lab8-1

May 16, 2021

[1]:
```
import keras
from keras import layers
from keras import backend as K
from keras.models import Model
from keras.datasets import mnist
import matplotlib.pyplot as plt
import numpy as np
import tensorflow as tf
%tensorflow_version 1.x
print(tf.__version__)
tf.compat.v1.disable_eager_execution()

img_shape = (28, 28, 1)
batch_size = 16
latent_dim = 2
#Define encoder network
#Note that we are using keras functional API
input_img = keras.Input(shape=img_shape)
x = layers.Conv2D(32, 3, padding='same', activation='relu')(input_img)
x = layers.Conv2D(64, 3, padding='same', activation='relu',strides=(2, 2))(x)
x = layers.Conv2D(64, 3, padding='same', activation='relu')(x)
x = layers.Conv2D(64, 3, padding='same', activation='relu')(x)

shape_before_flattening = K.int_shape(x)
x = layers.Flatten()(x)
x = layers.Dense(32, activation='relu')(x)
#x = layers.Dense(2, activation='relu')(x)

z_mean = layers.Dense(latent_dim)(x)
z_log_var = layers.Dense(latent_dim)(x)
#Sampling from the distributions to obtain latent space
def sampling(args):
    z_mean, z_log_var = args
    epsilon = K.random_normal(shape=(K.shape(z_mean)[0], latent_dim),
    mean=0., stddev=1.)
    return z_mean + K.exp(z_log_var) * epsilon
z = layers.Lambda(sampling)([z_mean, z_log_var])
```

```
encoder = Model(input_img, z)
#Define decoder network
decoder_input = layers.Input(K.int_shape(z)[1:])
x = layers.Dense(np.prod(shape_before_flattening[1:]),␣
↪activation='relu')(decoder_input)
x = layers.Reshape(shape_before_flattening[1:])(x)
x = layers.Conv2DTranspose(32, 3,padding='same', activation='relu', strides=(2,␣
↪2))(x)
x = layers.Conv2D(1, 3,padding='same', activation='sigmoid')(x)

decoder = Model(decoder_input, x)
z_decoded = decoder(z)
def vae_loss(input_img, z_decoded):
    input_img = K.flatten(input_img)
    z_decoded = K.flatten(z_decoded)
    xent_loss = keras.metrics.binary_crossentropy(input_img, z_decoded)
    kl_loss = -5e-4 * K.mean(1 + z_log_var - K.square(z_mean) - K.
↪exp(z_log_var), axis=-1)
    return K.mean(xent_loss + kl_loss)

vae = Model(input_img, z_decoded)
vae.compile(optimizer='adam', loss=vae_loss)
vae.summary()
decoder.summary()
#load the data and split into train + test sets
(x_train, _), (x_test, y_test) = mnist.load_data()
x_train = x_train.astype('float32') / 255.
x_train = x_train.reshape(x_train.shape + (1,))
x_test = x_test.astype('float32') / 255.
x_test = x_test.reshape(x_test.shape + (1,))
vae.fit(x=x_train,y=x_train, shuffle=True, epochs=10, batch_size=batch_size)
encoded = encoder.predict(x_test)
decoded = decoder.predict(encoded)
```

```
TensorFlow is already loaded. Please restart the runtime to change versions.
2.4.1
Model: "model_2"
________________________________________________________________________________
__________________
Layer (type)                    Output Shape         Param #     Connected to
================================================================================
==================
input_1 (InputLayer)            [(None, 28, 28, 1)]  0

________________________________________________________________________________
__________________
conv2d (Conv2D)                 (None, 28, 28, 32)   320         input_1[0][0]
```

```
__________________________________________________________________________________________________
conv2d_1 (Conv2D)               (None, 14, 14, 64)   18496       conv2d[0][0]
__________________________________________________________________________________________________
conv2d_2 (Conv2D)               (None, 14, 14, 64)   36928       conv2d_1[0][0]
__________________________________________________________________________________________________
conv2d_3 (Conv2D)               (None, 14, 14, 64)   36928       conv2d_2[0][0]
__________________________________________________________________________________________________
flatten (Flatten)               (None, 12544)        0           conv2d_3[0][0]
__________________________________________________________________________________________________
dense (Dense)                   (None, 32)           401440      flatten[0][0]
__________________________________________________________________________________________________
dense_1 (Dense)                 (None, 2)            66          dense[0][0]
__________________________________________________________________________________________________
dense_2 (Dense)                 (None, 2)            66          dense[0][0]
__________________________________________________________________________________________________
lambda (Lambda)                 (None, 2)            0           dense_1[0][0]
                                                                 dense_2[0][0]
__________________________________________________________________________________________________
model_1 (Functional)            (None, 28, 28, 1)    56385       lambda[0][0]
==================================================================================================
Total params: 550,629
Trainable params: 550,629
Non-trainable params: 0
__________________________________________________________________________________________________
Model: "model_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_2 (InputLayer)         [(None, 2)]               0
_________________________________________________________________
dense_3 (Dense)              (None, 12544)             37632
_________________________________________________________________
reshape (Reshape)            (None, 14, 14, 64)        0
_________________________________________________________________
conv2d_transpose (Conv2DTran (None, 28, 28, 32)        18464
_________________________________________________________________
conv2d_4 (Conv2D)            (None, 28, 28, 1)         289
```

```
=================================================================
Total params: 56,385
Trainable params: 56,385
Non-trainable params: 0
_________________________________________________________________
Train on 60000 samples
Epoch 1/10
60000/60000 [==============================] - 19s 323us/sample - loss: 0.2230
Epoch 2/10
60000/60000 [==============================] - 16s 267us/sample - loss: 0.2007
Epoch 3/10
60000/60000 [==============================] - 16s 269us/sample - loss: 0.1927
Epoch 4/10
60000/60000 [==============================] - 16s 264us/sample - loss: 0.1882
Epoch 5/10
60000/60000 [==============================] - 16s 267us/sample - loss: 0.1855
Epoch 6/10
60000/60000 [==============================] - 16s 266us/sample - loss: 0.1835
Epoch 7/10
60000/60000 [==============================] - 16s 267us/sample - loss: 0.1822
Epoch 8/10
60000/60000 [==============================] - 16s 269us/sample - loss: 0.1812
Epoch 9/10
60000/60000 [==============================] - 16s 266us/sample - loss: 0.1803
Epoch 10/10
60000/60000 [==============================] - 16s 267us/sample - loss: 0.1795
```

```
/usr/local/lib/python3.7/dist-
packages/tensorflow/python/keras/engine/training.py:2325: UserWarning:
`Model.state_updates` will be removed in a future version. This property should
not be used in TensorFlow 2.0, as `updates` are applied automatically.
  warnings.warn('`Model.state_updates` will be removed in a future version. '
```

HOMEWORK 1

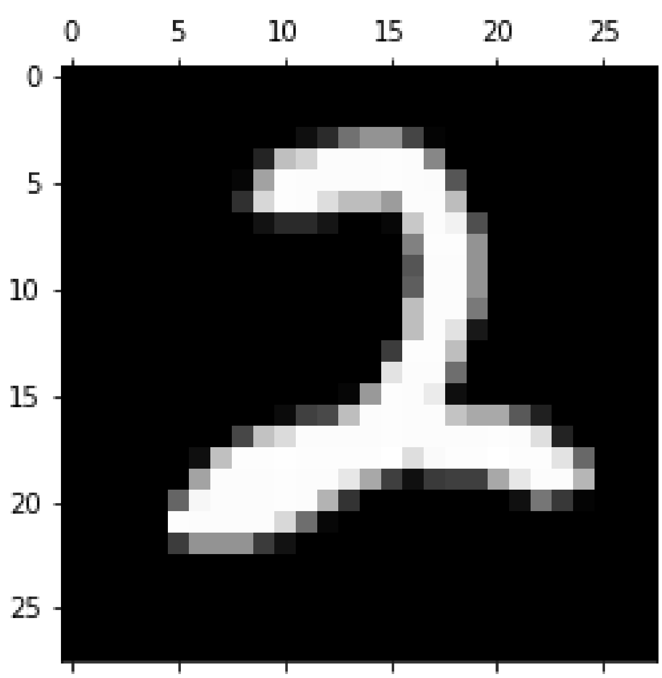
Interpolate between two latent vectors (i.e., moving in the latent space) and decode and visualize the interpolations. Provide a code (python notebook) to do this interpolation; and provide 3 interpolated images in-between.

