Practice: VAE and GAN

Hao Dong

Peking University

Practice: VAE + GAN

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- Hello World: MNIST Classification

- Introduction of VAE
- VAE Architecture
- VAE Training
- VAE Interpolation
- Sampling

- Introduction of DCGAN
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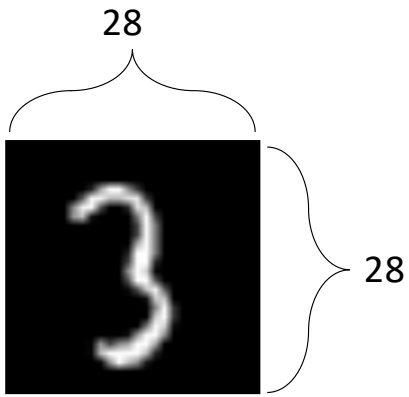
Hello World: MNIST Classification

MNIST dataset



(height, width, channels)

28x28x1 = 784 binary values/image

If RGB image, we will have 3 channels

- **Image X is a list of row vectors:**

```
>>> X_train, y_train, X_val, y_val, X_test, y_test = tl.files.load_mnist_dataset(shape=(-1, 784))
>>> print(X_train.shape)
... (50000, 784)
```

- **Image X is a list of images:**

```
>>> X_train, y_train, X_val, y_val, X_test, y_test = tl.files.load_mnist_dataset(shape=(-1, 28, 28, 1))
>>> print(X_train.shape)
... (50000, 28, 28, 1)
```

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- Simple Iteration

```
>>> X = np.asarray([['a','a'], ['b','b'], ['c','c'], ['d','d'], ['e','e'], ['f','f']])
>>> y = np.asarray([0,1,2,3,4,5])
>>> for batch in tl.iterate.minibatches(inputs=X, targets=y, batch_size=2, shuffle=False):
>>>     print(batch)
... (array([['a', 'a'], ['b', 'b']], dtype='<U1'), array([0, 1]))
... (array([['c', 'c'], ['d', 'd']], dtype='<U1'), array([2, 3]))
... (array([['e', 'e'], ['f', 'f']], dtype='<U1'), array([4, 5]))
```

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- Dataset API

```python
def get_mnist(batch_size):
    X_train, y_train, X_val, y_val, X_test, y_test = tl.files.load_mnist_dataset(shape=(-1, 784))
    train_set = X_train
    length = len(train_set)

    def generator_train():
        for img in train_set:
            yield (img - 0.5) / 0.5 # a Tensor with values range in [-1, 1]

    train_ds = tf.data.Dataset.from_generator(generator_train, output_types=tf.float32)
    ds = train_ds.batch(batch_size)
    ds = ds.prefetch(buffer_size=2)
    return ds, length
```

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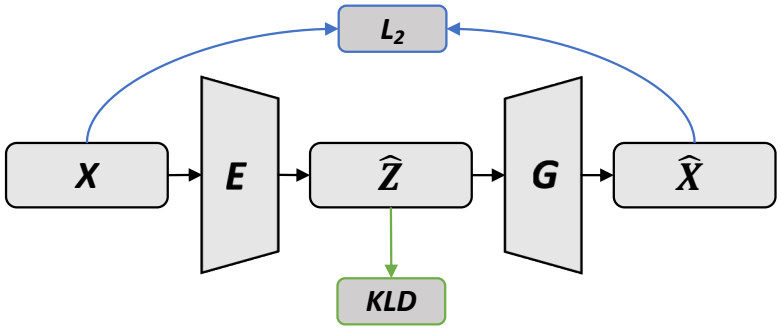
Introduction of VAE



- Two network architectures
- Two loss functions
- Reparameterization trick

$$\tilde{\mathcal{L}}^B(\boldsymbol{\theta}, \boldsymbol{\phi}; \mathbf{x}^{(i)}) = -D_{KL}(q_{\boldsymbol{\phi}}(\mathbf{z}|\mathbf{x}^{(i)})||p_{\boldsymbol{\theta}}(\mathbf{z})) + \frac{1}{L}\sum_{l=1}^{L}(\log p_{\boldsymbol{\theta}}(\mathbf{x}^{(i)}|\mathbf{z}^{(i,l)}))$$

$$\text{where} \quad \mathbf{z}^{(i,l)} = g_{\boldsymbol{\phi}}(\boldsymbol{\epsilon}^{(i,l)}, \mathbf{x}^{(i)}) \quad \text{and} \quad \boldsymbol{\epsilon}^{(l)} \sim p(\boldsymbol{\epsilon})$$

