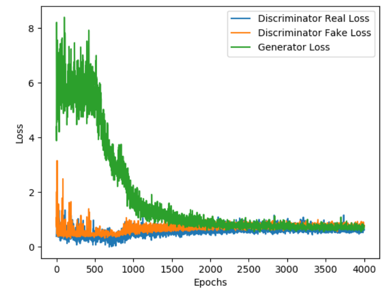
In next experiment, we use t-SNE visualization to see how good generative model have learned the distribution of the real data. Figure 7 and Figure 8 shows the results of the experiments. We can see that GAN with capsule networks as the generator has the worst performance while other capsGAN tends to learn the distribution of the input data distribution

Finally, we compare the semisupervised classification performance of all of these GANs for MNIST and CIFAR10 datasets.Figure 9 shows the results of the experiment. From the results we can say that capsGAN with capsule network as a discriminator, capsGANs with capsule netwokr as a disriminator and as a generator has superior classification performance compared to convGAN. However, the performance of capsGAN with capsule network as a generator is not so good.

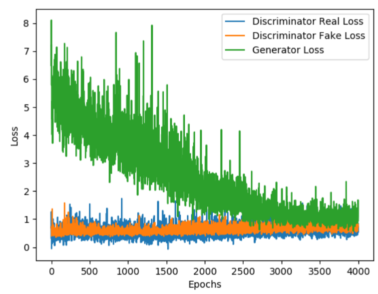
From all of these figures, we see that CapsGAN with capsule network as both discriminator and generator has the best classification performance and outperforms the performance of the benchmark convolutional neural network. However, capsGAN with capsule network as the generator has the worst performance. The classification performance is worst and



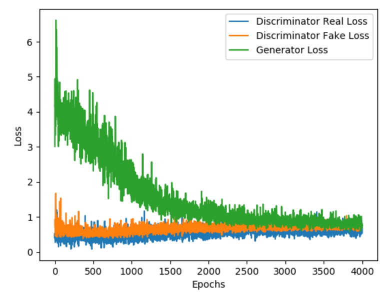
(a) Conv GAN



(b) Capsule Network as a Discriminator



(c) Capsule Network as a Generator



(d) Capsule Network as a Discriminator

Figure 5: Discriminator Real loss, Discriminator fake loss and Generator loss for ConvGAN and different architecture of CapsGAN for MNIST dataset.

the generator loss is higher and the TSNE visuaizaltion shows that the generator has least learned the probability distribution.

Conclusion

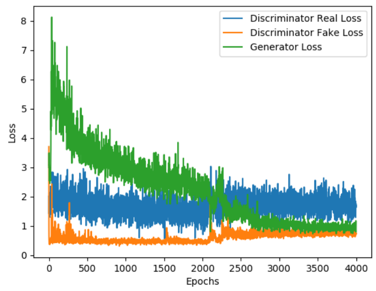
In this course project, we developed GAN with capsule networks. Initial numerical results of these capsGAN when capsule network is used as a discriminator or both as generator and discriminator has better performance than the convGAN in both of the given dataset. This motivates us to carefully design and execute experiments so that we can make a claim of capsGAN having better performance than convGAN.

5 Reference

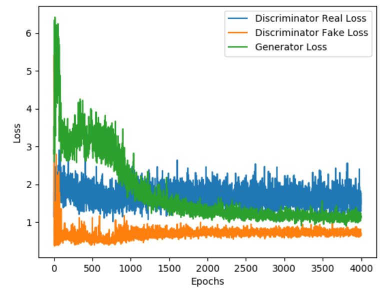
1 I. Goodgellow, et al., "Generative adversarial nets," in Advances in neural information processing, 2014.

2 S. Sabour, et al., "Dynamic routing between capsules," Advances in neural information processing, 2017

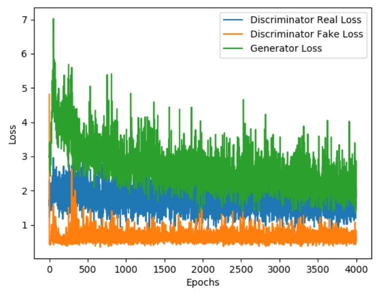
3 O. Augustus, et al., "Semi-supervised learning with generative adversarial networks," arXiv preprint