[2]:
```python
def interpolate_and_vis(num1, num2, num_of_images):
  idex_num1 = [idx for idx in range(len(y_test)) if y_test[idx] == num1]
  idex_num2 = [idx for idx in range(len(y_test)) if y_test[idx] == num2]

  encoded_num1 = encoded[idex_num1]
  encoded_num2 = encoded[idex_num2]

  idx1 = np.random.choice(idex_num1)
  idx2 = np.random.choice(idex_num2)
```

```python
    mu1, sigma1 = encoded[idx1]
    mu2, sigma2 = encoded[idx2]

    mu_linspace = np.linspace(mu1, mu2, num_of_images)
    sigma_linspace = np.linspace(sigma1, sigma2, num_of_images)

    params = np.array(list(zip(mu_linspace, sigma_linspace)))
    decoded = decoder.predict(params)

    print('First base image, from class: ', num1)
    plt.matshow(x_test[idx1][:,:,0], cmap='gray')
    plt.show()

    print('Second base image, from class: ', num2)
    plt.matshow(x_test[idx2][:,:,0], cmap='gray')
    plt.show()
    print('\n\n')

    for index, param in enumerate(params):
      print('Image num: ', index+1)
      plt.matshow(decoded[index][:,:,0], cmap='gray')
      plt.show()
```

[3]:
```python
# between 2 and 8
interpolate_and_vis(2, 8, 3)
```

```
First base image, from class:  2
```



Second base image, from class: 8

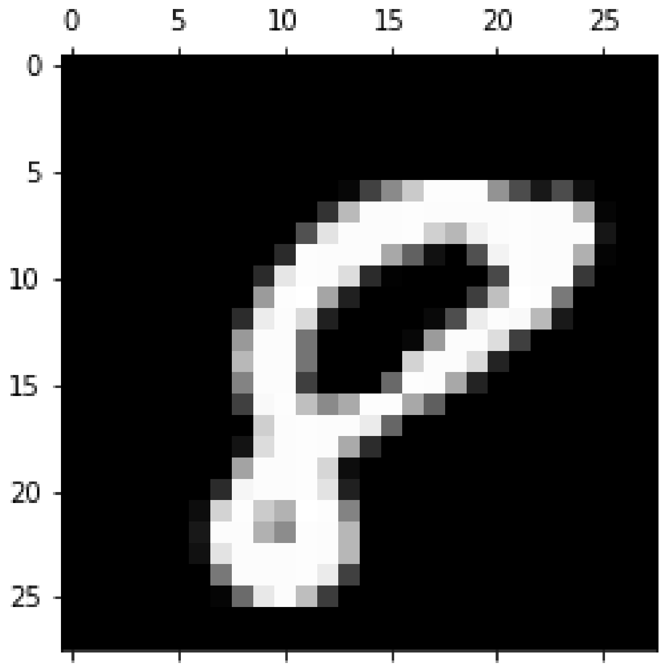


Image num: 1

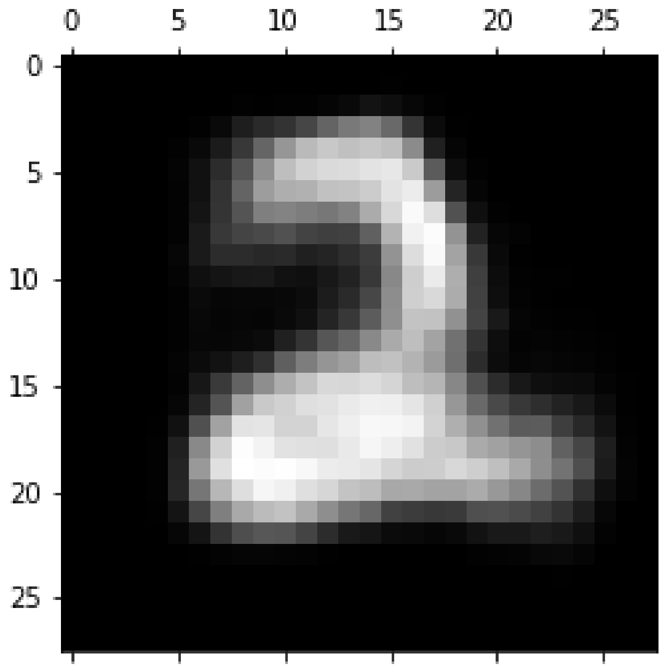


Image num: 2

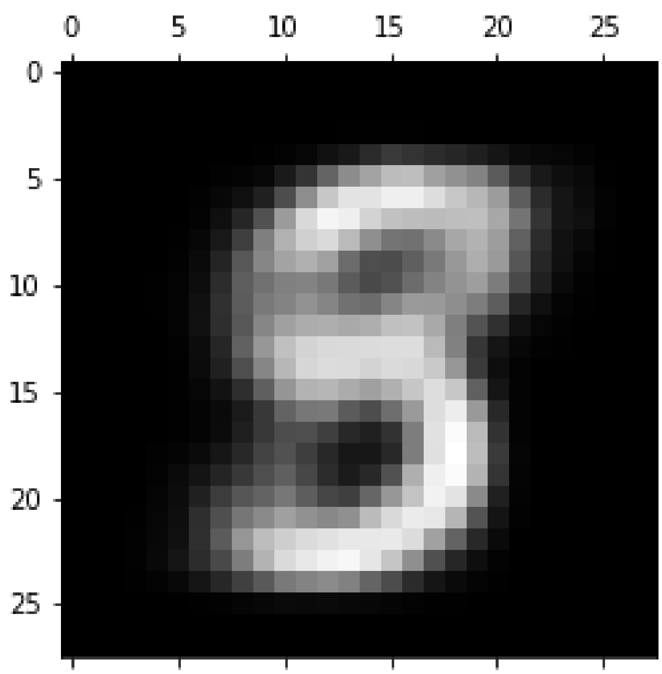
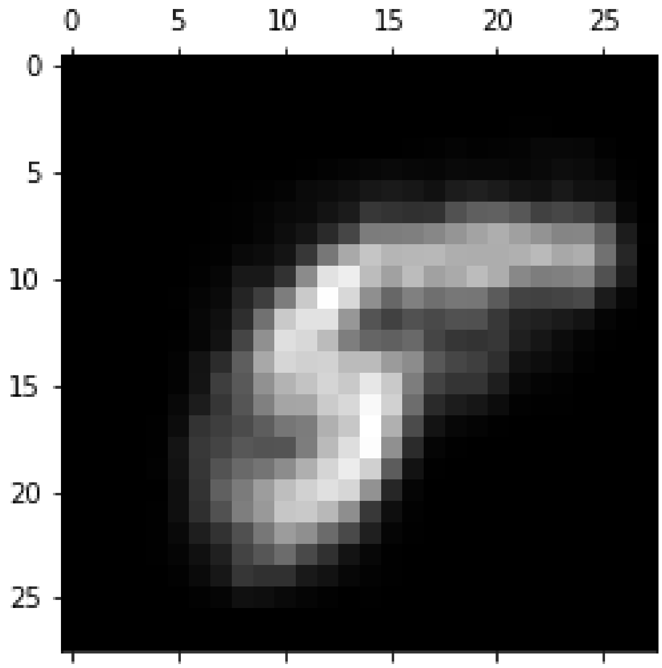
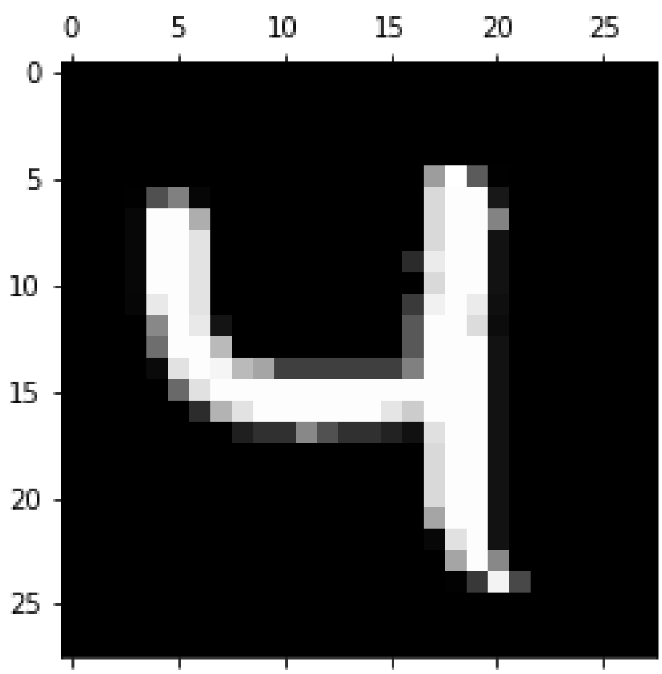