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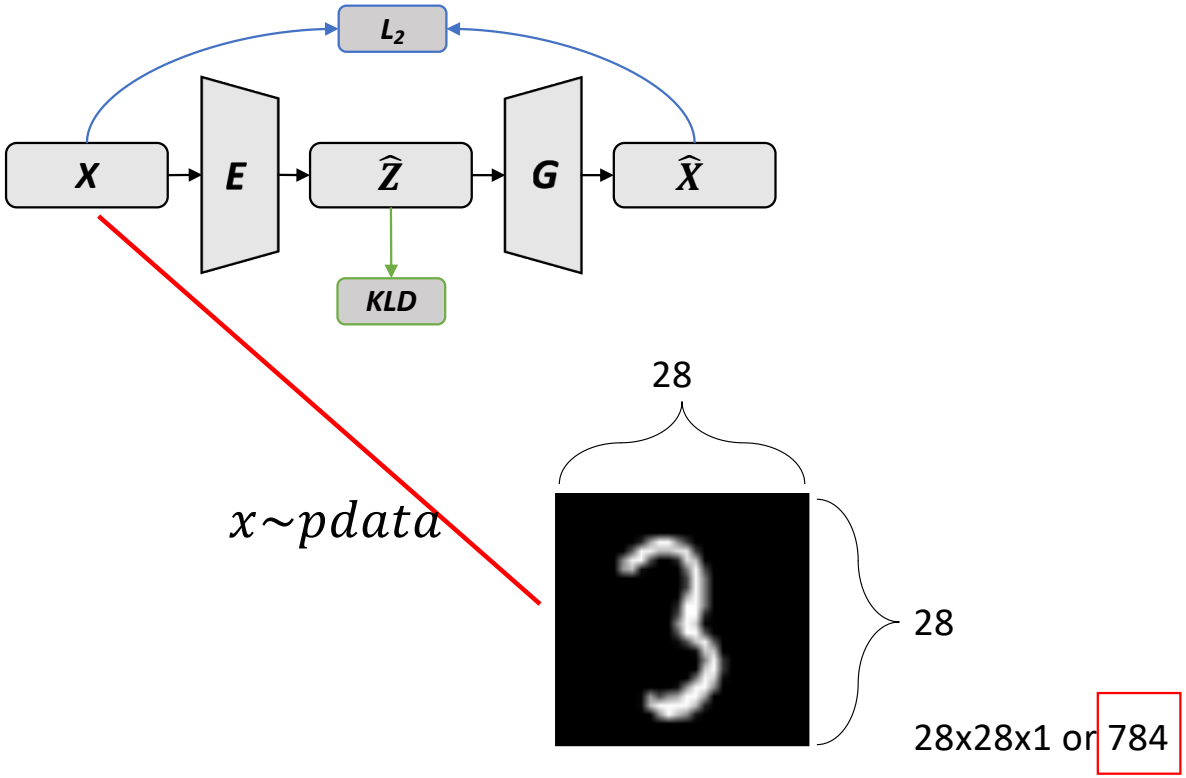
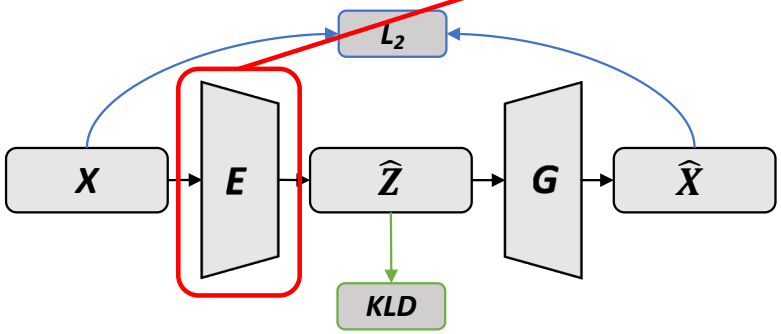
VAE Architecture



