Problem 2

In [1]:
```
import numpy as np
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras.models import load_model
from tensorflow.keras.optimizers import Adam
#initialization code required to make tensorflow work on my systemabs
config = tf.compat.v1.ConfigProto()
config.gpu_options.allow_growth = True
session = tf.compat.v1.Session(config=config)
# #disabling eager execution
# tf.compat.v1.disable_eager_execution()
print("Num GPUs Available: ", len(tf.config.list_physical_devices('GPU')))
print("Tensorflow version: ",tf.__version__)
import math
from tensorflow.keras.losses import CategoricalCrossentropy
import pandas as pd
from tqdm import trange
import matplotlib.pyplot as plt
```

```
Num GPUs Available:  1
Tensorflow version:  2.4.0
```

load trained model (without softmax) and test images

In [2]:
```
model = keras.models.load_model(r'model')
x_attack_test = np.load(r'x_attack_test.npy')
y_attack_test = np.load(r'y_attack_test.npy')
#make sure it is not trainable
model.trainable = False
```

l2 dist utility

In [3]:
```
#l2 dist is a utility we will use
def l2_squared(a,b):
    #returns the square of the l2 norm of the given matrices (multiple batches)
    #given matrices must have equal dimension
    assert a.shape == b.shape
    return tf.reduce_sum(tf.math.square(a - b),axis=[1,2,3])
```

General C&W attack framework

In [7]:
```
class CustomCW:
    ## my custom custom CW attack class: customizable objective function
    def __init__(self,c,objective,num_iters,learning_rate,verbose=False):
        self.c = c
        self.objective = objective
        self.num_iters = num_iters
        self.lr=learning_rate
        self.verbose = verbose
```

```
    def delta(self,w):
        #simply applies tanh to the given input multiplies by half and adds 1 and adds
        #this is the perturbation
        out =  0.5*(tf.tanh(w)+1)
        return out


    def get_loss(self,x,adv_x):
        #x and transformed to tanh space for optimization as per C&W code: this improve
        loss = l2_squared(adv_x,self.delta(x)) + self.c*self.objective.get_obj(adv_x)
        #sum up losses across images
        return tf.reduce_sum(loss)



    def attack(self,images):
        ##attack the images so they  are misclassified to the target class

        #w and orginal images as tensorflow variables
        w = tf.Variable(np.zeros(images.shape,dtype=np.float32))
        original_images = tf.Variable(images,dtype=np.float32)

        optimizer = Adam(self.lr)

        #so we can stop training wehen loss stops increasing
        prev_loss = math.inf


        for it in trange(self.num_iters):
            with tf.GradientTape() as tape:
                delta = self.delta(w)
                adversarial_images = original_images + delta

                loss = self.get_loss(original_images,adversarial_images)

                #stop training if loss stops decreasing by 0.1
                if(abs(prev_loss-loss)<0.1):
                    break


            #update w using gradients
            gradients = tape.gradient(loss, [w])
            optimizer.apply_gradients(zip(gradients, [w]))

            #printing out progress
            if(it%100==0 and self.verbose):
                print(f"iteration {it}: loss = {loss}")


        #return images
        return adversarial_images
```

(1) Szedegy et al objective

In [8]:
```
class szedegy:
    #thi class is a function object that applies the loss function from szedegy et al:
    #the objective in question here is simply the cross entropy loss on the target clas

    def __init__(self, model, target, num_classes):
        #init with model we are attacking and target

        self.model = model
        self.num_classes = num_classes

        #transform target to categorical space
        target_cat = [0]*num_classes
        target_cat[target] = 1
        self.target = tf.constant([target_cat])

        #loss object: we use categorical cross entropy
        self.loss = CategoricalCrossentropy(from_logits=True)

    def get_obj(self,adv_x):
        batch_size = len(adv_x)
        #get logits on adv_x
        logits = self.model(adv_x)
        #simply returns cross entropy loss wrt to target

        return self.loss(tf.broadcast_to(self.target,[batch_size,self.num_classes]),log
```

(2) f_6 objective from C&W paper

In [9]:
```
class f6:

    #this class is a function object that applies f6 loss from the C&W Paper
    def __init__(self,model,target,num_classes):
        self.model = model
        self.target = target
        self.num_classes = num_classes

    def get_max_z_not_t(self,logits):
        #gets the maximum logit thats not the target class
        return tf.reduce_max(tf.gather(logits,indices = [i for i in list(range(self.num
    def get_obj(self,x_adv):
        #returns the f6 objective of the given adversarial image
        logits = self.model(x_adv)
        return tf.math.maximum(self.get_max_z_not_t(logits)-logits[:,self.target],tf.co
```

Problem 2a - adversarial success as a function of c

In [13]:
```
#same learning rate as ART to standardize
learning_rate = 0.01
num_iters = 50
constants = constants = [0.5,1,5,10]

target = 7
num_test_samples = len(x_attack_test)
num_classes = 10
```

Szedegy objective

In [14]:
```
#store attack metrics for various c's in a list of dictionaries
szedegy_attack_metrics = []
for idx,c in enumerate(constants):
    ## Szedegy objective

    print(f"=====attacking at c = {c}=====")
    #generate attack images
    szedegy_obj = szedegy(model,target,num_classes)
    sz_cw = CustomCW(c,szedegy_obj,num_iters,learning_rate)
    sz_attacks = sz_cw.attack(x_attack_test)

    #predictions
    sz_predict = model.predict(sz_attacks)

    #calculate success rate
    success_mask = np.argmax(sz_predict, axis=1) == target
    attack_success_rate = sum(success_mask)/num_test_samples


    #calculate l2 norm
    l2dist = np.sqrt(np.sum(np.square(x_attack_test - sz_attacks).reshape(num_test_samp

    #create series out of l2 dist to pull out min,max,median
    l2dist = pd.Series(l2dist,index=range(num_test_samples))


    #Report attack success rate and avg l2 norm
    print(f"Attack Success Rate targeted C&W attack with Szedegy obj at c= {c} : {round
    print(f"Avg L2 Norm on targeted C&W with Szedegy obj at c = {c} : {round(l2dist.mea



    min_l2_idx = pd.Series.idxmin(l2dist[success_mask])
    max_l2_idx = pd.Series.idxmax(l2dist[success_mask])
    median_l2_idx = int(l2dist[success_mask].sort_values(ignore_index=False).reset_inde


    #append the l2 metrics
    szedegy_attack_metrics.append(
    {
        'c':c,
        'attack_success_rate':attack_success_rate,
        'min_l2_idx':min_l2_idx,
```

```
        'max_l2_idx':max_l2_idx,
        'median_l2_idx':median_l2_idx,

        'min_l2':l2dist[min_l2_idx],
        'max_l2':l2dist[max_l2_idx],
        'median_l2':l2dist[median_l2_idx],

        'original_image_min_l2':x_attack_test[min_l2_idx],
        'original_image_max_l2':x_attack_test[max_l2_idx],
        'original_image_median_l2':x_attack_test[median_l2_idx],

        'attack_image_min_l2':sz_attacks[min_l2_idx],
        'attack_image_max_l2':sz_attacks[max_l2_idx],
        'attack_image_median_l2':sz_attacks[median_l2_idx],

        'perturbation_min_l2':x_attack_test[min_l2_idx]- sz_attacks[min_l2_idx],
        'perturbation_max_l2':x_attack_test[max_l2_idx] - sz_attacks[max_l2_idx],
        'perturbation_median_l2':x_attack_test[median_l2_idx] - sz_attacks[median_l2_id



    })
```

```
=====attacking at c = 0.5=====
100%|████████████████████████████████████████████████████████████████████████████████
████████| 50/50 [00:00<00:00, 63.37it/s]
Attack Success Rate targeted C&W attack with Szedegy obj at c= 0.5 : 35.0%
Avg L2 Norm on targeted C&W with Szedegy obj at c = 0.5 : 13.279999732971191
=====attacking at c = 1=====
100%|████████████████████████████████████████████████████████████████████████████████
████████| 50/50 [00:00<00:00, 62.74it/s]
Attack Success Rate targeted C&W attack with Szedegy obj at c= 1 : 56.0%
Avg L2 Norm on targeted C&W with Szedegy obj at c = 1 : 13.350000381469727
=====attacking at c = 5=====
100%|████████████████████████████████████████████████████████████████████████████████
████████| 50/50 [00:00<00:00, 63.69it/s]
Attack Success Rate targeted C&W attack with Szedegy obj at c= 5 : 71.0%
Avg L2 Norm on targeted C&W with Szedegy obj at c = 5 : 13.649999618530273
=====attacking at c = 10=====
100%|████████████████████████████████████████████████████████████████████████████████
████████| 50/50 [00:00<00:00, 61.73it/s]
Attack Success Rate targeted C&W attack with Szedegy obj at c= 10 : 71.0%
Avg L2 Norm on targeted C&W with Szedegy obj at c = 10 : 13.800000190734863
```

In [28]:

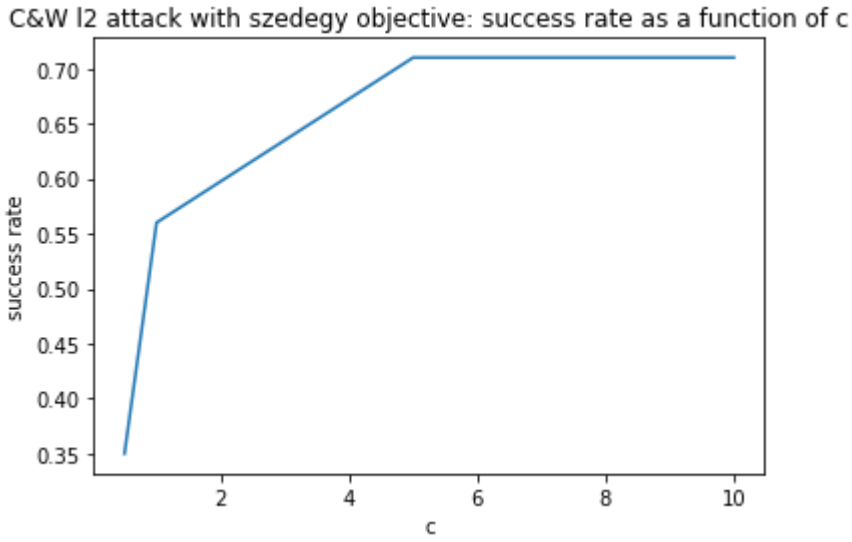
```
szedegy_df = pd.DataFrame(szedegy_attack_metrics)
```

In [29]:

```
fig = plt.figure()
ax = plt.axes()
ax.plot(szedegy_df['c'], szedegy_df['attack_success_rate'])
plt.title("C&W l2 attack with szedegy objective: success rate as a function of c")
```

```
plt.xlabel("c")
plt.ylabel("success rate")
```