Image num: 3



```
[4]: # between 4 and 0
interpolate_and_vis(4, 0, 3)
```

First base image, from class: 4



Second base image, from class: 0

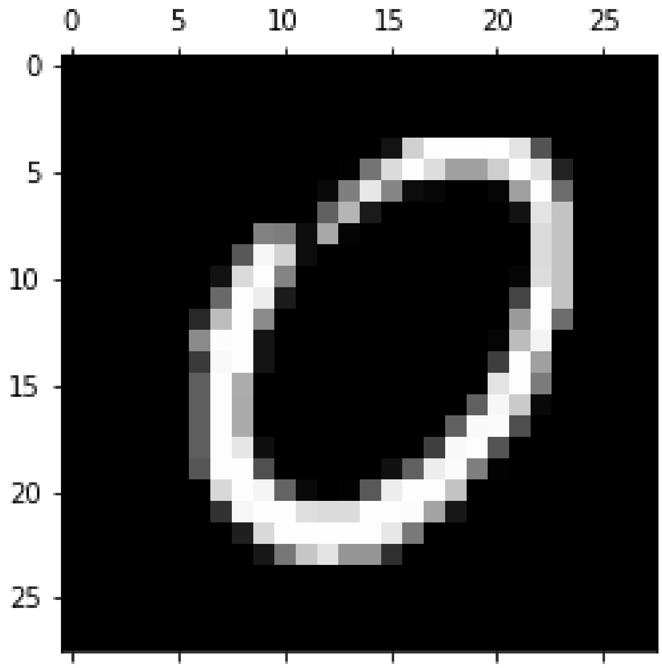


Image num: 1

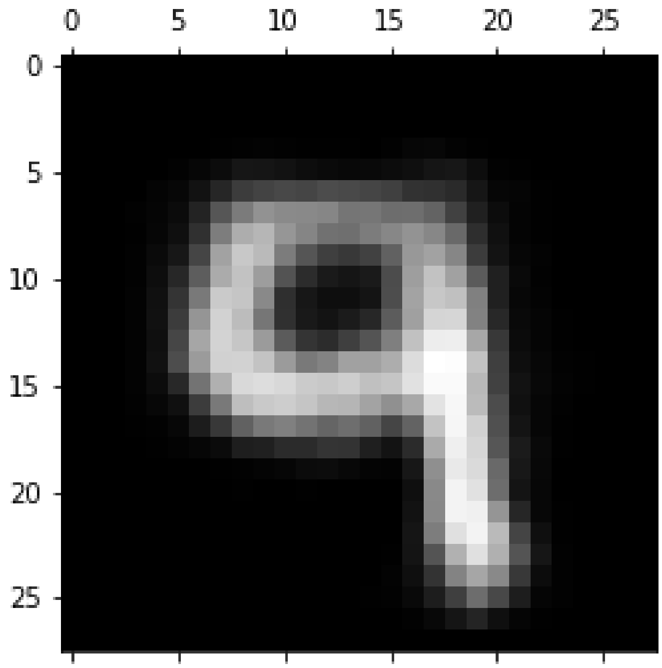


Image num: 2

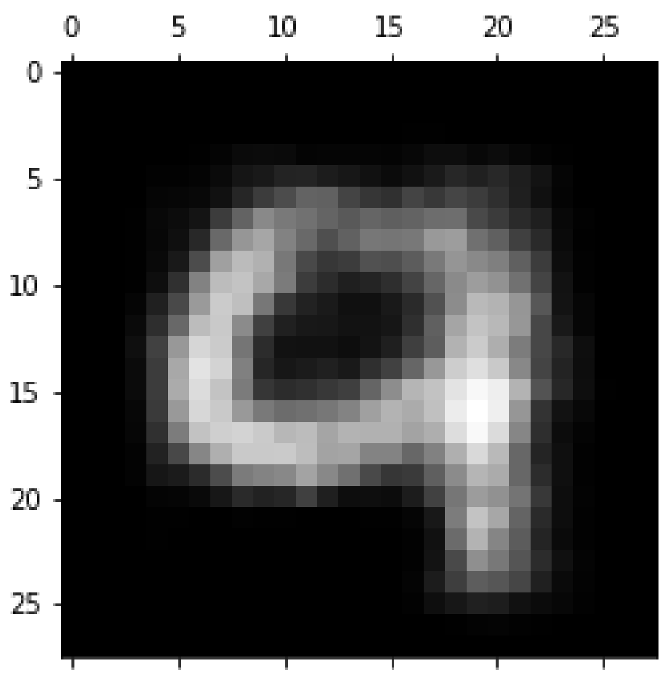
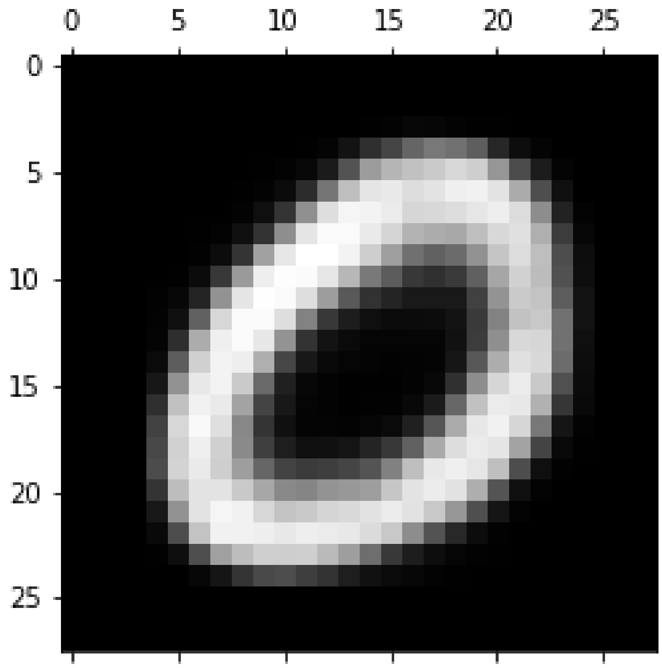


Image num: 3



HOMEWORK 2

Apply VAE on the above ST data. Modify the earlier VAE architecture (used on MNIST), such as input data dimensions and other parameters (strides, layers, etc). Keep the 2 dimensions as latent variables. Visualize the scatter plot. Visualize the reconstructed data as the 2D heatmap. Make sure to submit the jupyterlab code.

[5]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from google.colab import drive
drive.mount('/content/drive')
#file = 'drive/MyDrive/Colab Notebooks/Rep01_MOB_count_matrix-1.tsv'
file = '/content/drive/MyDrive/Colab Notebooks/Rep1_MOB_count_matrix-1.tsv'
data_orig = pd.read_csv(file, sep='\t')
x = [float(i.partition('x')[0]) for i in data_orig.iloc[:,0]]
y = [float(i.partition('x')[2]) for i in data_orig.iloc[:,0]]
x_round = [int(i+0.5) for i in x]
y_round = [int(i+0.5) for i in y]
data = []

#loop over genes
for i in range(1,data_orig.shape[1]):
    mat = np.zeros([32,32])
    #fill spatial arrays for each gene
    for x_, y_, val in zip(x_round, y_round, data_orig.iloc[:,i]):
```

```
        mat[y_,x_] = val
    #scaling the data on each gene from 0 to 1
    mat = mat/(mat.max())
    data.append(mat)
data = np.array(data)
```

Mounted at /content/drive

[72]:

```
import keras
from keras import layers
from keras import backend as K
from keras.models import Model
from keras.datasets import mnist
import matplotlib.pyplot as plt
import numpy as np
import tensorflow as tf
%tensorflow_version 1.x
print(tf.__version__)
tf.compat.v1.disable_eager_execution()

img_shape = (32, 32, 1)
batch_size = 16
latent_dim = 2
#Define encoder network
#Note that we are using keras functional API
input_img = keras.Input(shape=img_shape)
x = layers.Conv2D(32, 3, padding='same', activation='relu')(input_img)
x = layers.Conv2D(64, 3, padding='same', activation='relu',strides=(2, 2))(x)
x = layers.Conv2D(64, 3, padding='same', activation='sigmoid')(x)


shape_before_flattening = K.int_shape(x)
x = layers.Flatten()(x)
x = layers.Dense(32, activation='relu')(x)


z_mean = layers.Dense(latent_dim)(x)
z_log_var = layers.Dense(latent_dim)(x)
#Sampling from the distributions to obtain latent space
def sampling(args):
    z_mean, z_log_var = args
    epsilon = K.random_normal(shape=(K.shape(z_mean)[0], latent_dim),
    mean=0., stddev=1.)
    return z_mean + K.exp(z_log_var) * epsilon
z = layers.Lambda(sampling)([z_mean, z_log_var])

encoder = Model(input_img, z)
```

```
#Define decoder network
decoder_input = layers.Input(K.int_shape(z)[1:])
x = layers.Dense(np.prod(shape_before_flattening[1:]),␣
 ↪activation='relu')(decoder_input)
x = layers.Reshape(shape_before_flattening[1:])(x)
x = layers.Conv2DTranspose(32, 3,padding='same', activation='relu', strides=(2,␣
 ↪2))(x)
x = layers.Conv2D(1, 3,padding='same', activation='sigmoid')(x)

decoder = Model(decoder_input, x)
z_decoded = decoder(z)
def vae_loss(input_img, z_decoded):
    input_img = K.flatten(input_img)
    z_decoded = K.flatten(z_decoded)
    xent_loss = keras.metrics.binary_crossentropy(input_img, z_decoded)
    kl_loss = -5e-4 * K.mean(1 + z_log_var - K.square(z_mean) - K.
 ↪exp(z_log_var), axis=-1)
    return K.mean(xent_loss + kl_loss)

vae = Model(input_img, z_decoded)
vae.compile(optimizer='adam', loss=vae_loss)
vae.summary()
decoder.summary()
#load the data and split into train + test sets
cut_point = round(len(data) * 0.8)
x_train = data[:cut_point]
x_test = data[cut_point:]
x_train = x_train.astype('float32') / 255.
x_train = x_train.reshape(x_train.shape + (1,))
x_test = x_test.astype('float32') / 255.
x_test = x_test.reshape(x_test.shape + (1,))
```

```
TensorFlow is already loaded. Please restart the runtime to change versions.
2.4.1
Model: "model_11"
________________________________________________________________________________
__________________
Layer (type)                    Output Shape         Param #     Connected to
================================================================================
==================
input_7 (InputLayer)            [(None, 32, 32, 1)]  0

________________________________________________________________________________
__________________
conv2d_14 (Conv2D)              (None, 32, 32, 32)   320         input_7[0][0]

________________________________________________________________________________
__________________
conv2d_15 (Conv2D)              (None, 16, 16, 64)   18496       conv2d_14[0][0]
```