VAE Architecture



- Architecture of Encoder

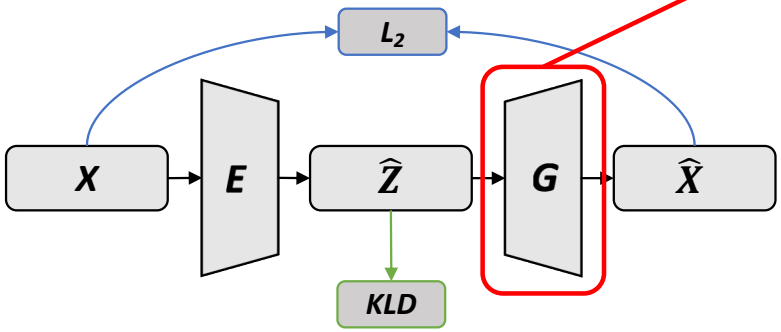
```
def get_encoder(self, batch_size, origin_units, hidden_units, latent_units):
    init = tf.initializers.he_uniform()
    ni = Input((batch_size, origin_units))
    nn = Dense(hidden_units, act=tf.nn.relu, W_init=init, b_init=init)(ni)

    mean = Dense(latent_units, W_init=init, b_init=init)(nn)
    log_sigma = Dense(latent_units, W_init=init, b_init=init)(nn)

    def sample(data):
        mean, log_sigma = data
        stddev = 0.5 * tf.exp(log_sigma)
        out = mean + stddev * tf.random.normal(mean.shape)
        return out

    z = Lambda(sample)([mean, log_sigma])
    return tl.models.Model(inputs=ni, outputs=[z, mean, log_sigma])
```

VAE Architecture



- Architecture of Decoder/Generator

```
def get_decoder(self, batch_size, origin_units, hidden_units, latent_units):
    init = tf.initializers.he_uniform()
    ni = Input((batch_size, latent_units))
    nn = Dense(hidden_units, act=tf.nn.relu, W_init=init, b_init=init)(ni)
    no = Dense(origin_units, act=tf.nn.sigmoid, W_init=init, b_init=init)(nn)
    return tl.models.Model(inputs=ni, outputs=no)
```

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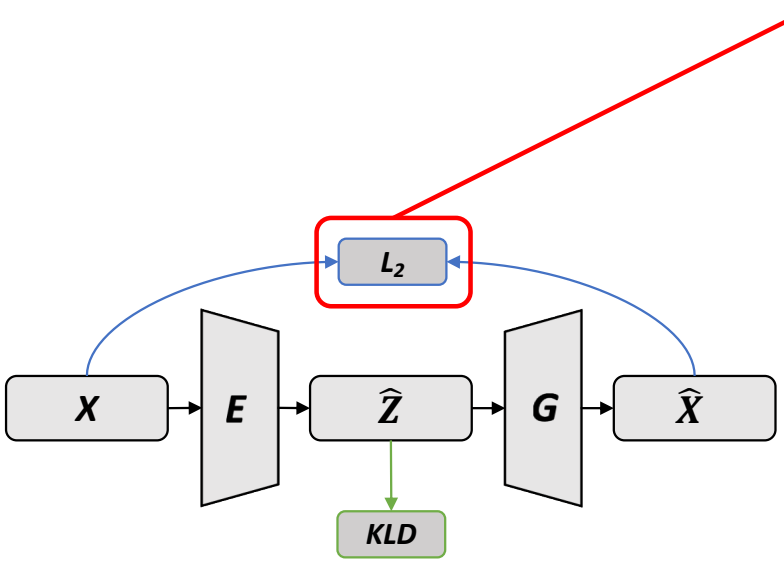
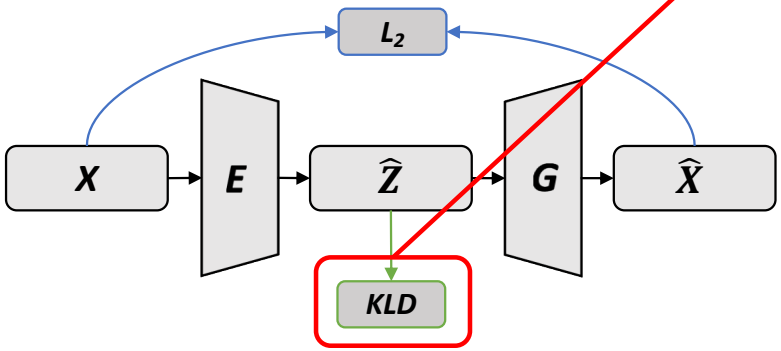
VAE Training



Reconstruction Loss

```
def recon_loss(x, y, k):
    loss = k * tf.losses.binary_crossentropy(x, y)
    loss = tf.reduce_sum(loss)
    return loss
```