Out[29]:
```
Text(0, 0.5, 'success rate')
```



f_6 objective from C&W paper

In [15]:
```
#store attack metrics for various c's in a list of dictionaries
f6_attack_metrics = []
for idx,c in enumerate(constants):
    ## f6 objective

    print(f"=====attacking at c = {c}=====")
    #generate attack images
    f6_obj = f6(model,target,num_classes)
    #higher learning rates for lower c's
    f6_cw = CustomCW(c,f6_obj,num_iters,learning_rate)
    f6_attacks = f6_cw.attack(x_attack_test)

    #predictions
    f6_predict = model.predict(f6_attacks)

    #calculate success rate
    success_mask = np.argmax(f6_predict, axis=1) == target
    attack_success_rate = sum(success_mask)/num_test_samples


    #calculate l2 norm
    l2dist = np.sqrt(np.sum(np.square(x_attack_test - f6_attacks).reshape(num_test_samp
    #create series out of l2 dist to pull out min,max,median
    l2dist = pd.Series(l2dist,index=range(num_test_samples))


    #Report attack success rate and avg l2 norm
    print(f"Attack Success Rate targeted C&W attack with f6 obj at c= {c} : {round(atta
    print(f"Avg L2 Norm on targeted C&W with f6 obj at c = {c} : {round(l2dist.mean(),2

    min_l2_idx = pd.Series.idxmin(l2dist[success_mask])
    max_l2_idx = pd.Series.idxmax(l2dist[success_mask])
    median_l2_idx = int(l2dist[success_mask].sort_values(ignore_index=False).reset_inde
```

```
    #append the l2 metrics
    f6_attack_metrics.append(
    {
        'c':c,
        'attack_success_rate':attack_success_rate,
        'min_l2_idx':min_l2_idx,
        'max_l2_idx':max_l2_idx,
        'median_l2_idx':median_l2_idx,

        'min_l2':l2dist[min_l2_idx],
        'max_l2':l2dist[max_l2_idx],
        'median_l2':l2dist[median_l2_idx],

        'original_image_min_l2':x_attack_test[min_l2_idx],
        'original_image_max_l2':x_attack_test[max_l2_idx],
        'original_image_median_l2':x_attack_test[median_l2_idx],

        'attack_image_min_l2':f6_attacks[min_l2_idx],
        'attack_image_max_l2':f6_attacks[max_l2_idx],
        'attack_image_median_l2':f6_attacks[median_l2_idx],

        'perturbation_min_l2':x_attack_test[min_l2_idx]- f6_attacks[min_l2_idx],
        'perturbation_max_l2':x_attack_test[max_l2_idx] - f6_attacks[max_l2_idx],
        'perturbation_median_l2':x_attack_test[median_l2_idx] - f6_attacks[median_l2_id




    })
```

```
=====attacking at c = 0.5=====
100%|████████████████████████████████████████████████████████████████████████████████
████████| 50/50 [00:00<00:00, 59.17it/s]
Attack Success Rate targeted C&W attack with f6 obj at c= 0.5 : 32.0%
Avg L2 Norm on targeted C&W with f6 obj at c = 0.5 : 13.289999961853027
=====attacking at c = 1=====
100%|████████████████████████████████████████████████████████████████████████████████
████████| 50/50 [00:00<00:00, 58.89it/s]
Attack Success Rate targeted C&W attack with f6 obj at c= 1 : 48.0%
Avg L2 Norm on targeted C&W with f6 obj at c = 1 : 13.359999656677246
=====attacking at c = 5=====
100%|████████████████████████████████████████████████████████████████████████████████
████████| 50/50 [00:00<00:00, 59.74it/s]
Attack Success Rate targeted C&W attack with f6 obj at c= 5 : 73.0%
Avg L2 Norm on targeted C&W with f6 obj at c = 5 : 13.680000305175781
=====attacking at c = 10=====
100%|████████████████████████████████████████████████████████████████████████████████
████████| 50/50 [00:00<00:00, 59.17it/s]
Attack Success Rate targeted C&W attack with f6 obj at c= 10 : 75.0%
Avg L2 Norm on targeted C&W with f6 obj at c = 10 : 13.819999694824219
```

In [30]:

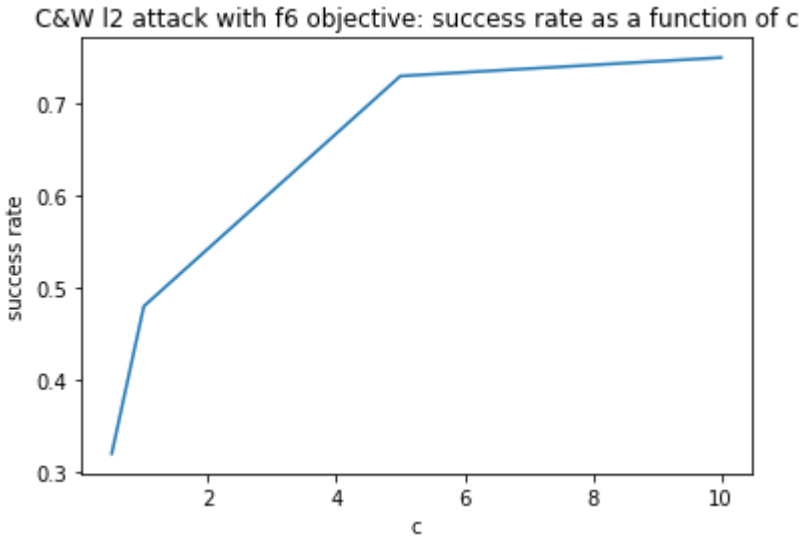
```
f6_df = pd.DataFrame(f6_attack_metrics)
```

In [31]:

```
fig = plt.figure()
ax = plt.axes()
ax.plot(f6_df['c'], f6_df['attack_success_rate'])
plt.title("C&W l2 attack with f6 objective: success rate as a function of c")
```

```
plt.xlabel("c")
plt.ylabel("success rate")
```

Out[31]:
```
Text(0, 0.5, 'success rate')
```



Observations

1. Szegedy objective seems to perform slightly worse than the f_6 objective, but only for the high values of c like 5 and 10. It performs better than f_6 for low values of c
2. Both attacks have very similar avg l2 perturbation norms, which dont vary much as per c.

Problem 2b Min,Max and Median l2 distance images for various values of c: Successful Carlini Wagner attacks

Szedegy objective

In [34]:
```
szedegy_df[['c','attack_success_rate','min_l2_idx','min_l2','max_l2_idx','max_l2','medi
```

Out[34]:

	c	attack_success_rate	min_l2_idx	min_l2	max_l2_idx	max_l2	median_l2_idx	median_l2
0	0.5	0.35	10	12.843558	50	13.571725	1	13.209056
1	1.0	0.56	51	12.629746	55	13.789464	53	13.385027
2	5.0	0.71	77	13.042408	28	14.113783	82	13.674903
3	10.0	0.71	1	13.203969	28	14.229536	82	13.847279

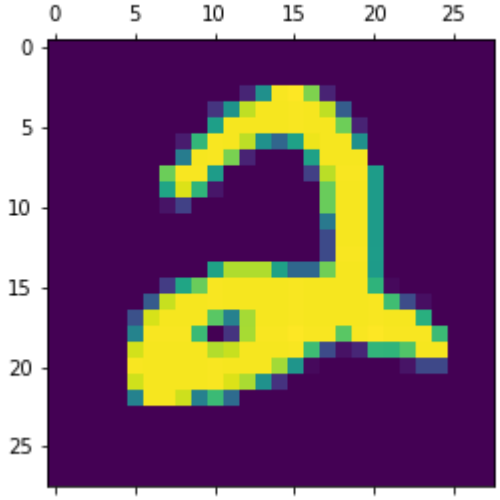
C = 0.5

In [16]:
```
c_i,c = 0,0.01
print(f"==========MIN L2 ================")
l2_type = "min_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
```

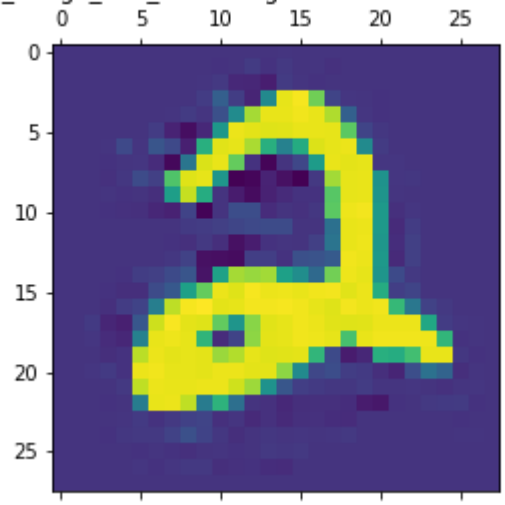
```
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

print(f"===========MAX L2 ================")
l2_type = "max_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

print(f"===========MEDIAN L2 ================")
l2_type = "median_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()
```

```
===========MIN L2 ================
```

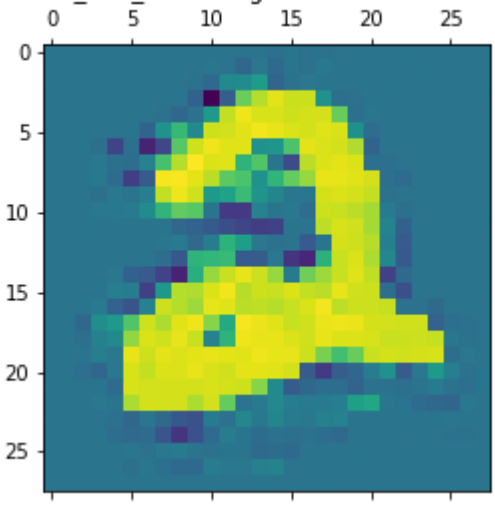
original_image_min_l2 for targeted C&W attack at c = 0.01



attack_image_min_l2 for targeted C&W attack at c = 0.01

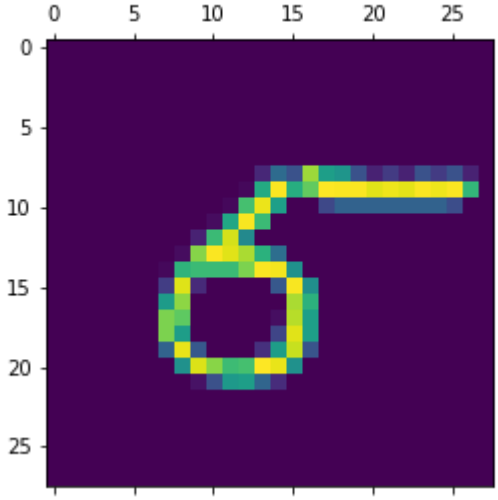


perturbation_min_l2 for targeted C&W attack at c = 0.01

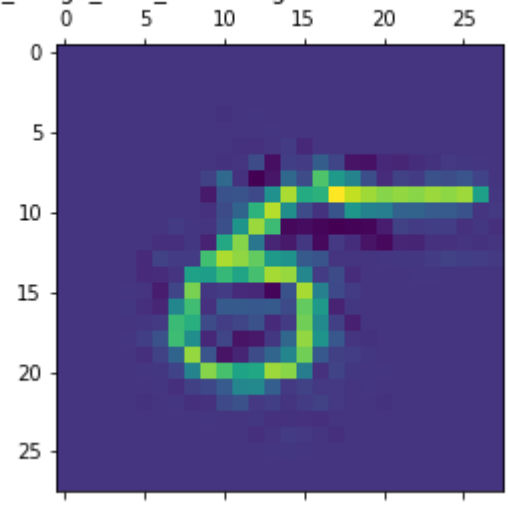


==========MAX L2 ================

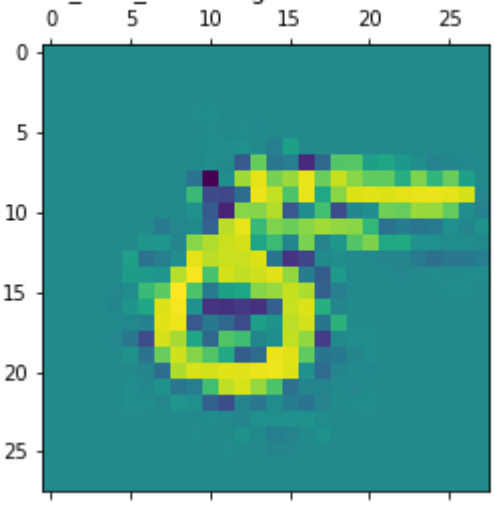
original_image_max_l2 for targeted C&W attack at c = 0.01