```
__________________________________________________________________________________
__________________
conv2d_16 (Conv2D)              (None, 16, 16, 64)   36928       conv2d_15[0][0]
__________________________________________________________________________________
__________________
flatten_3 (Flatten)             (None, 16384)        0           conv2d_16[0][0]
__________________________________________________________________________________
__________________
dense_12 (Dense)                (None, 32)           524320      flatten_3[0][0]
__________________________________________________________________________________
__________________
dense_13 (Dense)                (None, 2)            66          dense_12[0][0]
__________________________________________________________________________________
__________________
dense_14 (Dense)                (None, 2)            66          dense_12[0][0]
__________________________________________________________________________________
__________________
lambda_3 (Lambda)               (None, 2)            0           dense_13[0][0]
                                                                 dense_14[0][0]
__________________________________________________________________________________
__________________
model_10 (Functional)           (None, 32, 32, 1)    67905       lambda_3[0][0]
==================================================================================
==================
Total params: 648,101
Trainable params: 648,101
Non-trainable params: 0
__________________________________________________________________________________
__________________
Model: "model_10"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_8 (InputLayer)         [(None, 2)]               0
_________________________________________________________________
dense_15 (Dense)             (None, 16384)             49152
_________________________________________________________________
reshape_3 (Reshape)          (None, 16, 16, 64)        0
_________________________________________________________________
conv2d_transpose_3 (Conv2DTr (None, 32, 32, 32)        18464
_________________________________________________________________
conv2d_17 (Conv2D)           (None, 32, 32, 1)         289
=================================================================
Total params: 67,905
Trainable params: 67,905
Non-trainable params: 0
_________________________________________________________________
```

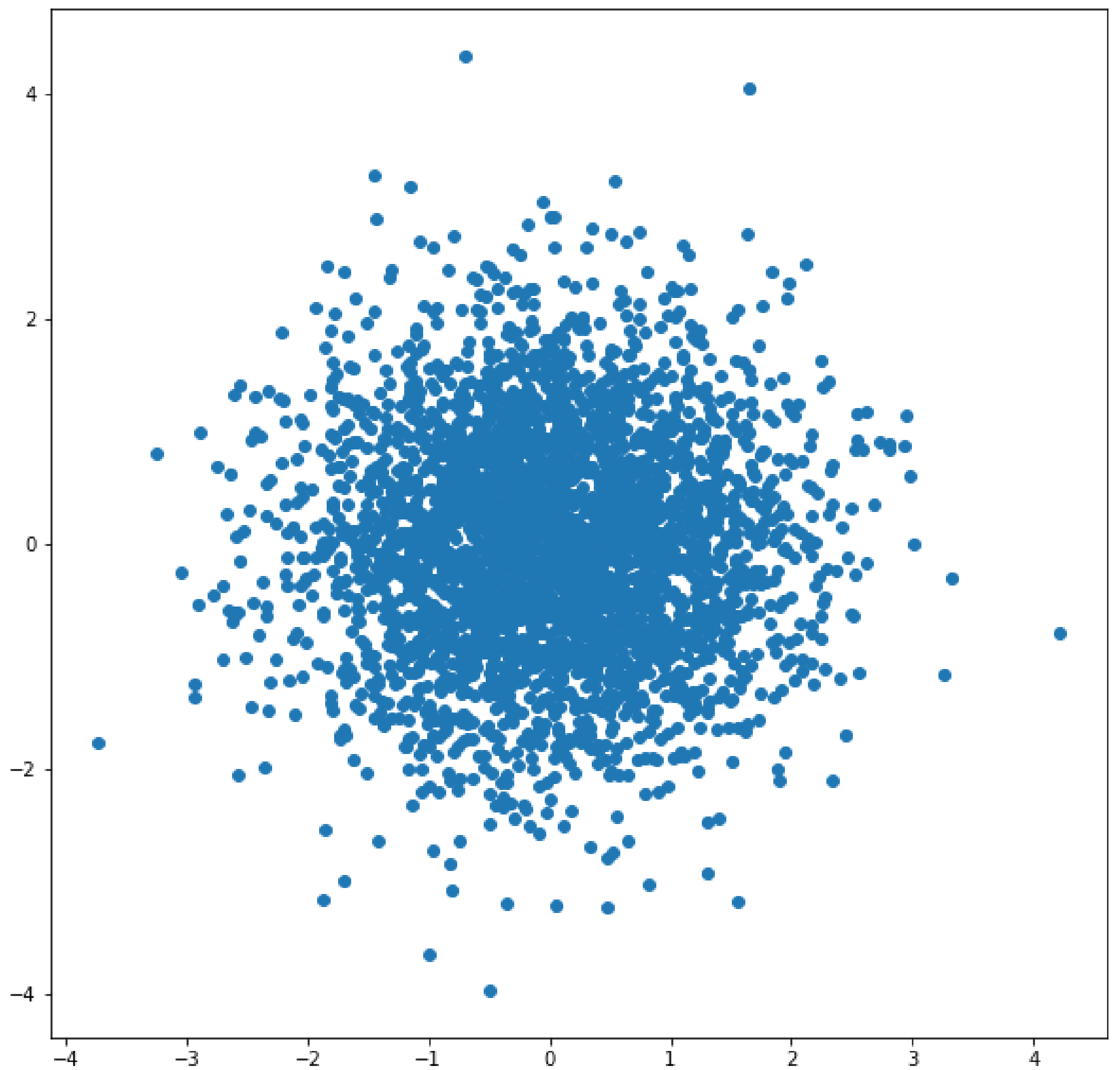
[73]:
```python
vae.fit(x=x_train, y=x_train, shuffle=True, epochs=10, batch_size=batch_size)
```

```
Train on 13258 samples
Epoch 1/10
13258/13258 [==============================] - 4s 311us/sample - loss: 0.0340
Epoch 2/10
13258/13258 [==============================] - 4s 271us/sample - loss:
8.3309e-04
Epoch 3/10
13258/13258 [==============================] - 4s 269us/sample - loss:
7.7646e-04
Epoch 4/10
13258/13258 [==============================] - 4s 268us/sample - loss:
7.5625e-04
Epoch 5/10
13258/13258 [==============================] - 4s 270us/sample - loss:
7.4923e-04
Epoch 6/10
13258/13258 [==============================] - 4s 269us/sample - loss:
7.4597e-04
Epoch 7/10
13258/13258 [==============================] - 4s 273us/sample - loss:
7.4378e-04
Epoch 8/10
13258/13258 [==============================] - 4s 270us/sample - loss:
7.4215e-04
Epoch 9/10
13258/13258 [==============================] - 4s 273us/sample - loss:
7.4100e-04
Epoch 10/10
13258/13258 [==============================] - 4s 272us/sample - loss:
7.4034e-04
```

[73]:
```
<tensorflow.python.keras.callbacks.History at 0x7f3f041ef390>
```

[74]:
```python
x_test_encoded_st = encoder.predict(x_test)
plt.figure(figsize=(10, 10))
plt.scatter(x_test_encoded[:, 0], x_test_encoded[:, 1])
plt.savefig('scatter_st.png')
plt.show()
```

```
/usr/local/lib/python3.7/dist-
packages/tensorflow/python/keras/engine/training.py:2325: UserWarning:
`Model.state_updates` will be removed in a future version. This property should
not be used in TensorFlow 2.0, as `updates` are applied automatically.
  warnings.warn('`Model.state_updates` will be removed in a future version. '
```

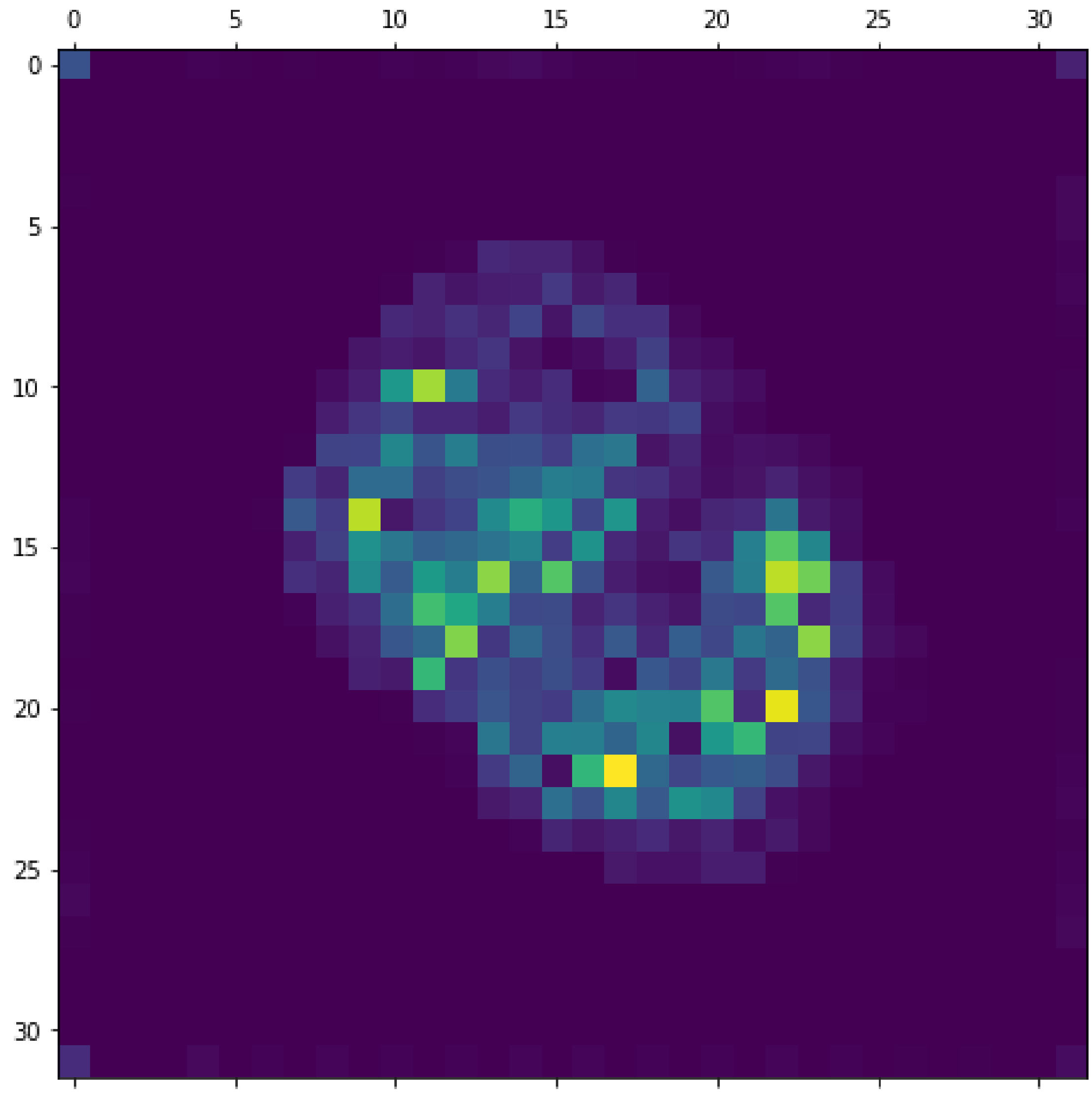


[75]:
```
def heatmap(num_of_images):
  mu_linspace = np.linspace(-8, 8, num_of_images)
  sigma_linspace = np.linspace(-4, -4, num_of_images)