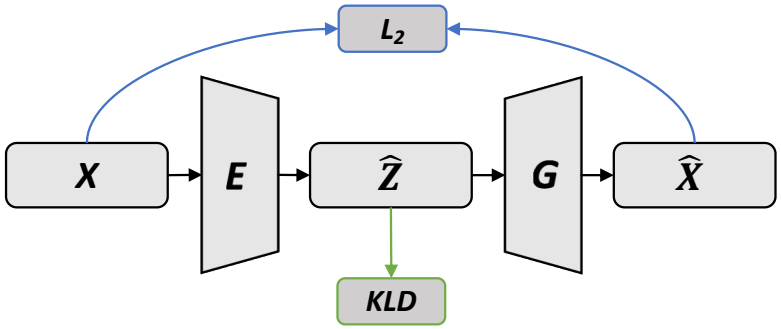
VAE Training



KL-Divergence loss

```
def KL_loss(mu, log_sigma):
    loss = -0.5 * tf.reduce_sum(1 + log_sigma - tf.exp(log_sigma) - mu**2)
    loss = tf.reduce_sum(loss)
    return loss
```

VAE Training



Training Pipeline

```
for epoch in range(flags.n_epoch):
    for step, batch_images in enumerate(images):
        if batch_images.shape[0] != flags.batch_size:
            break
        step_time = time.time()
        last_batch = batch_images

        with tf.GradientTape(persistent=True) as tape:
            reconstr_img, n_mean, n_log_sigma = vae(batch_images)

            reconstr_loss = recon_loss(batch_images, reconstr_img, k)
            latent_loss = KL_loss(n_mean, n_log_sigma)

            loss = tf.add(reconstr_loss, latent_loss)

        grad = tape.gradient(loss, vae.trainable_weights)
        vae_optimizer.apply_gradients(zip(grad, vae.trainable_weights))
        del tape
```

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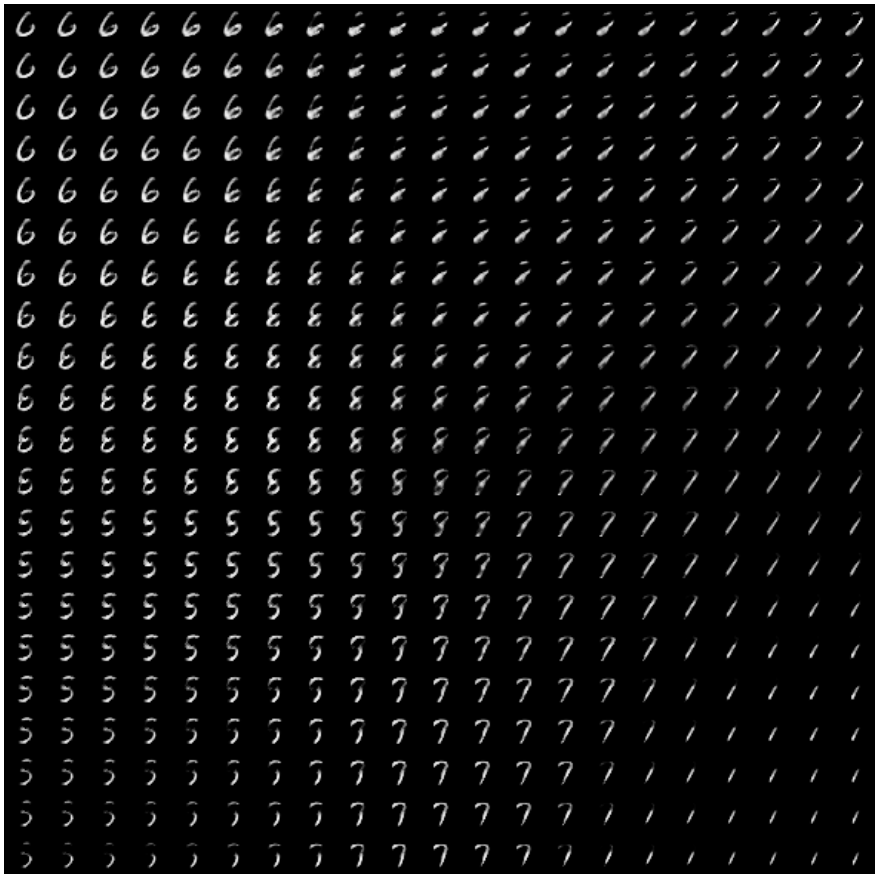
VAE Interpolation



```python
if flags.z_dim == 2:
    z = []
    for x in range(21):
        for y in range(21):
            z.append([(x-10)/10., (y-10)/10.])
    z = np.array(z).astype(np.float32)
    vae.eval()
    gen_result = vae.generate(z)
    tl.visualize.save_images(gen_result.numpy().reshape([-1, 28, 28, 1]), [21, 21],
                             '{}/feature_visualization.png'.format(flags.sample_dir))
```