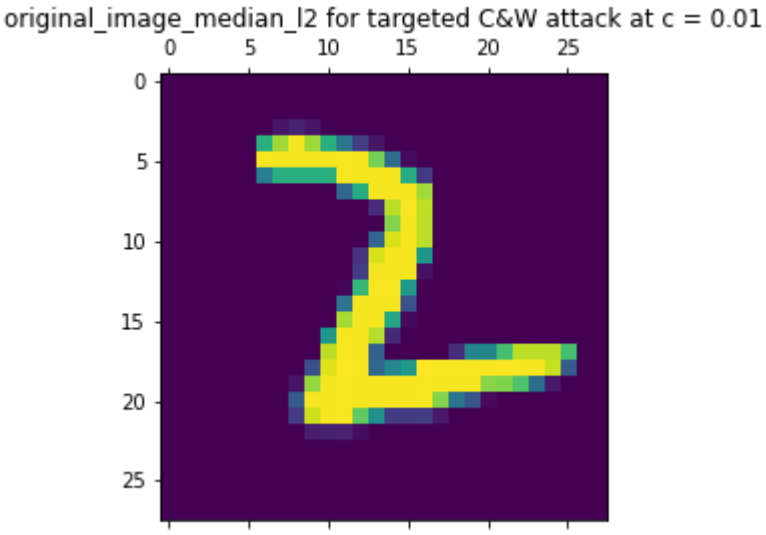
attack_image_max_l2 for targeted C&W attack at c = 0.01

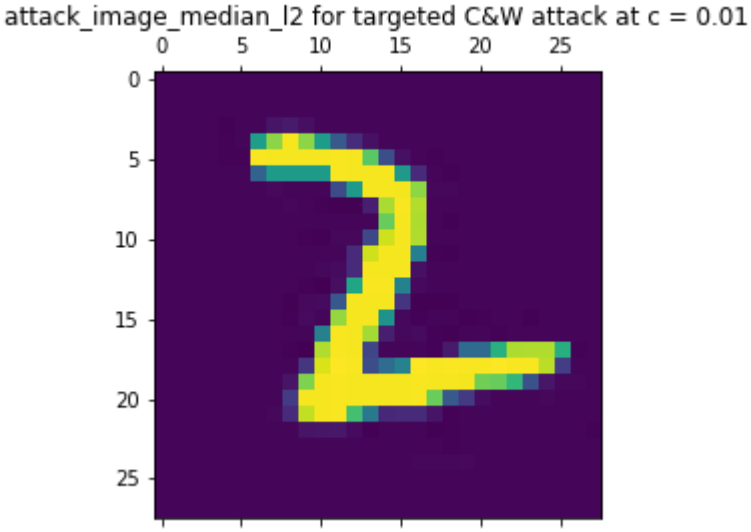


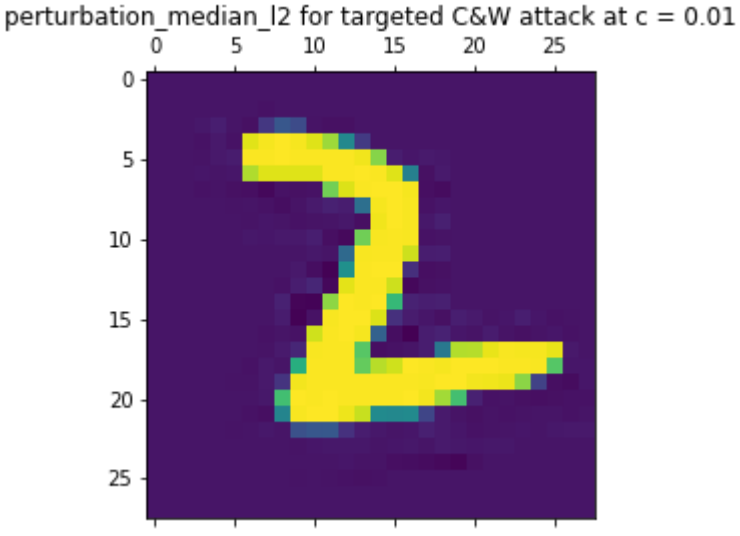
perturbation_max_l2 for targeted C&W attack at c = 0.01




```
==========MEDIAN L2 ================
```







C = 1

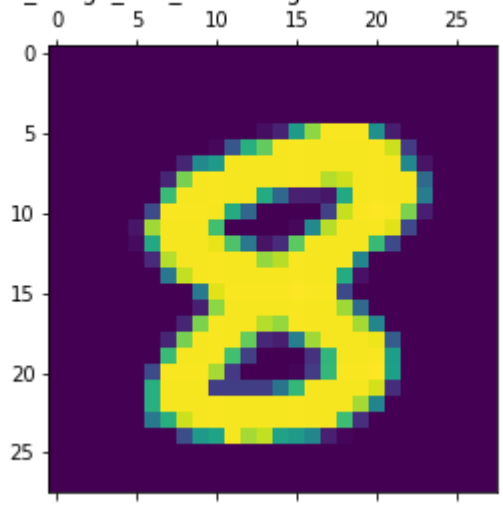
In [18]:

```
c_i,c = 1,1
print(f"===========MIN L2 ================")
l2_type = "min_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
```

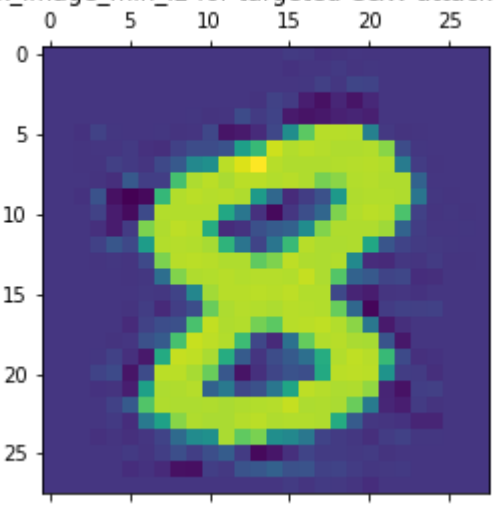
```
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

print(f"===========MAX L2 ================")
l2_type = "max_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

print(f"===========MEDIAN L2 ================")
l2_type = "median_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()
```

```
===========MIN L2 ================
```

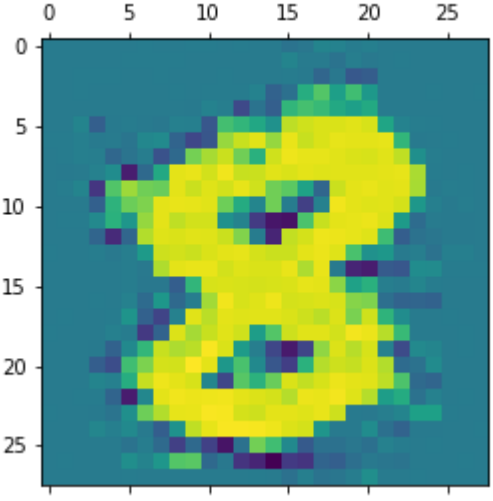
original_image_min_l2 for targeted C&W attack at c = 1



attack_image_min_l2 for targeted C&W attack at c = 1

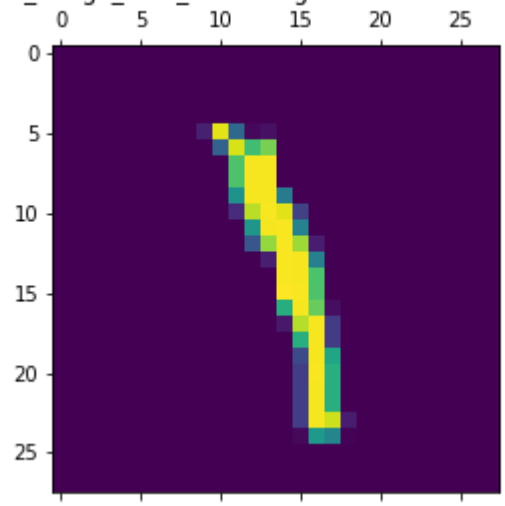


perturbation_min_l2 for targeted C&W attack at c = 1

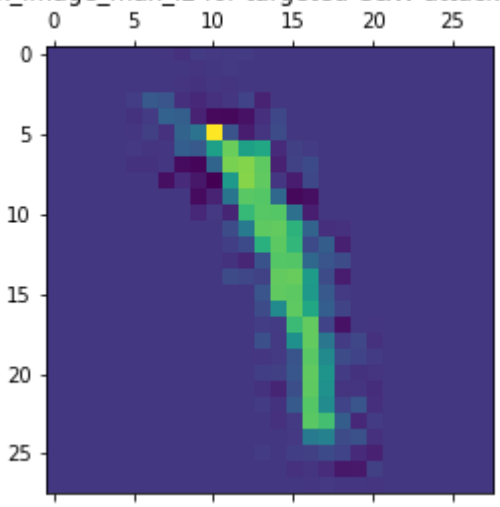


==========MAX L2 ================

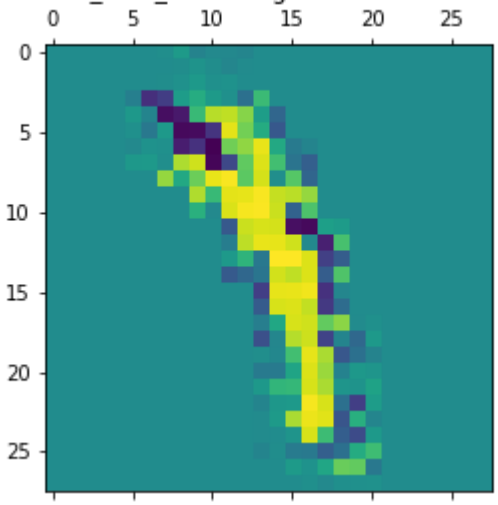
original_image_max_l2 for targeted C&W attack at c = 1



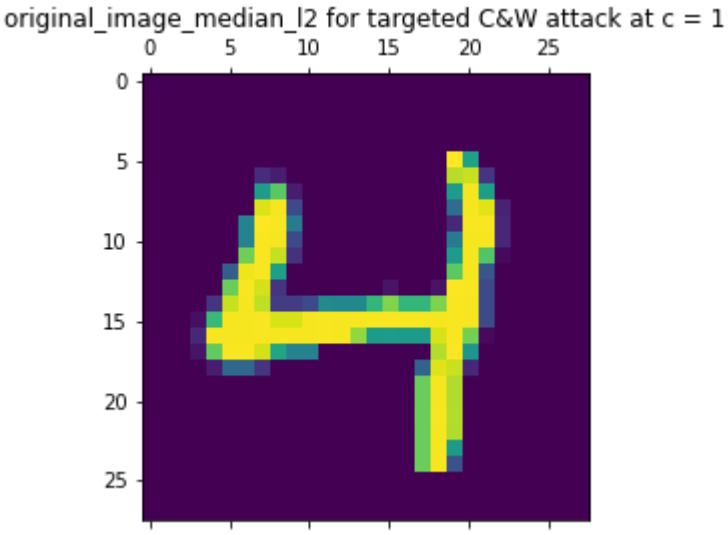
attack_image_max_l2 for targeted C&W attack at c = 1