  params = np.array(list(zip(mu_linspace, sigma_linspace)))
  decoded_new = decoder.predict(params).reshape(num_of_images, 32, 32)

  for index, param in enumerate(params):
    print('Image num: ', index+1)
    plt.matshow(decoded_new[index])
    plt.show()
```

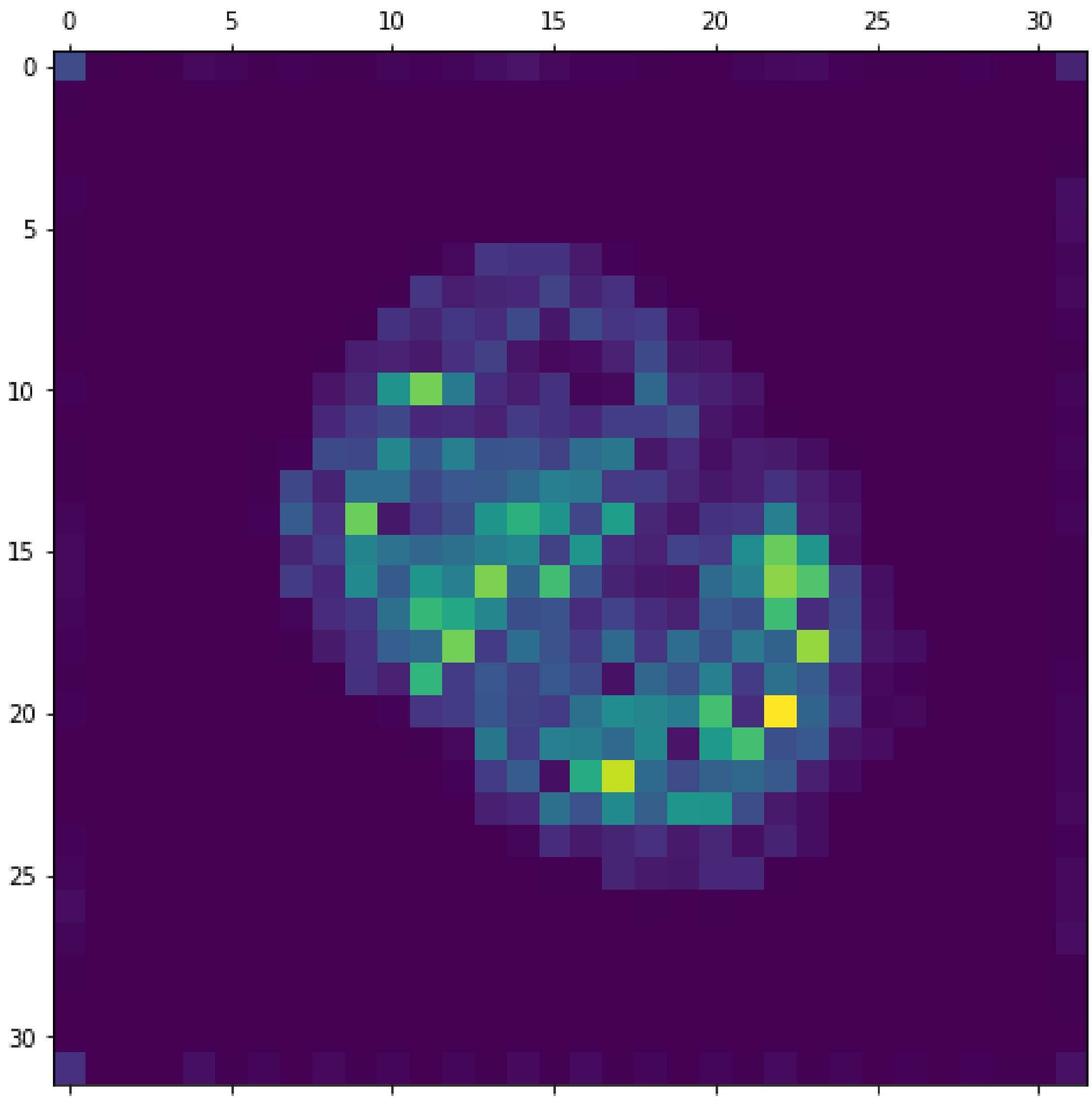
[76]:
```
heatmap(10)
```

```
/usr/local/lib/python3.7/dist-
packages/tensorflow/python/keras/engine/training.py:2325: UserWarning:
`Model.state_updates` will be removed in a future version. This property should
not be used in TensorFlow 2.0, as `updates` are applied automatically.
  warnings.warn('`Model.state_updates` will be removed in a future version. '
```