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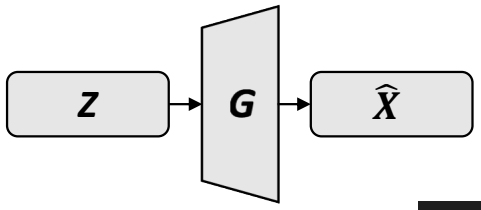
Sampling




```python
def generate(self, z_in):
    assert z_in.shape[-1] == self.latent_units

    return self.decoder(z_in)
```

```python
vae.eval()
tmp_result, tmp_mean, tmp_logvar = vae(last_batch) # get the reconstruction results
z = np.random.normal(0.0, 1.0, (flags.sample_size, flags.z_dim)).astype(np.float32)
gen_result = vae.generate(z) # get a randomly generated results
vae.train()
tl.visualize.save_images(tmp_result.numpy().reshape([-1, 28, 28, 1]), [num_tiles, num_tiles],
                         '{}/train_{:02d}.png'.format(flags.sample_dir, epoch))
tl.visualize.save_images(gen_result.numpy().reshape([-1, 28, 28, 1]), [num_tiles, num_tiles],
                         '{}/generate_{:02d}.png'.format(flags.sample_dir, epoch))
```

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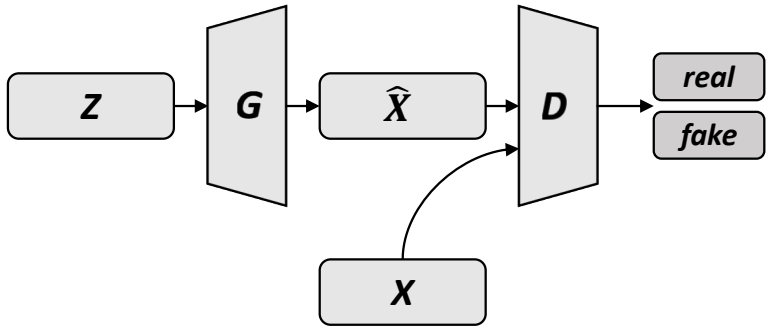
Introduction of DCGAN



- Two network architectures
- Two loss functions

$$\min_G \max_D V(D,G) = \mathbb{E}_{\boldsymbol{x}\sim p_{\text{data}}(\boldsymbol{x})}[\log D(\boldsymbol{x})] + \mathbb{E}_{\boldsymbol{z}\sim p_{\boldsymbol{z}}(\boldsymbol{z})}[\log(1 - D(G(\boldsymbol{z})))].$$