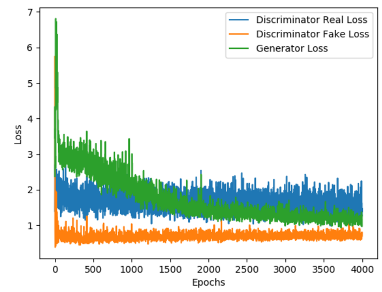
(a) Conv GAN



(b) Capsule Network as a Discriminator

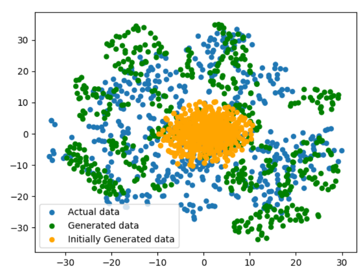


(c) Capsule Network as a Generator

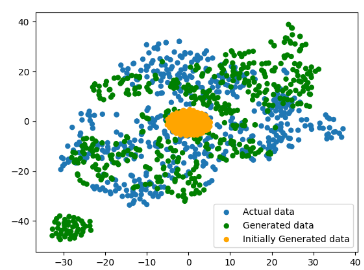


(d) Capsule Network as a Discriminator

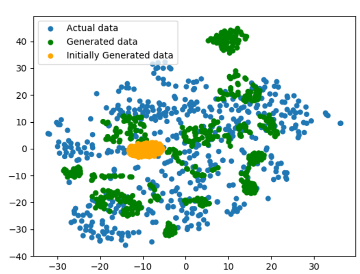
Figure 6: Discriminator Real loss, Discriminator fake loss and Generator loss for ConvGAN and different architecture of CapsGAN for CIFAR10 dataset.



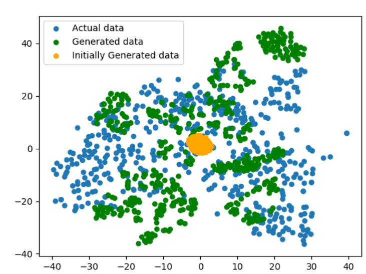
(a) Conv GAN



(b) Capsule Network as a Discriminator

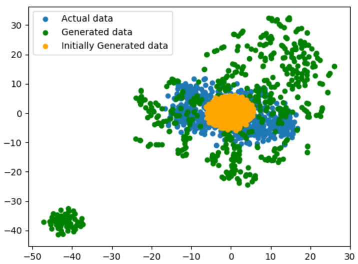


(c) Capsule Network as a Generator

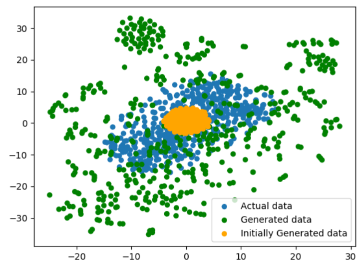


(d) Capsule Network as a Discriminator

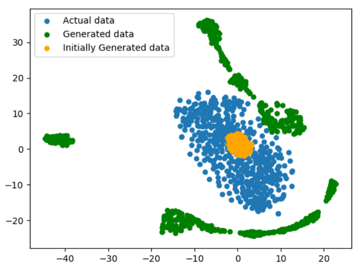
Figure 7: Discriminator Real loss, Discriminator fake loss and Generator loss for ConvGAN and different architecture of CapsGAN for MNIST10 dataset.



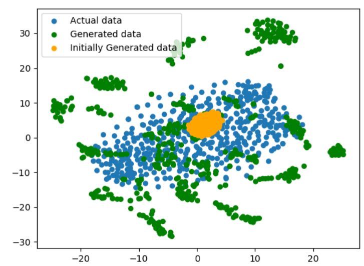
(a) Conv GAN



(b) Capsule Network as a Discriminator

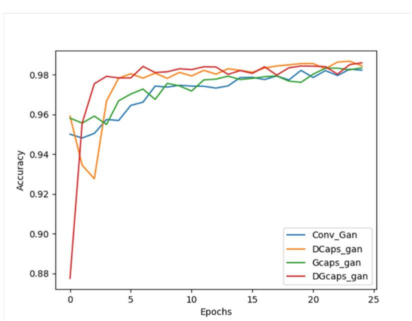


(c) Capsule Network as a Generator

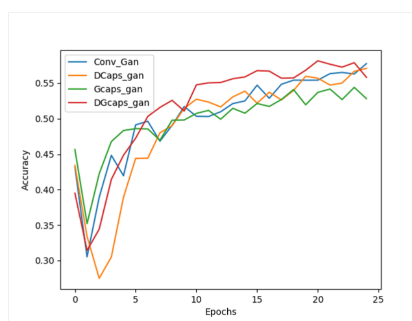


(d) Capsule Network as a Discriminator

Figure 8: Discriminator Real loss, Discriminator fake loss and Generator loss for ConvGAN and different architecture of CapsGAN for CIFAR10 dataset.



(a) Conv GAN



(b) Capsule Network as a Discriminator

Figure 9: Discriminator Real loss, Discriminator fake loss and Generator loss for ConvGAN and different architecture of CapsGAN for CIFAR10 dataset.