```
Image num:  1
```




```
Image num:  2
```




```
Image num:  3
```

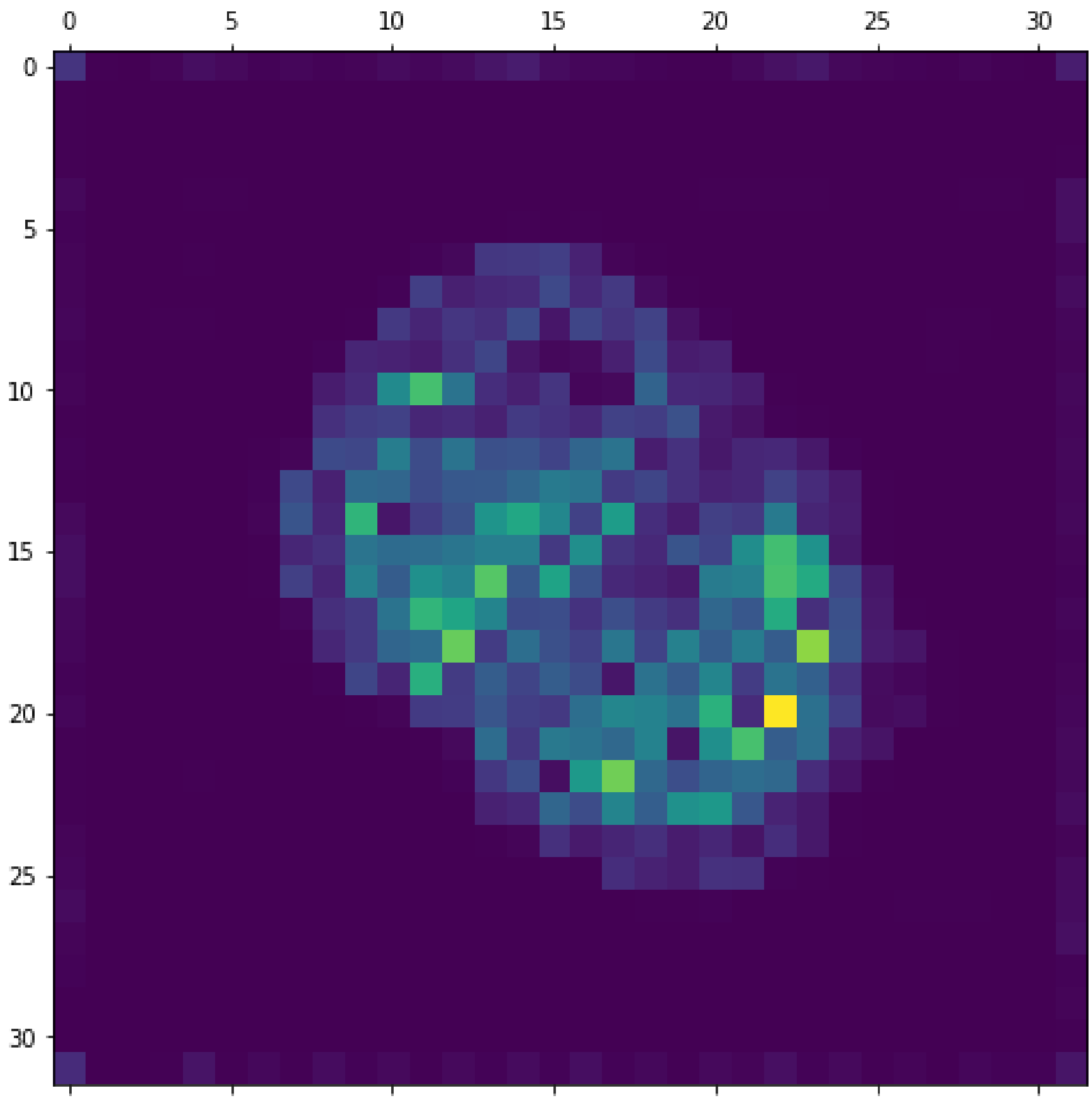


Image num: 4