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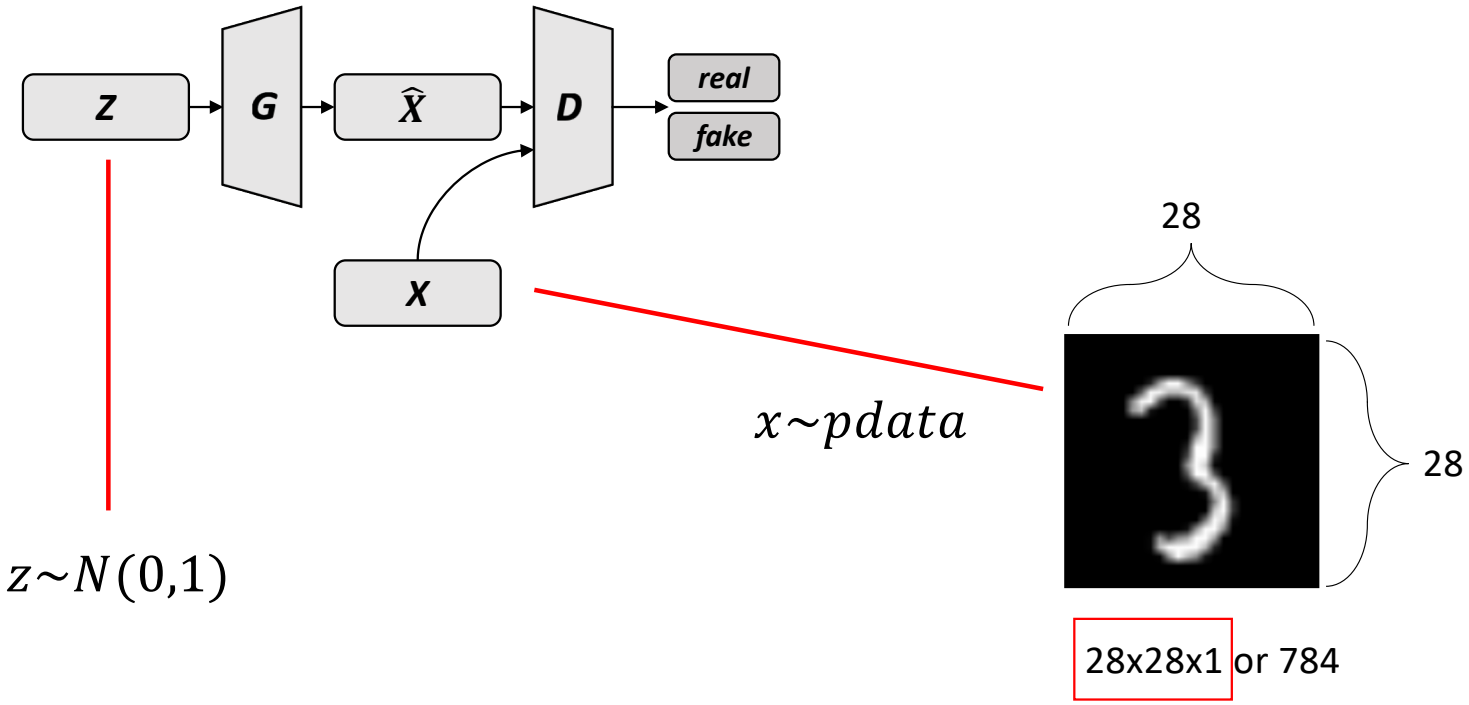
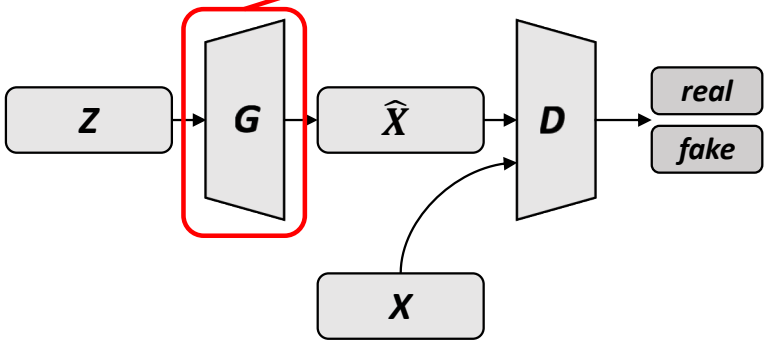
DCGAN Architecture



DCGAN Architecture



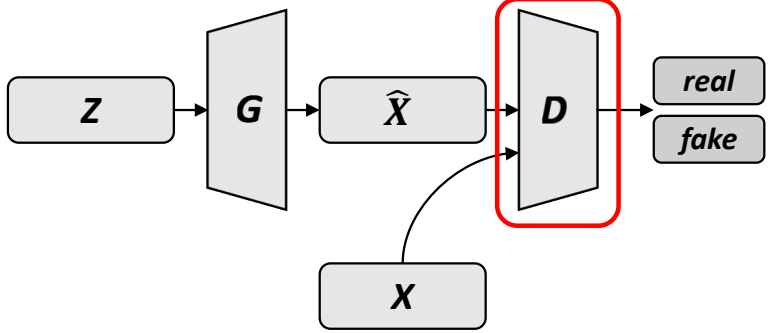
Architecture of generator

```
def get_generator(shape, gf_dim=64, o_size=32, o_channel=3):
    image_size = o_size
    s4 = image_size // 4
    lrelu = lambda x: tf.nn.leaky_relu(x, 0.2)

    ni = Input(shape)
    nn = Dense(n_units=(gf_dim * 4 * s4 * s4))(ni)
    nn = Reshape(shape=(-1, s4, s4, gf_dim * 4))(nn)
    nn = BatchNorm2d(decay=0.9, act=lrelu)(nn)
    nn = DeConv2d(gf_dim * 2, (5, 5), (1, 1))(nn)
    nn = BatchNorm2d(decay=0.9, act=lrelu)(nn)
    nn = DeConv2d(gf_dim, (5, 5), (2, 2))(nn)
    nn = BatchNorm2d(decay=0.9, act=lrelu)(nn)
    nn = DeConv2d(o_channel, (5, 5), (2, 2), act=tf.nn.tanh)(nn)

    return tl.models.Model(inputs=ni, outputs=nn, name='generator')
```