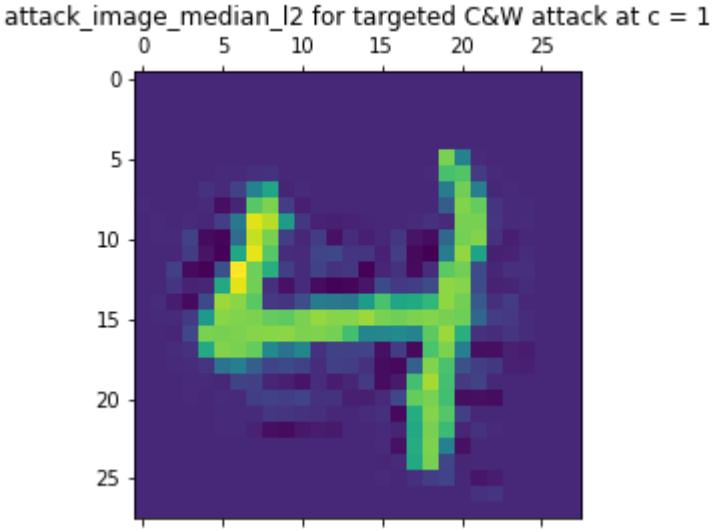


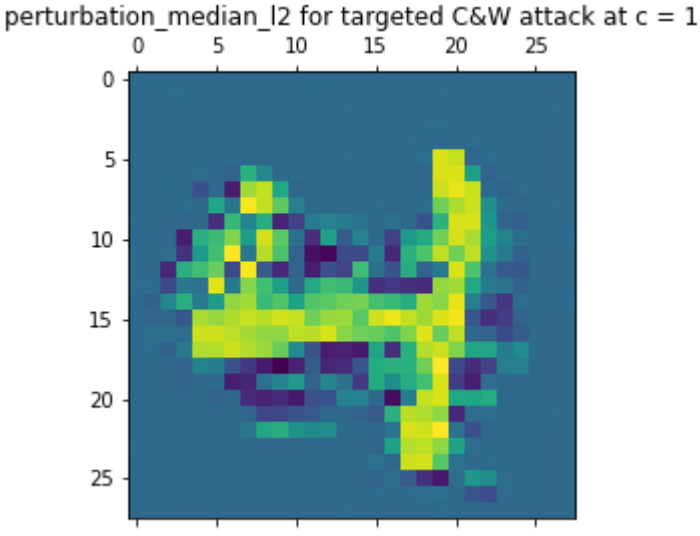
perturbation_max_l2 for targeted C&W attack at c = 1




```
==========MEDIAN L2 ================
```







C= 5

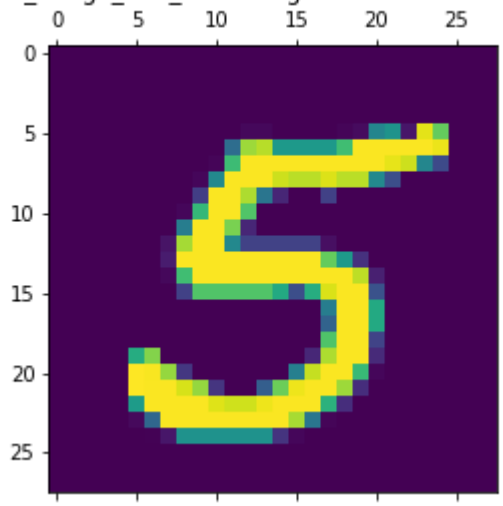
In [19]:

```
c_i,c = 2,5
print(f"===========MIN L2 ================")
l2_type = "min_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
```

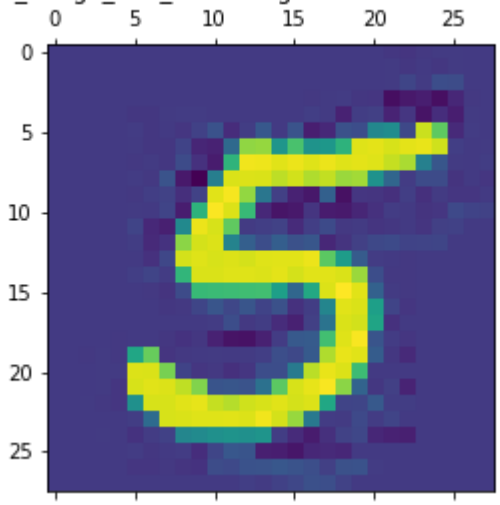
```
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

print(f"===========MAX L2 ================")
l2_type = "max_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

print(f"===========MEDIAN L2 ================")
l2_type = "median_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()
```

```
===========MIN L2 ================
```

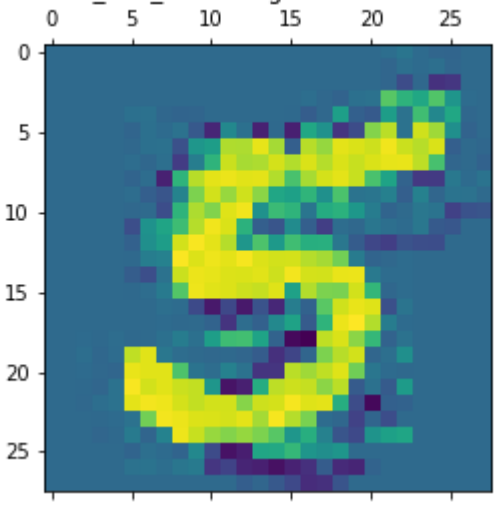
original_image_min_l2 for targeted C&W attack at c = 5



attack_image_min_l2 for targeted C&W attack at c = 5

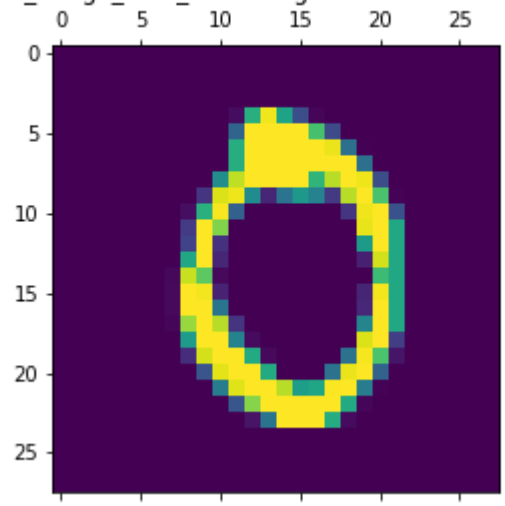


perturbation_min_l2 for targeted C&W attack at c = 5

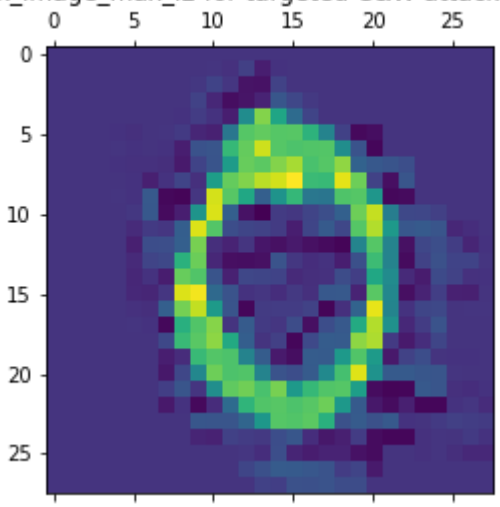


==========MAX L2 ================

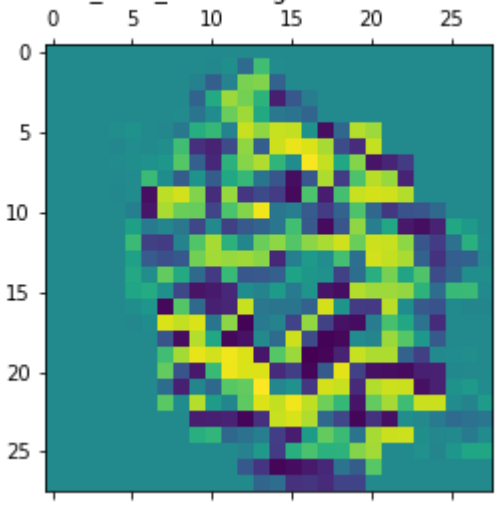
original_image_max_l2 for targeted C&W attack at c = 5



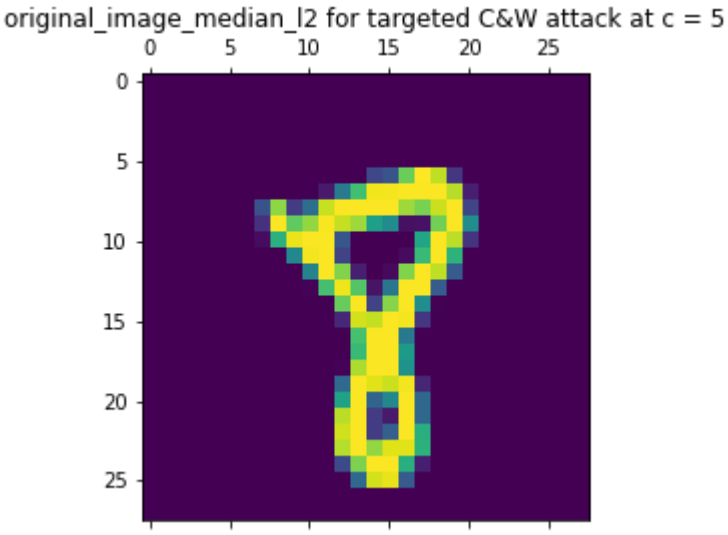
attack_image_max_l2 for targeted C&W attack at c = 5

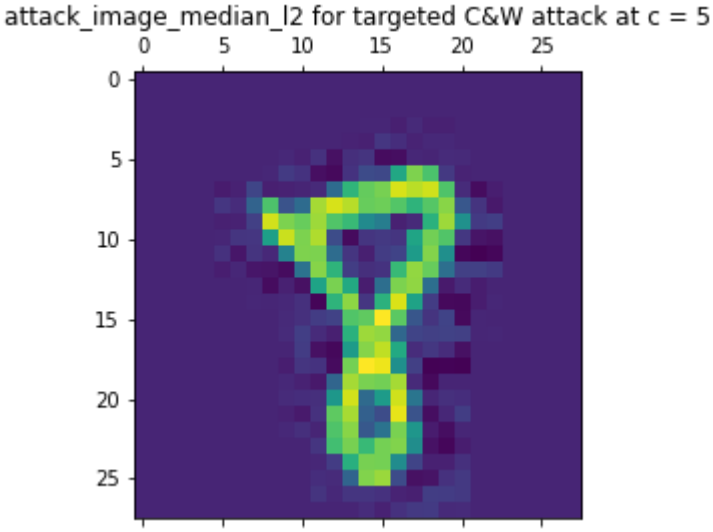


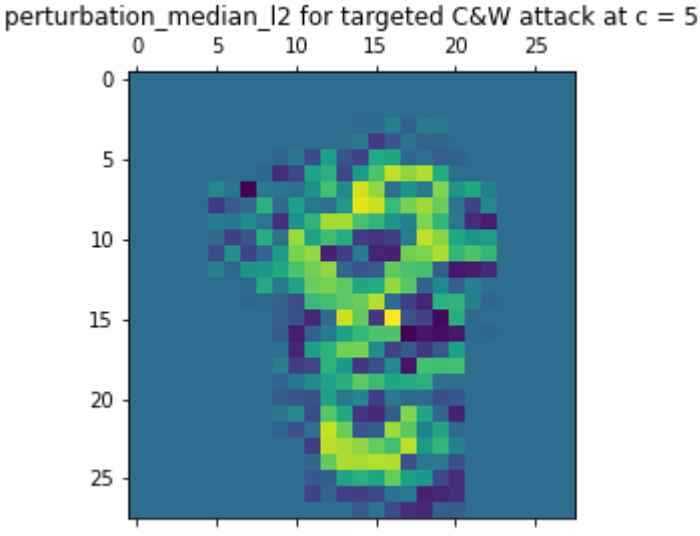
perturbation_max_l2 for targeted C&W attack at c = 5




```
==========MEDIAN L2 ================
```







C = 10

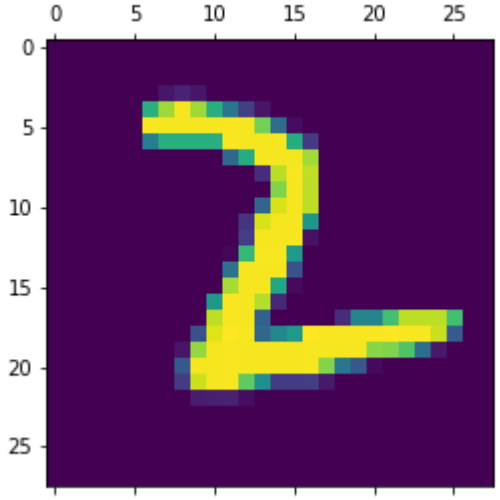
In [20]:

```
c_i,c = 3,10
print(f"===========MIN L2 ================")
l2_type = "min_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
```