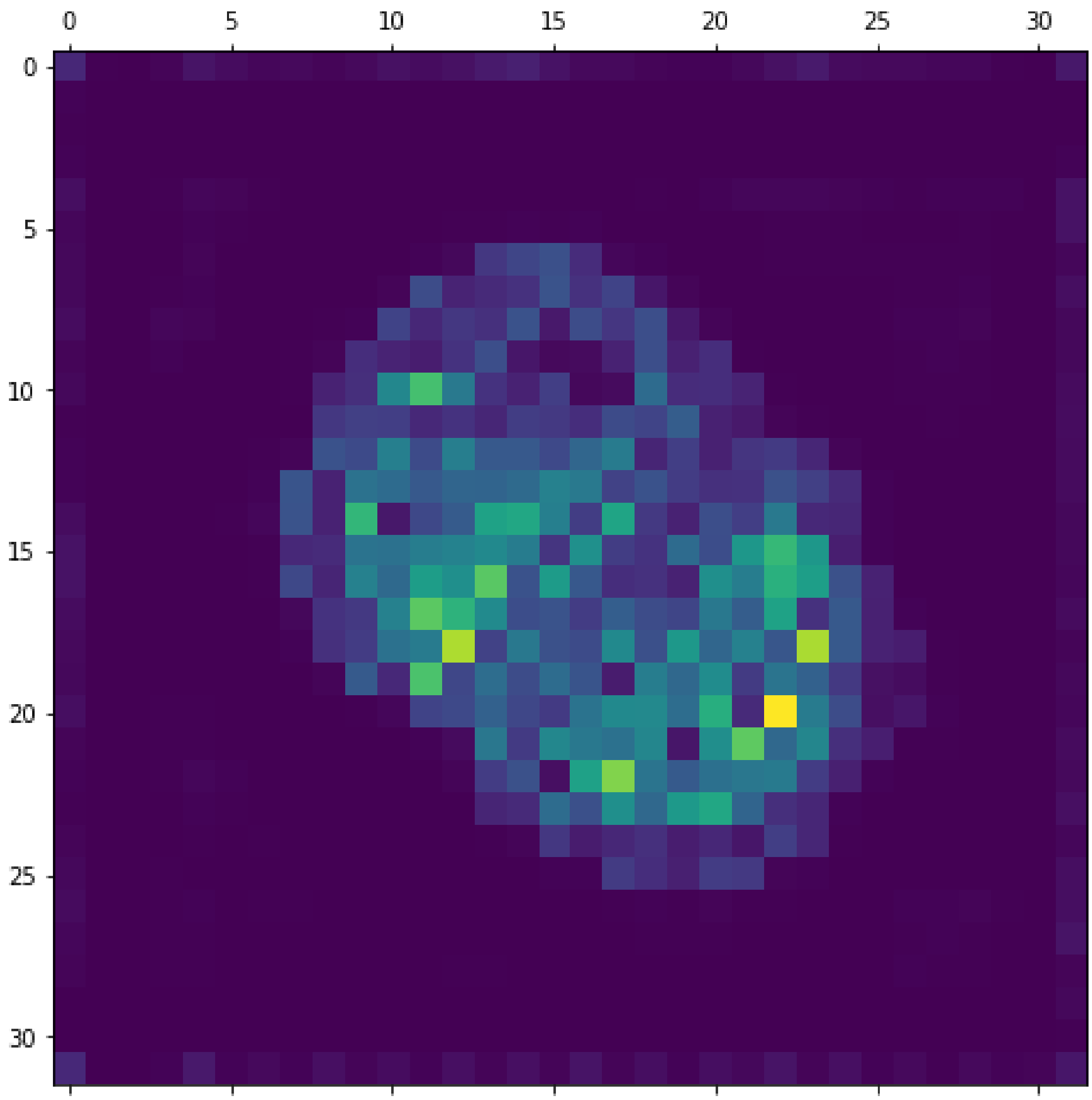
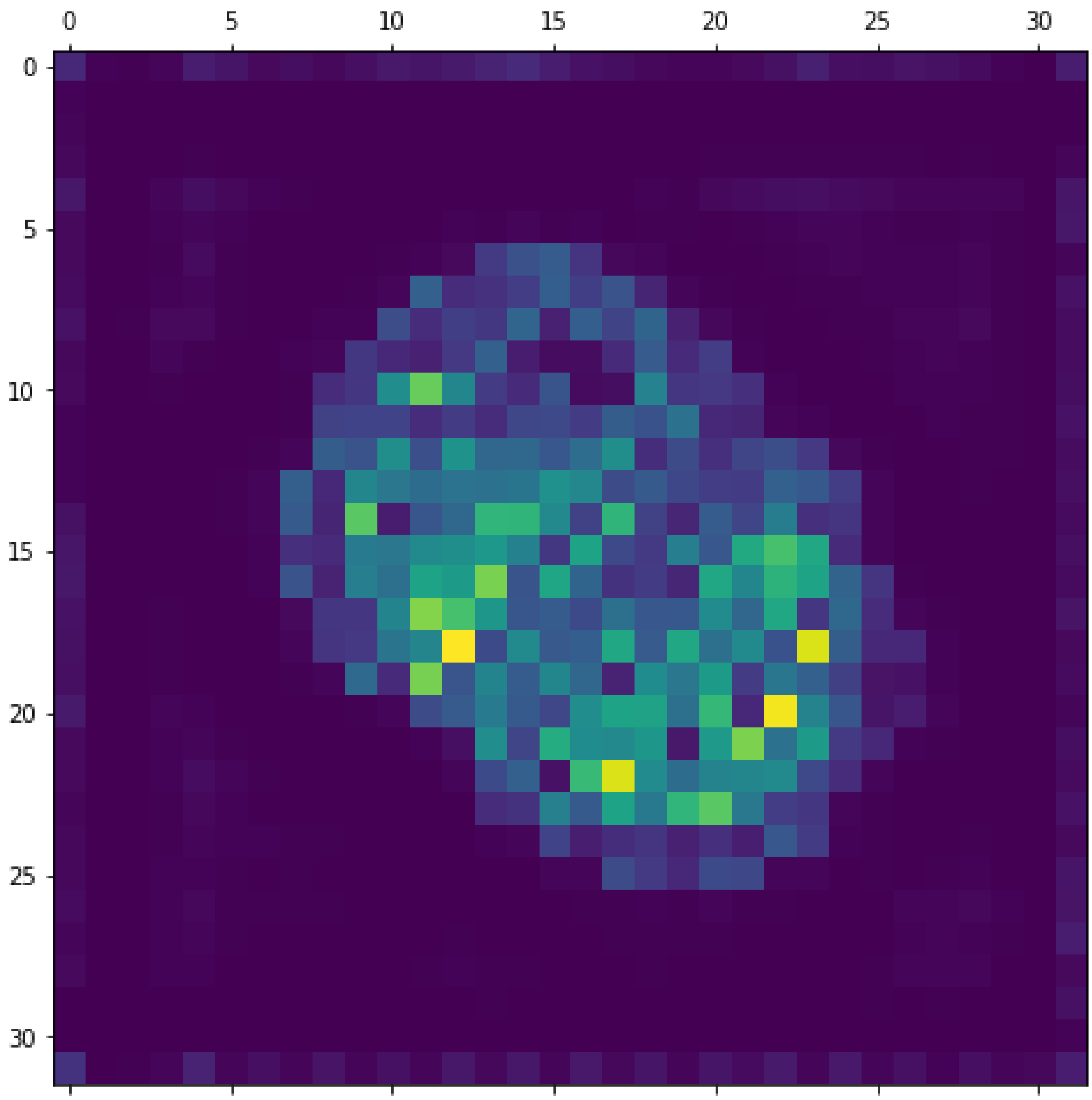
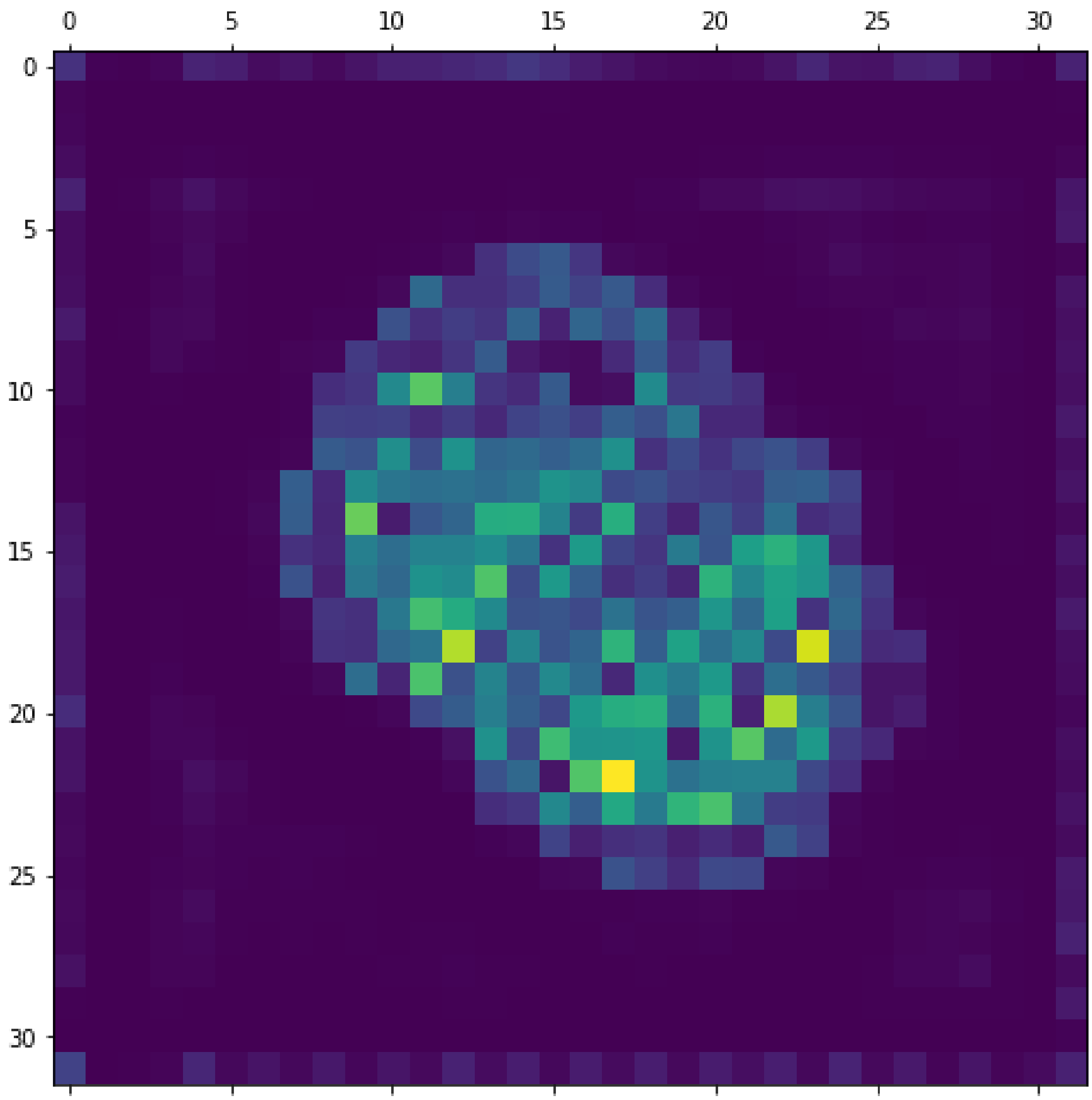


Image num: 5