DCGAN Architecture



Architecture of discriminator

```
def get_discriminator(shape, df_dim=64):
    lrelu = lambda x : tf.nn.leaky_relu(x, 0.2)

    ni = Input(shape)
    nn = Conv2d(df_dim, (5, 5), (2, 2), act=lrelu)(ni)
    nn = Conv2d(df_dim * 2, (5, 5), (2, 2))(nn)
    nn = BatchNorm2d(decay=0.9, act=lrelu)(nn)
    nn = Conv2d(df_dim*4, (5, 5), (2, 2))(nn)
    nn = BatchNorm2d(decay=0.9, act=lrelu)(nn)
    nn = Flatten()(nn)
    nn = Dense(n_units=1)(nn)

    return tl.models.Model(inputs=ni, outputs=nn, name='discriminator')
```

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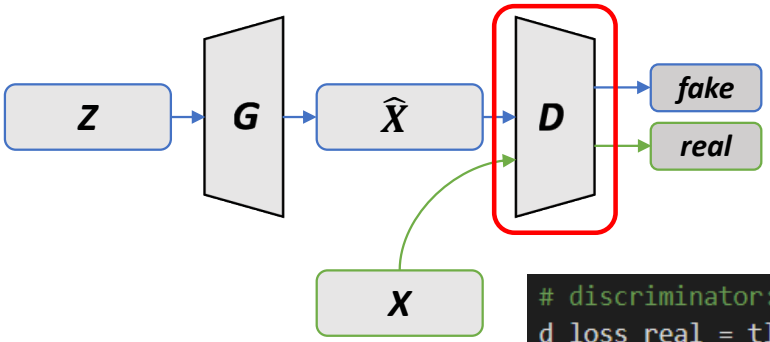
DCGAN Training

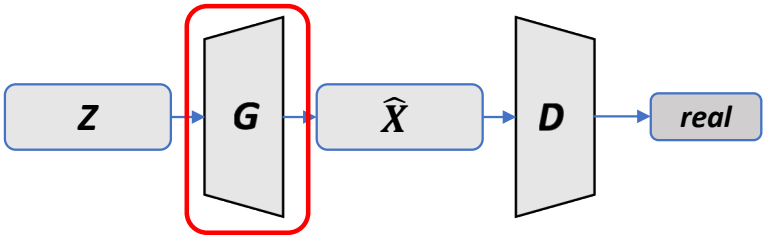
Loss of discriminator




```
# discriminator: real images are labelled as 1
d_loss_real = tl.cost.sigmoid_cross_entropy(d2_logits, tf.ones_like(d2_logits), name='dreal')
# discriminator: images from generator (fake) are labelled as 0
d_loss_fake = tl.cost.sigmoid_cross_entropy(d_logits, tf.zeros_like(d_logits), name='dfake')
# combined loss for updating discriminator
d_loss = d_loss_real + d_loss_fake
```

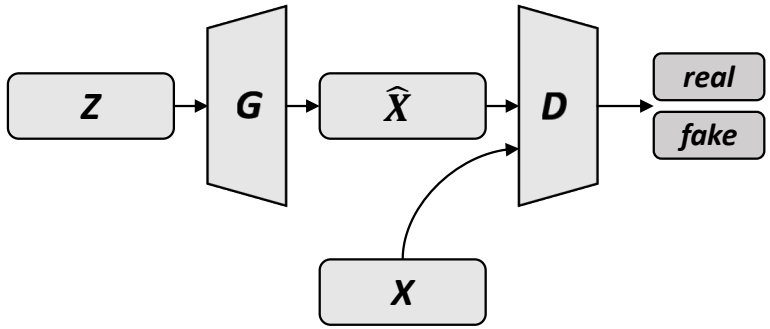
DCGAN Training

Loss of generator




```
# generator: try to fool discriminator to output 1
g_loss = tl.cost.sigmoid_cross_entropy(d_logits, tf.ones_like(d_logits), name='gfake')
```