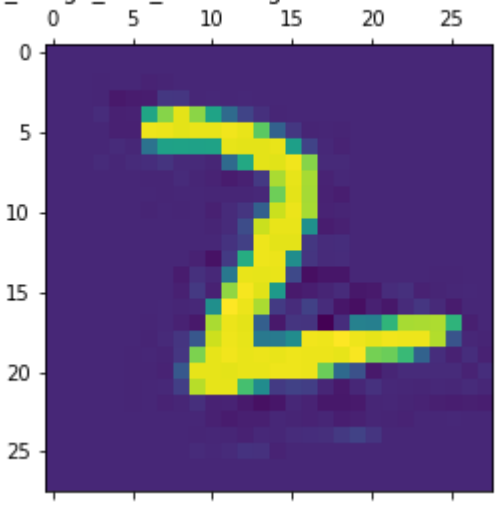
```
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

print(f"===========MAX L2 ================")
l2_type = "max_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

print(f"===========MEDIAN L2 ================")
l2_type = "median_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(szedegy_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()
```

```
===========MIN L2 ================
```

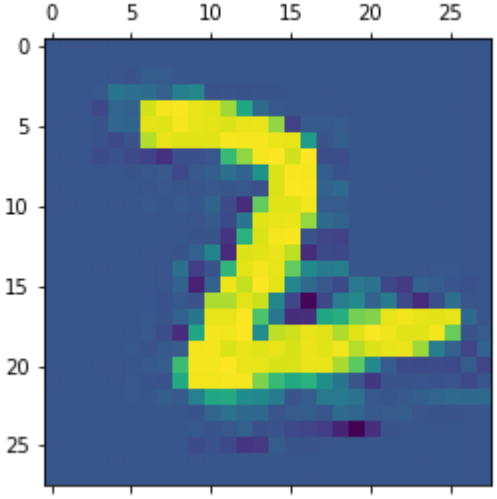
original_image_min_l2 for targeted C&W attack at c = 10



attack_image_min_l2 for targeted C&W attack at c = 10

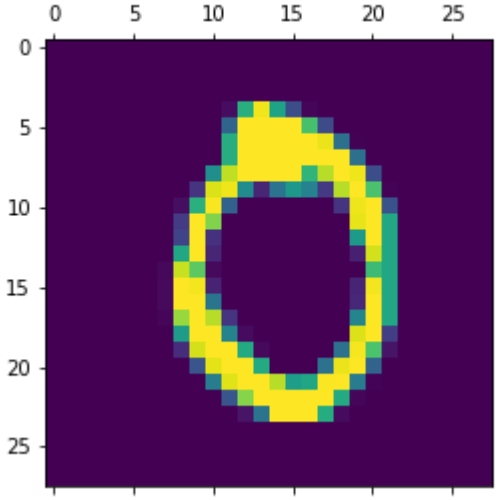


perturbation_min_l2 for targeted C&W attack at c = 10

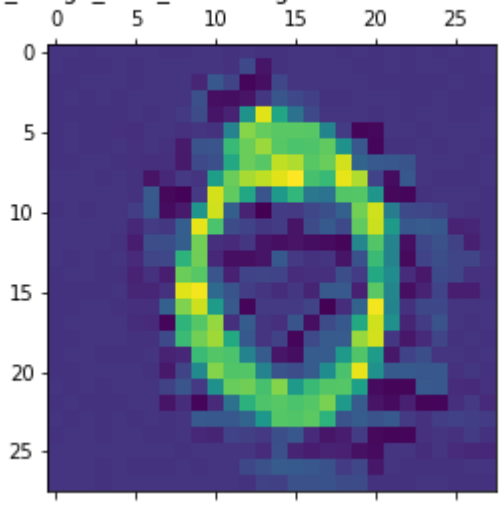


==========MAX L2 ================

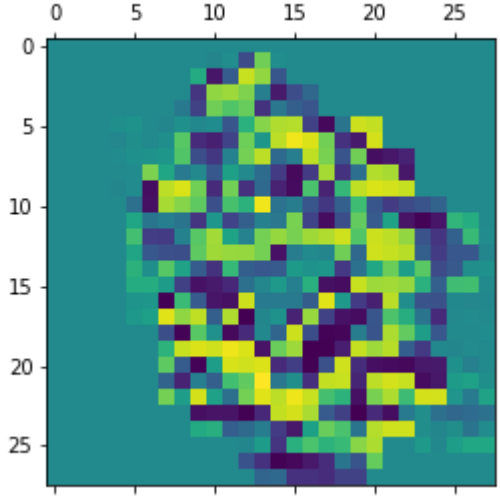
original_image_max_l2 for targeted C&W attack at c = 10



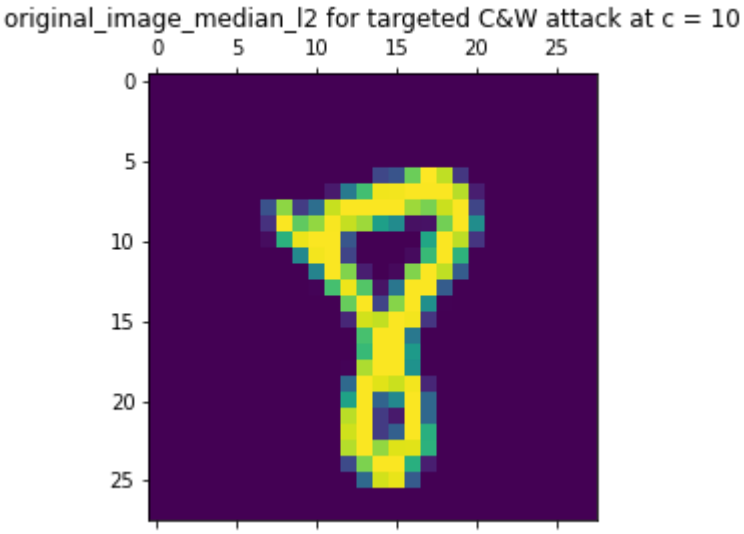
attack_image_max_l2 for targeted C&W attack at c = 10

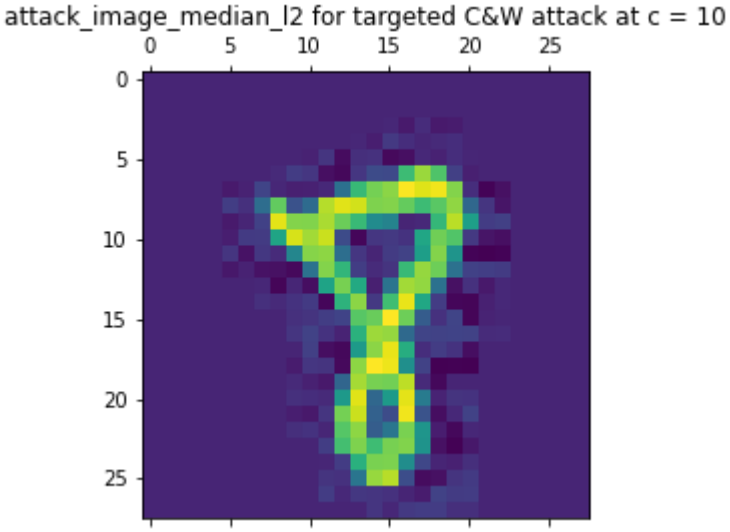


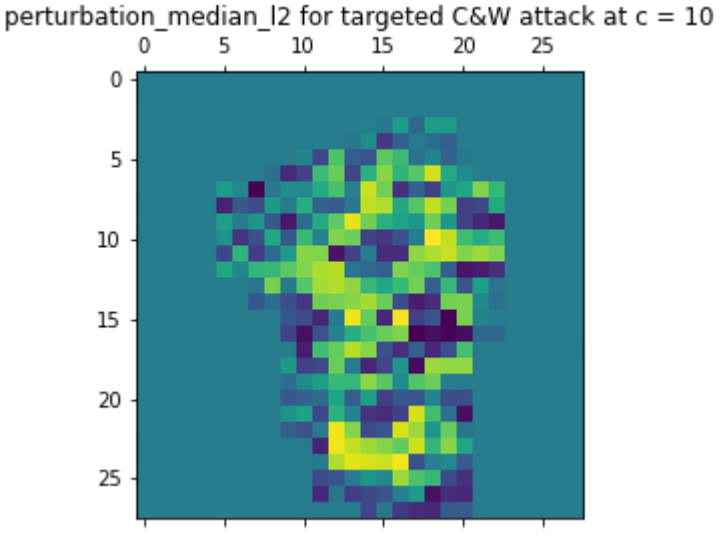
perturbation_max_l2 for targeted C&W attack at c = 10



```
==========MEDIAN L2 ================
```







f6 Objective

In [35]:
```
f6_df[['c','attack_success_rate','min_l2_idx','min_l2','max_l2_idx','max_l2','median_l2
```

Out[35]:

c	attack_success_rate	min_l2_idx	min_l2	max_l2_idx	max_l2	median_l2_idx	median_l2

	c	attack_success_rate	min_l2_idx	min_l2	max_l2_idx	max_l2	median_l2_idx	median_l2
0	0.5	0.32	8	12.868443	60	13.604152	65	13.360970
1	1.0	0.48	51	12.648972	55	13.793358	53	13.389554
2	5.0	0.73	75	13.034954	28	14.100512	14	13.693420
3	10.0	0.75	75	13.034954	28	14.231073	9	13.847732

C = 0.5

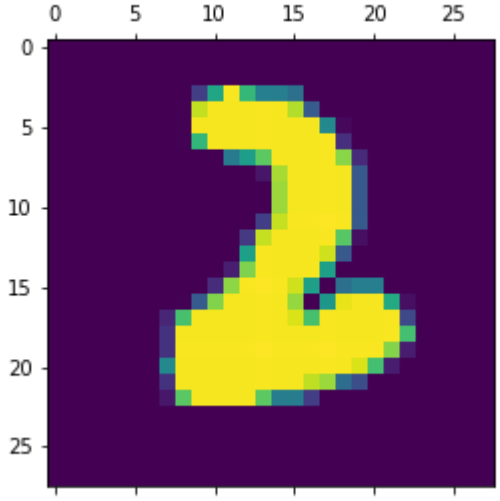
In [22]:

```
c_i,c = 0,0.01
print(f"===========MIN L2 ================")
l2_type = "min_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

print(f"===========MAX L2 ================")
l2_type = "max_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

print(f"===========MEDIAN L2 ================")
l2_type = "median_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()
```

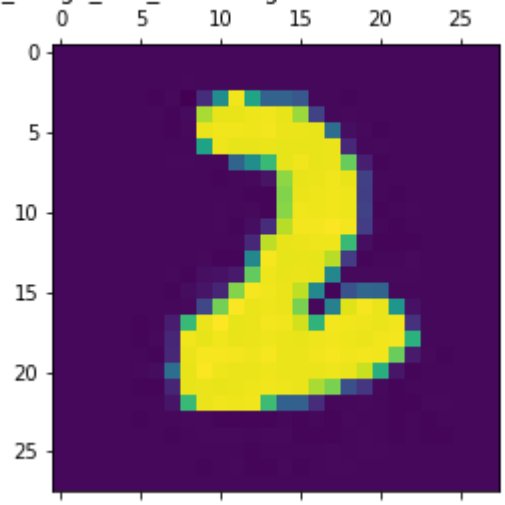
```
viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()
```

```
==========MIN L2 ================
```