```
Image num:  6
```




```
Image num:  7
```

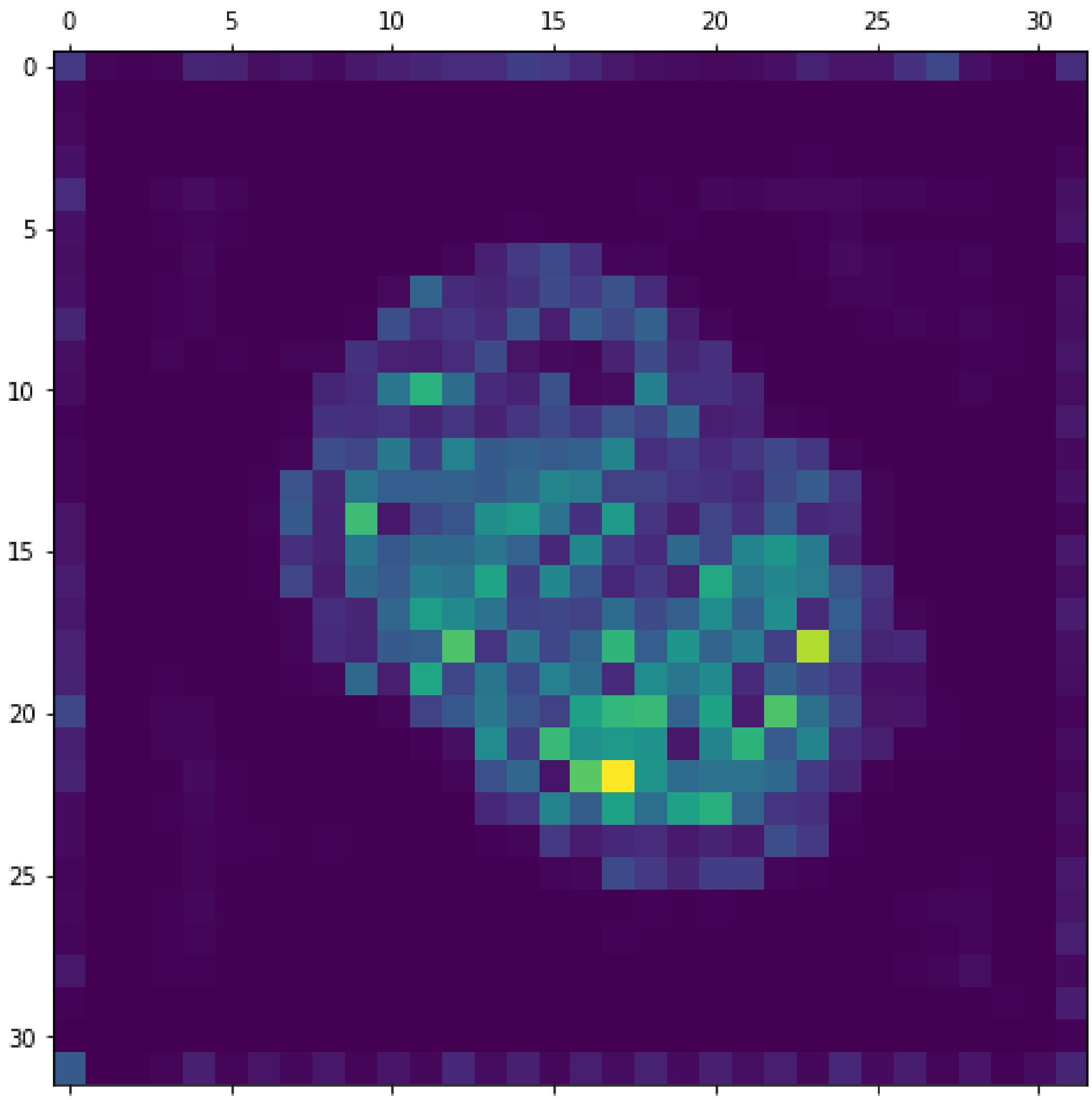


Image num: 8

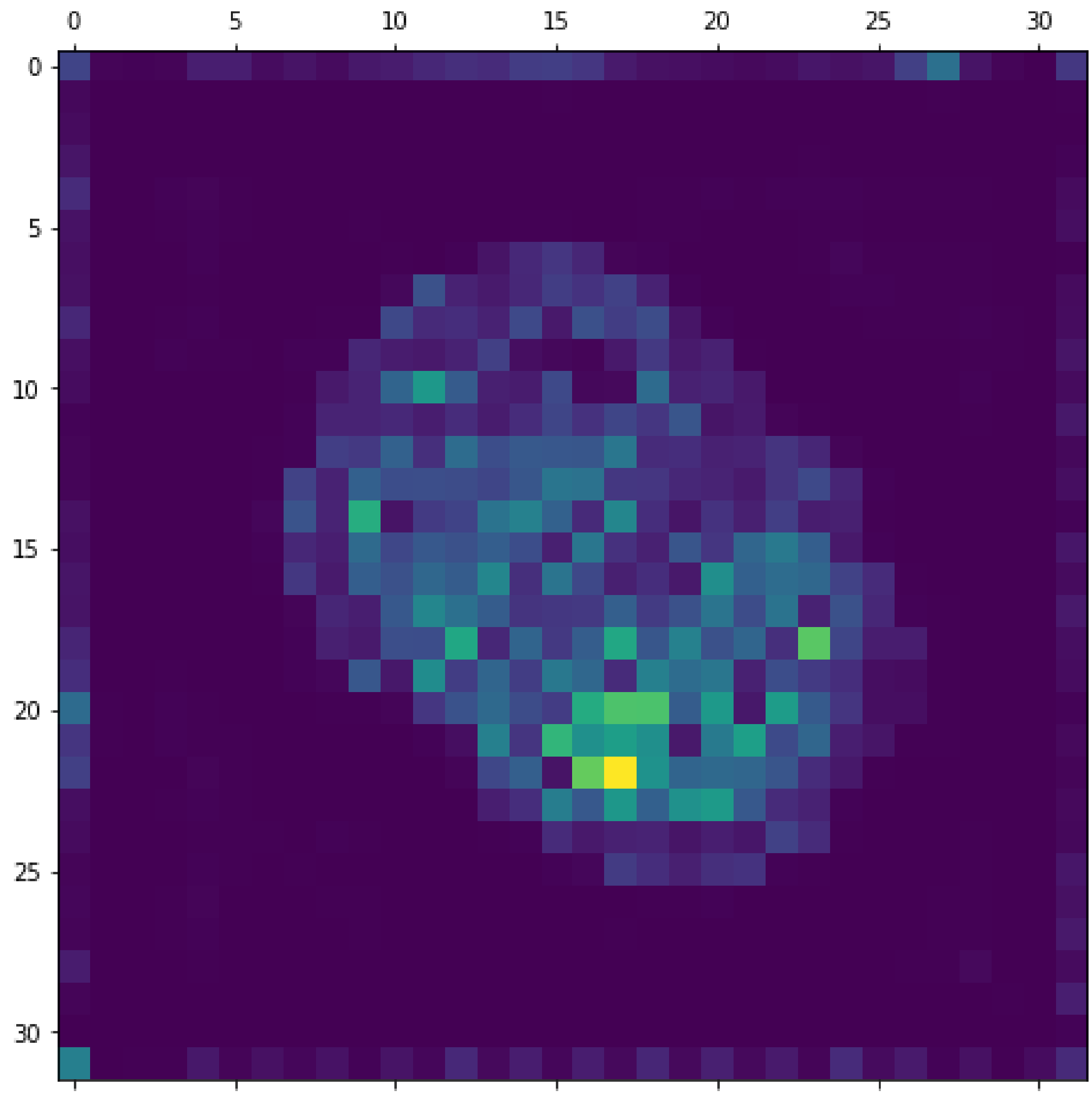
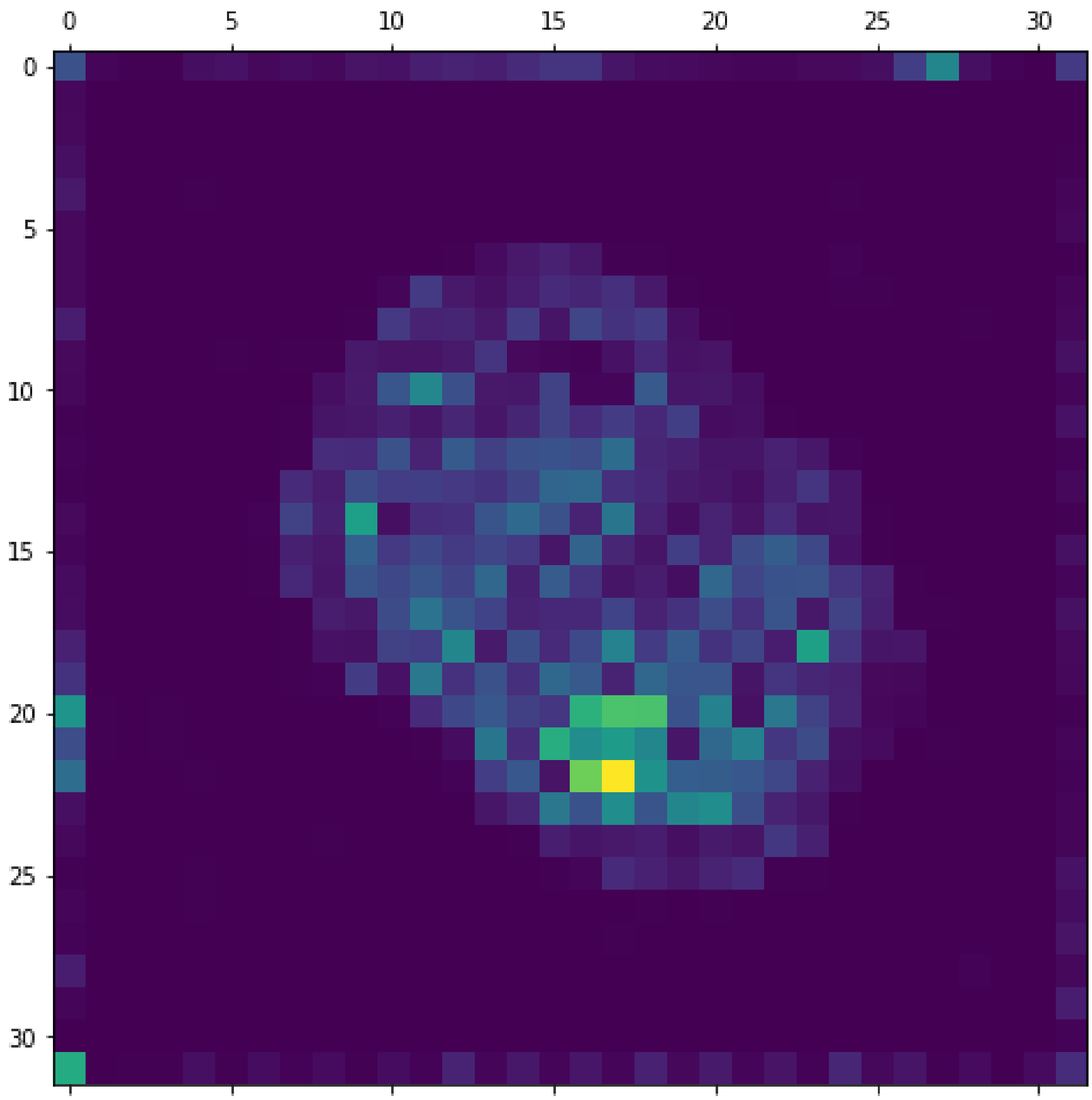


Image num: 9



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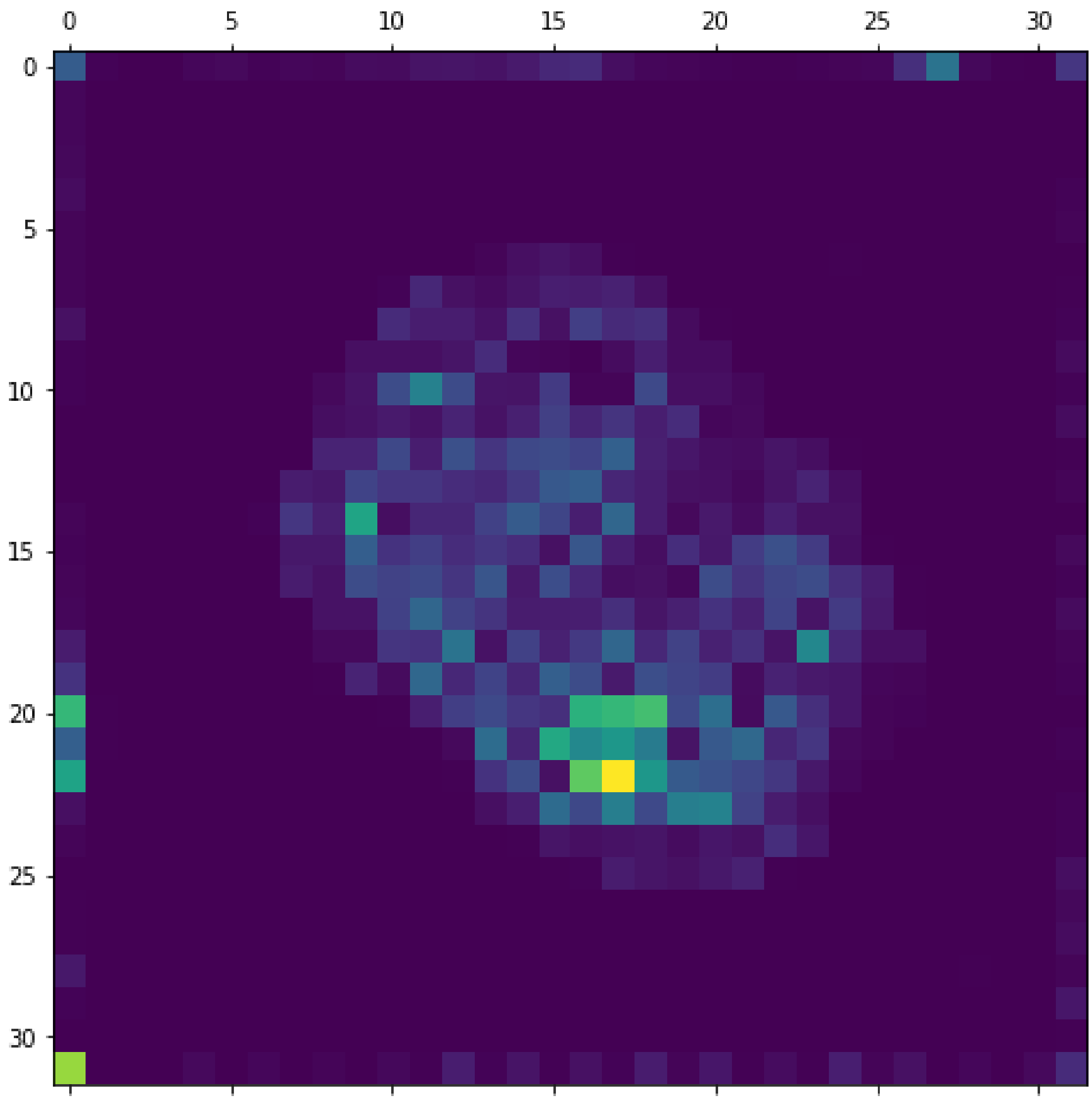
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