DCGAN Training



Training pipeline

```
for epoch in range(flags.n_epoch):
    for step, batch_images in enumerate(images):
        if batch_images.shape[0] != flags.batch_size:  # if the remaining data in this epoch < batch_size
            break
        step_time = time.time()
        with tf.GradientTape(persistent=True) as tape:
            z = np.random.normal(loc=0.0, scale=1.0, size=[flags.batch_size, flags.z_dim]).astype(np.float32)
            d_logits = D(G(z))
            d2_logits = D(batch_images)
            # discriminator: real images are labelled as 1
            d_loss_real = tl.cost.sigmoid_cross_entropy(d2_logits, tf.ones_like(d2_logits), name='dreal')
            # discriminator: images from generator (fake) are labelled as 0
            d_loss_fake = tl.cost.sigmoid_cross_entropy(d_logits, tf.zeros_like(d_logits), name='dfake')
            # combined loss for updating discriminator
            d_loss = d_loss_real + d_loss_fake
            # generator: try to fool discriminator to output 1
            g_loss = tl.cost.sigmoid_cross_entropy(d_logits, tf.ones_like(d_logits), name='gfake')

        grad = tape.gradient(g_loss, G.trainable_weights)
        g_optimizer.apply_gradients(zip(grad, G.trainable_weights))
        grad = tape.gradient(d_loss, D.trainable_weights)
        d_optimizer.apply_gradients(zip(grad, D.trainable_weights))
        del tape
```

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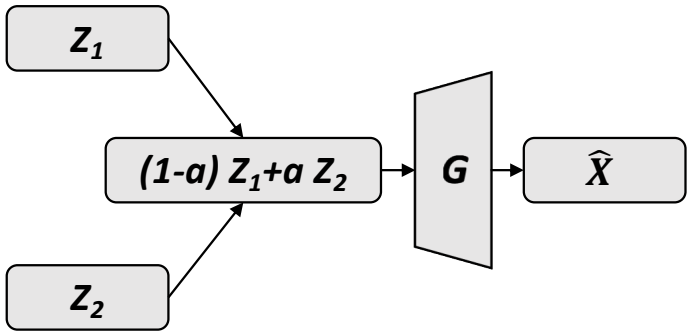
DCGAN Interpolation



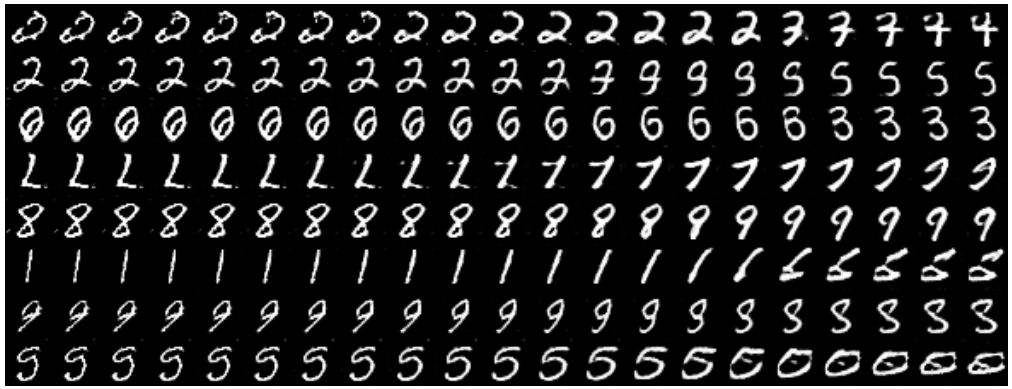

```
z1 = np.random.normal(loc=0.0, scale=1.0, size=[8, flags.z_dim]).astype(np.float32)
z2 = np.random.normal(loc=0.0, scale=1.0, size=[8, flags.z_dim]).astype(np.float32)

G = get_generator([None, flags.z_dim], gf_dim=64, o_size=flags.output_size, o_channel=flags.c_dim)
G.load_weights('{}/G.npz'.format(flags.checkpoint_dir))
G.eval()

z = []
for i in range(8):
    for j in range(21):
        a = (j - 10) / 10.
        z.append(a*z1[i] + (1-a)*z2[i])
z = np.array(z)

gen_img = G(z)

tl.visualize.save_images(gen_img.numpy(), [8, 21],
                         '{}/interplation.png'.format(flags.sample_dir))
```



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More

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Improved GAN
LSGAN
WGAN
WGAN-GP
BiGAN
VAE-GAN
…
with MNIST

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Pix2Pix
CycleGAN
SRGAN
…
with other datasets

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Proposal Your Projects

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Thanks