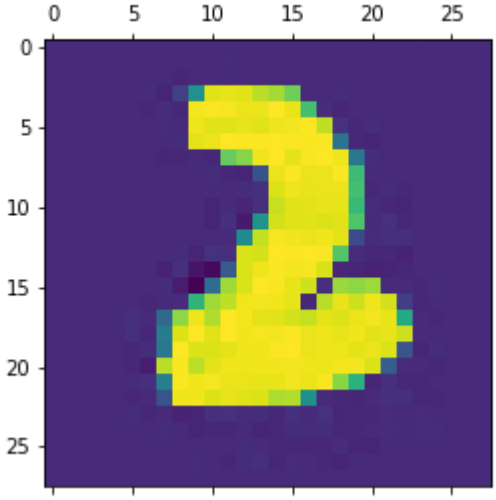
original_image_min_l2 for targeted C&W attack at c = 0.01



attack_image_min_l2 for targeted C&W attack at c = 0.01

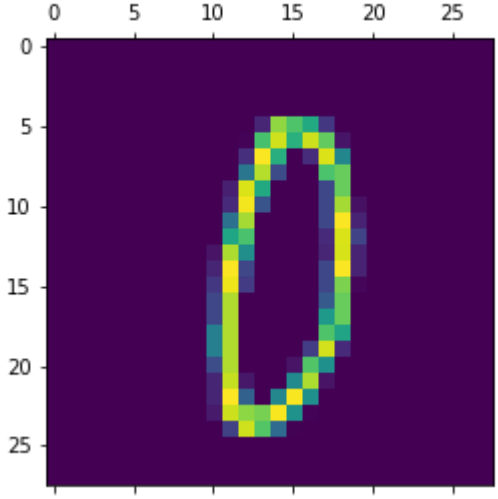


perturbation_min_l2 for targeted C&W attack at c = 0.01

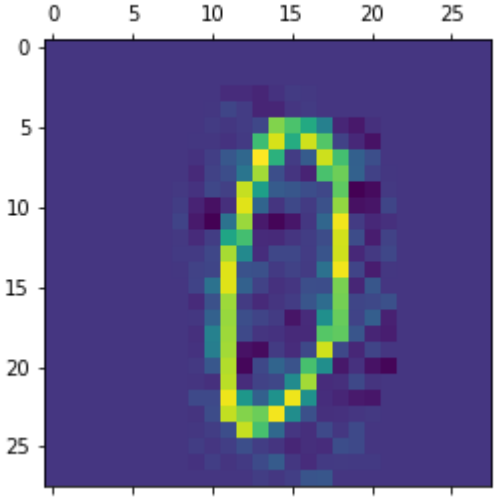


==========MAX L2 ================

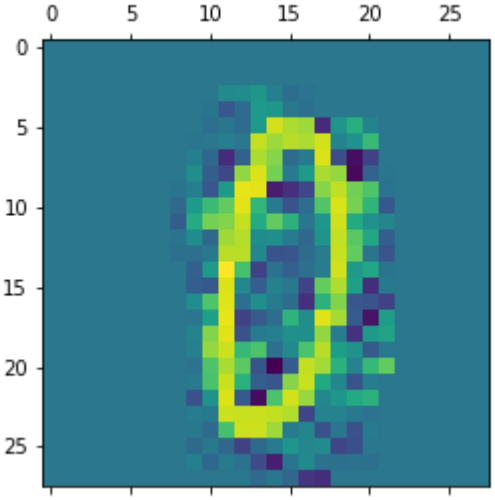
original_image_max_l2 for targeted C&W attack at c = 0.01



attack_image_max_l2 for targeted C&W attack at c = 0.01

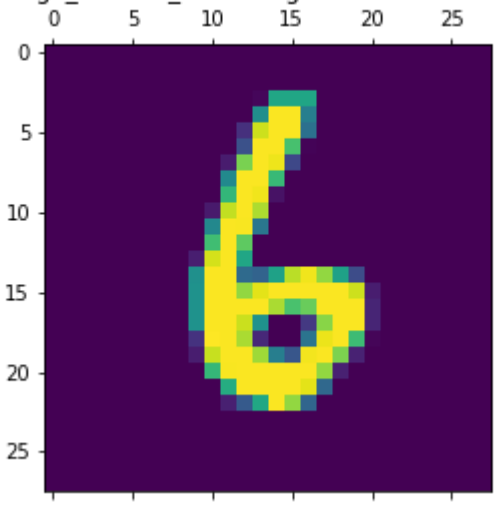


perturbation_max_l2 for targeted C&W attack at c = 0.01

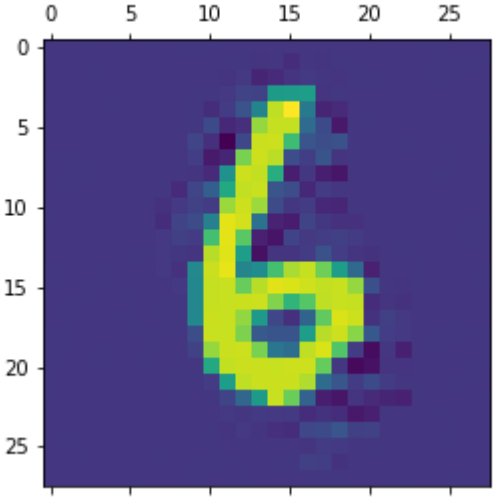


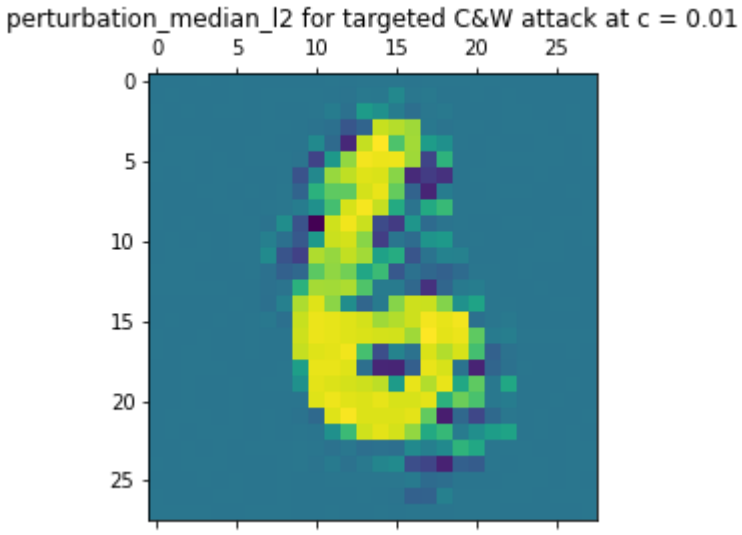
```
==========MEDIAN L2 ================
```

original_image_median_l2 for targeted C&W attack at c = 0.01



attack_image_median_l2 for targeted C&W attack at c = 0.01





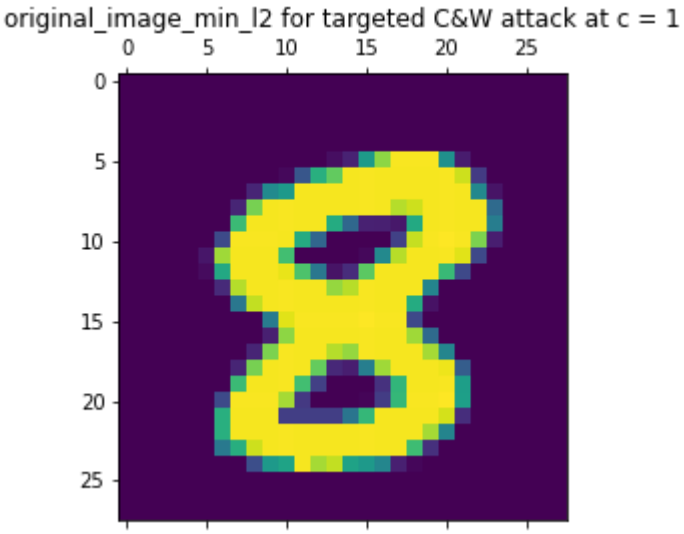
C = 1

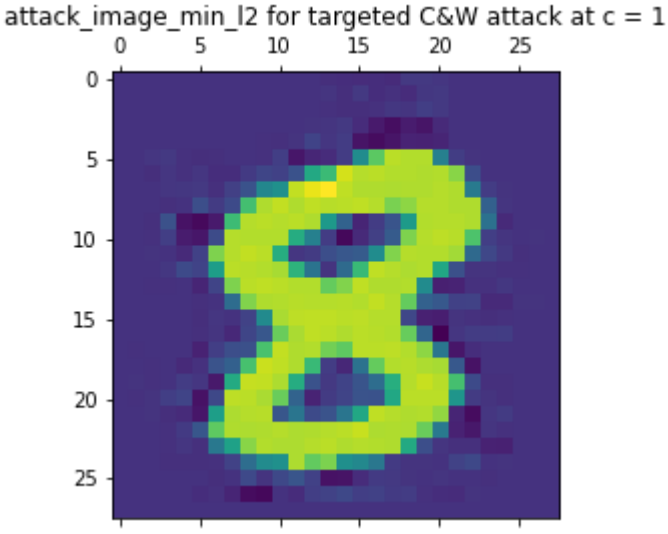
In [23]:

```
c_i,c = 1,1
print(f"===========MIN L2 ================")
l2_type = "min_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

print(f"===========MAX L2 ================")
l2_type = "max_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()
```

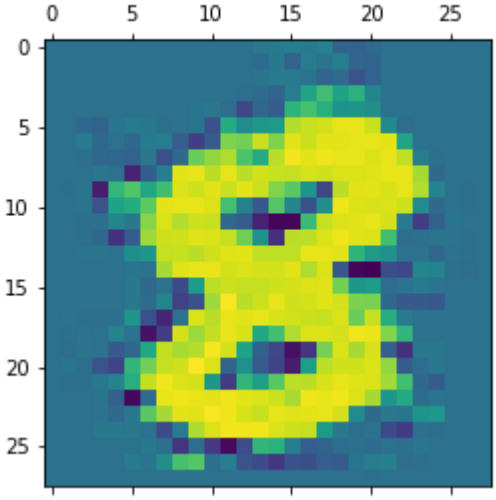
```
print(f"===========MEDIAN L2 ================")
l2_type = "median_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()
```

```
===========MIN L2 ================
```



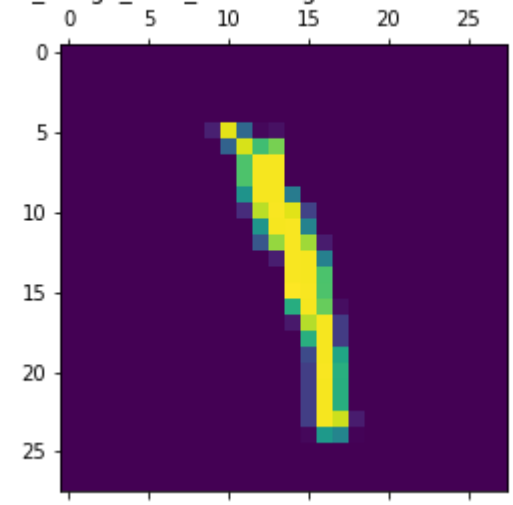


perturbation_min_l2 for targeted C&W attack at c = 1

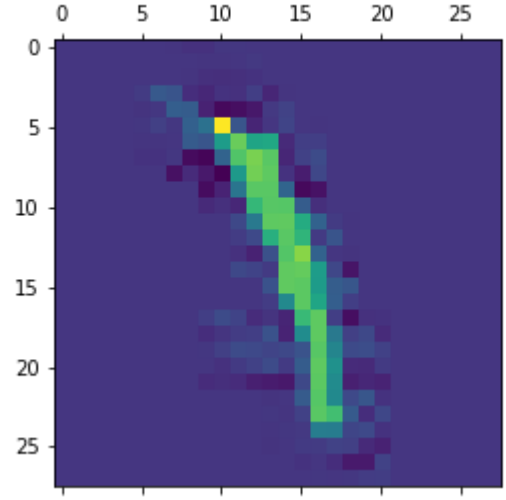


==========MAX L2 ================

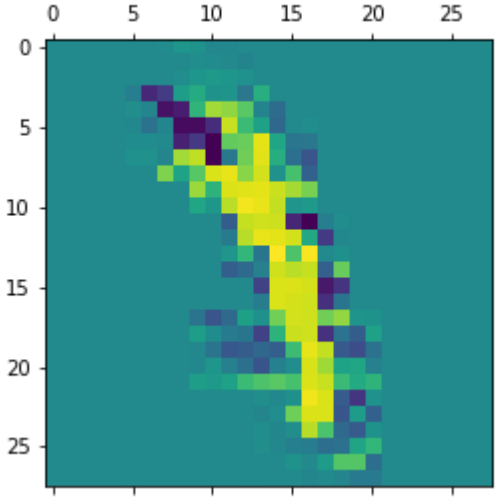
original_image_max_l2 for targeted C&W attack at c = 1



attack_image_max_l2 for targeted C&W attack at c = 1

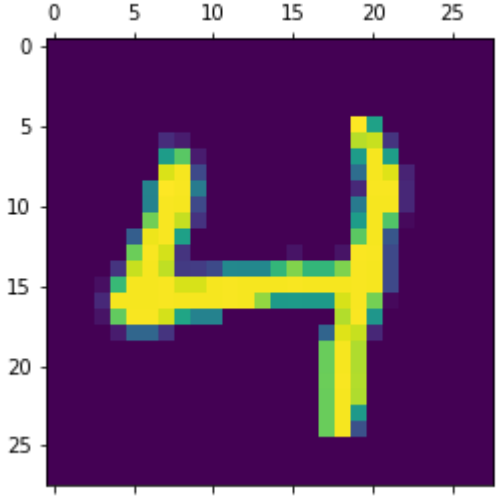


perturbation_max_l2 for targeted C&W attack at c = 1

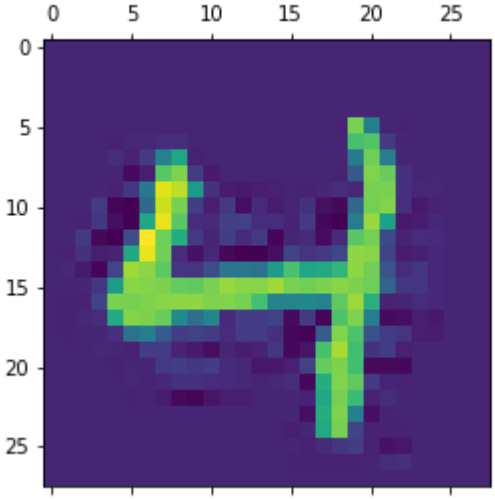


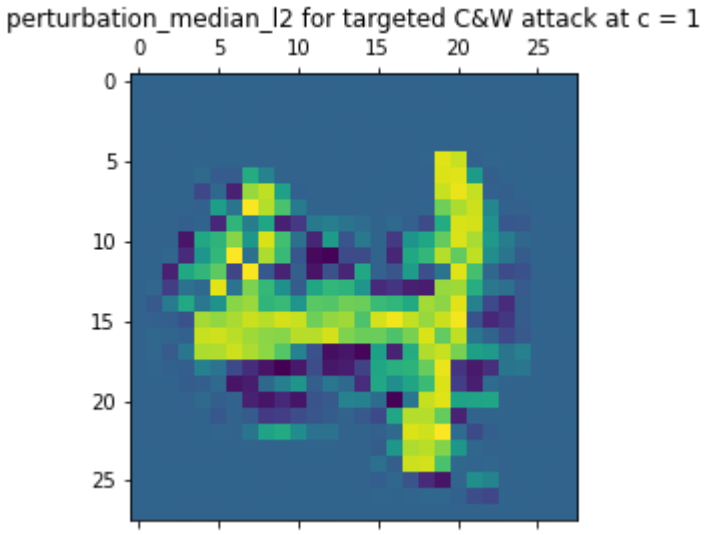
==========MEDIAN L2 ================

original_image_median_l2 for targeted C&W attack at c = 1



attack_image_median_l2 for targeted C&W attack at c = 1





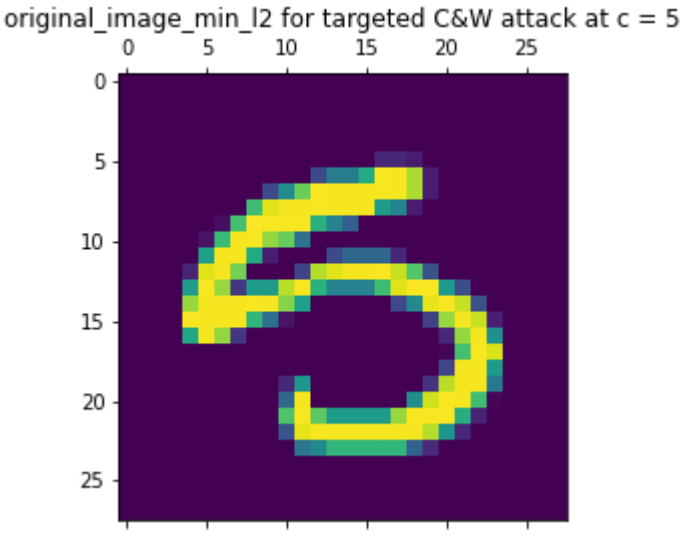
C = 5

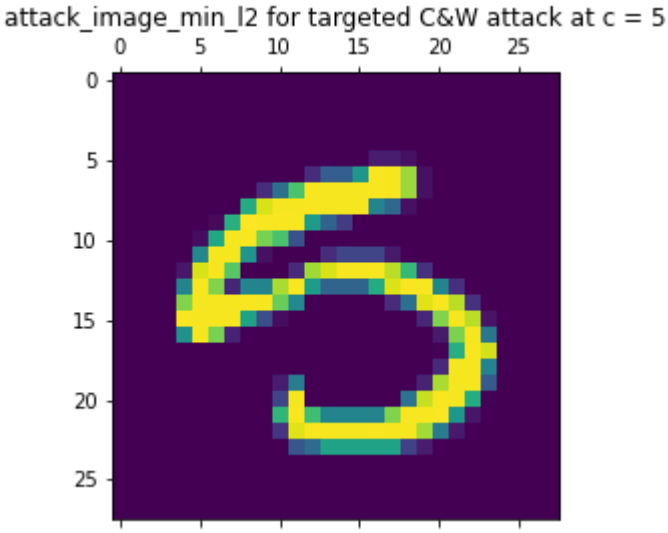
In [24]:

```
c_i,c = 2,5
print(f"===========MIN L2 ================")
l2_type = "min_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

print(f"===========MAX L2 ================")
l2_type = "max_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()
```

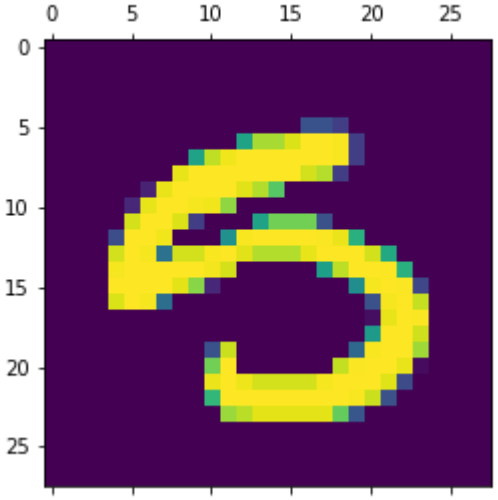
```
print(f"===========MEDIAN L2 ================")
l2_type = "median_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()
```

```
===========MIN L2 ================
```



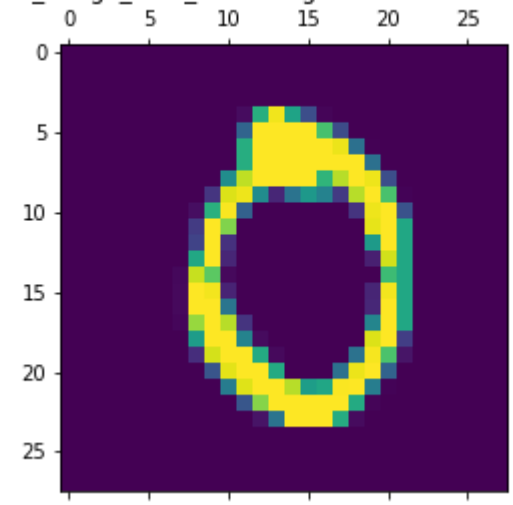


perturbation_min_l2 for targeted C&W attack at c = 5

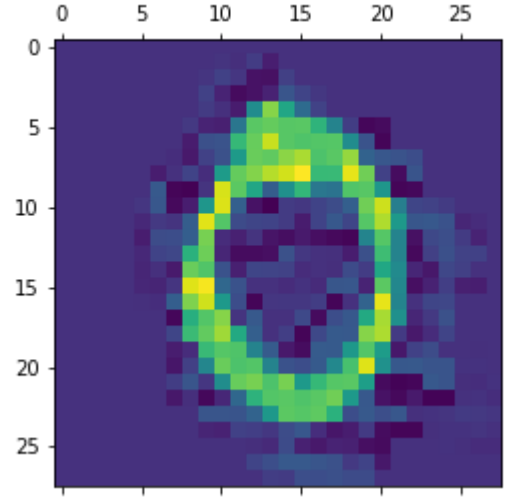


==========MAX L2 ================

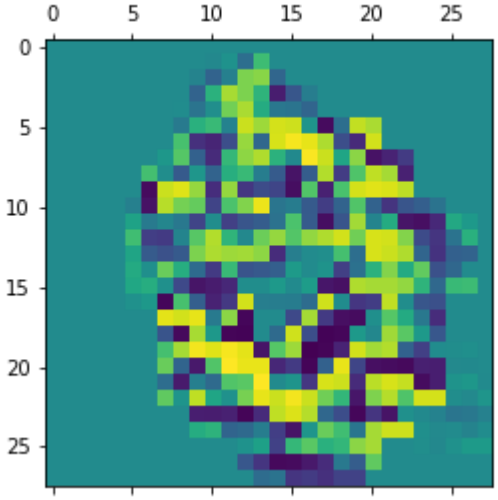
original_image_max_l2 for targeted C&W attack at c = 5



attack_image_max_l2 for targeted C&W attack at c = 5

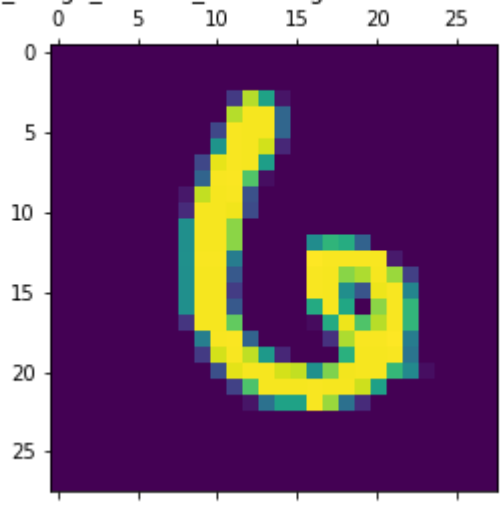


perturbation_max_l2 for targeted C&W attack at c = 5

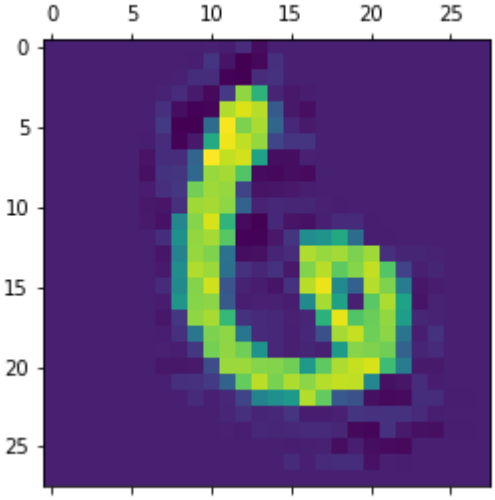


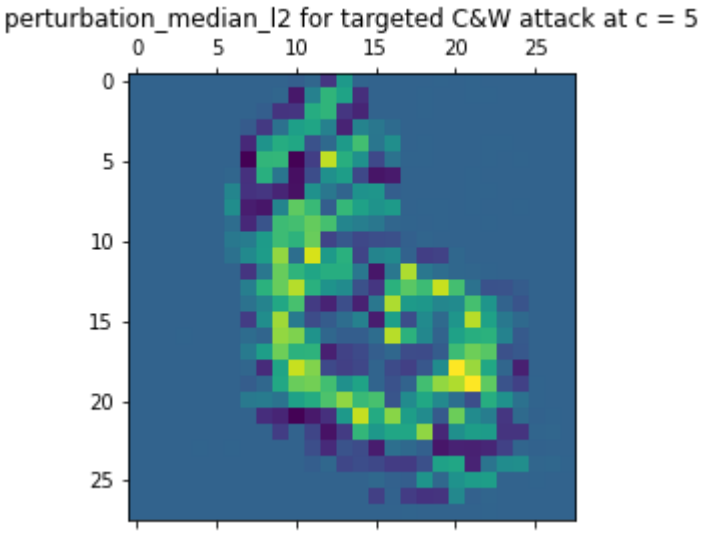
```
==========MEDIAN L2 ================
```

original_image_median_l2 for targeted C&W attack at c = 5



attack_image_median_l2 for targeted C&W attack at c = 5





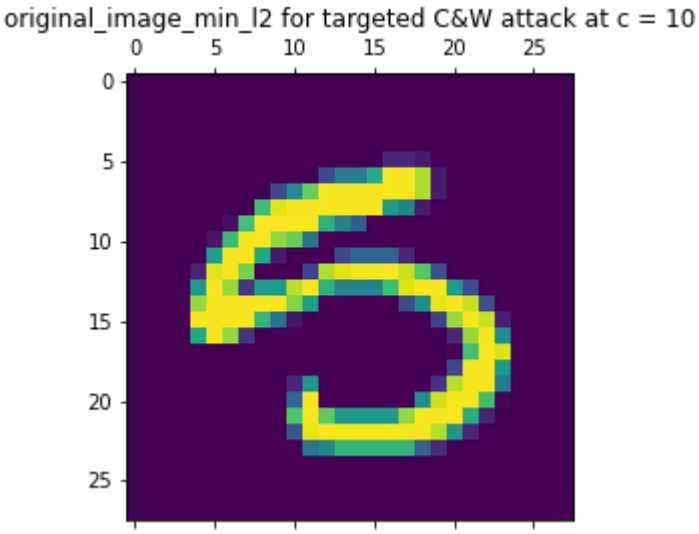
C = 10

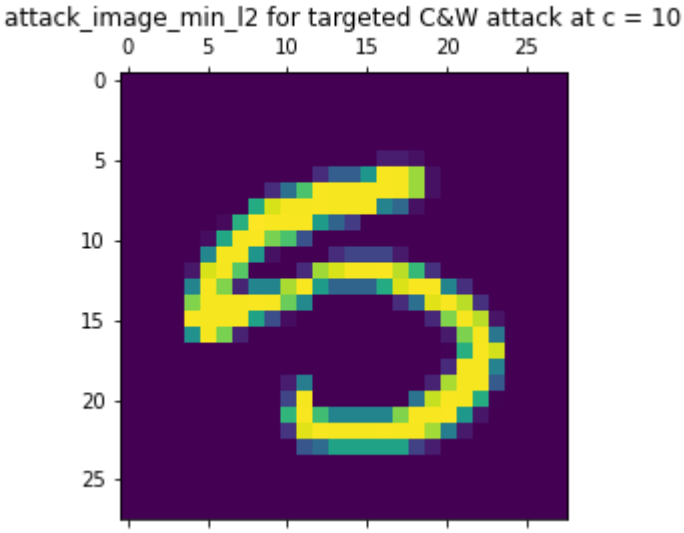
In [25]:

```
c_i,c = 3,10
print(f"===========MIN L2 ================")
l2_type = "min_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

print(f"===========MAX L2 ================")
l2_type = "max_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()
```

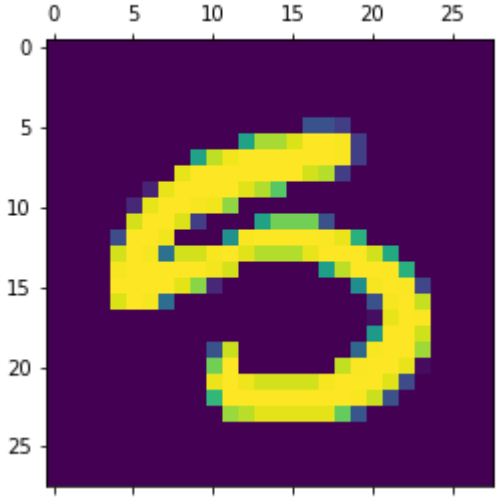
```
print(f"===========MEDIAN L2 ================")
l2_type = "median_l2"
viz_type = "original_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "attack_image_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()

viz_type = "perturbation_"
viz_key = viz_type + l2_type
plt.matshow(f6_attack_metrics[c_i][viz_key])
plt.title(f"{viz_key} for targeted C&W attack at c = {c}")
plt.show()
```

```
===========MIN L2 ================
```



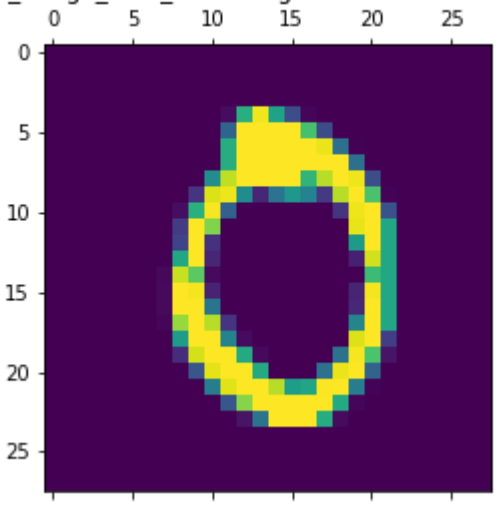


perturbation_min_l2 for targeted C&W attack at c = 10

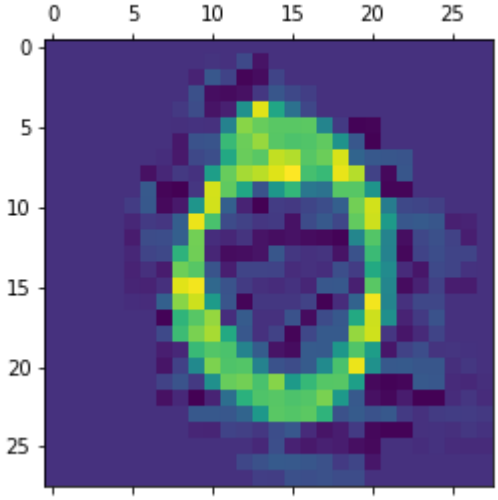


==========MAX L2 ================

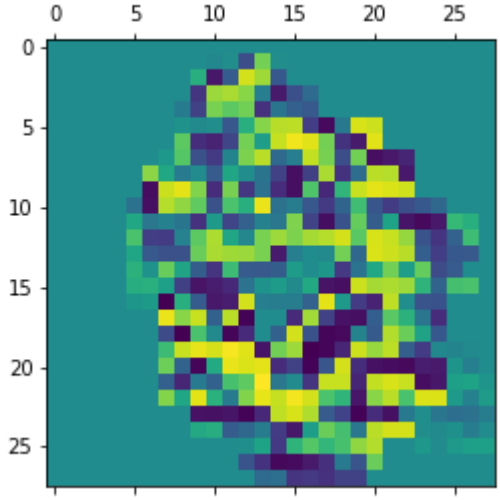
original_image_max_l2 for targeted C&W attack at c = 10



attack_image_max_l2 for targeted C&W attack at c = 10

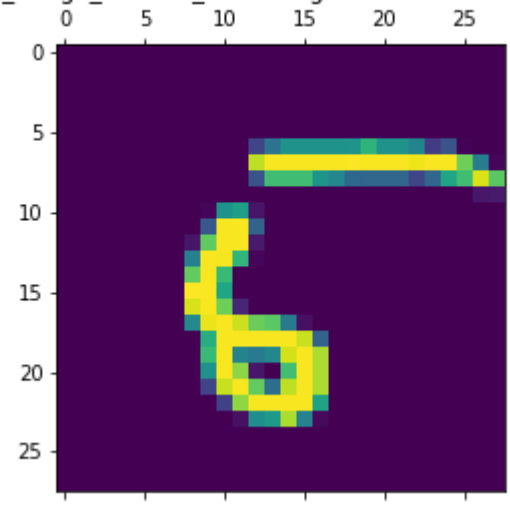


perturbation_max_l2 for targeted C&W attack at c = 10

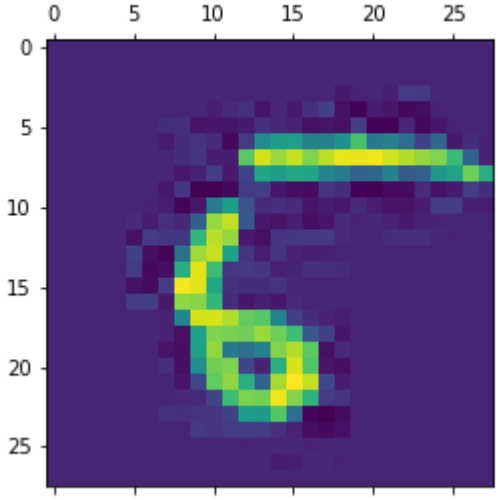


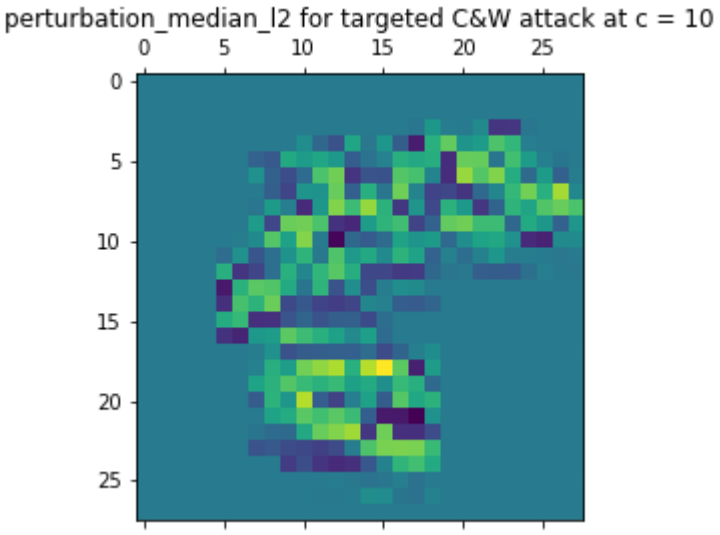
==========MEDIAN L2 ================

original_image_median_l2 for targeted C&W attack at c = 10



attack_image_median_l2 for targeted C&W attack at c = 10





2c: Obsevations

1. My results were slightly better than the ART library but mostly similar in terms of attack success per per c. The similarity can be explained by the fact that I fixed the learning rate, constant c and number of iterations to the ART library. The differences were more pronounced for smaller values of c like 0.5 and 1
2. There was A big difference was the L2 norm. It did not vary as much in my attack (stayed around 12-13). It was also much higher that the ART library, whose L2 norm stayed under 2-3.
3. The difference in l2 norm is quiet visible in the images. My attack seems to have much more visible perturbations.