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In [1]:
```
import torch
import torch.nn as nn
import torchvision.transforms as transforms
import torchvision.datasets as dsets
from torch.autograd import Variable
import random as rand
import matplotlib.pyplot as plt
import numpy as np
```

0.2 Task 1: obtaining the MNIST dataset:

In [2]:
```
'''
STEP 1: LOADING DATASET
'''

train_dataset = dsets.MNIST(root='./MNIST-data',
                            train=True,
                            transform=transforms.ToTensor(),
                            download=True)

test_dataset = dsets.MNIST(root='./MNIST-data',
                           train=False,
                           transform=transforms.ToTensor())
```

In [3]:
```
class LinearModel(nn.Module):

    def __init__(self, input_dim, output_dim,
                 algorithm_name='LogisticRegression',
                 train_batch_size=1000, num_epochs=10,
                 learning_rate=0.001, optimizer=torch.optim.Adam):

        super().__init__()
        self.linear = nn.Linear(input_dim, output_dim)
```

```
        parameters = self.linear.parameters()
        algorithm_to_loss = {
            'LogisticRegression': nn.CrossEntropyLoss(),
            'SVM': self.hingeLoss}

        if not any(algorithm_name==algorithm
                       for algorithm in algorithm_to_loss.keys()):
            raise ValueError ('{} not currently supported', algorithm_name)
        else:
            self.criterion = algorithm_to_loss[algorithm_name]

        self.batch_size = train_batch_size
        self.num_epochs = num_epochs
        self.learning_rate = learning_rate
        self.optimizer = optimizer

    def forward(self, x):
        return self.linear(x)

    def hingeLoss(self, logits, targets):

#          zero = torch.Tensor([0])
#          targets = targets.long()
#          score_target_class = logits.gather(1, targets.view(-1,1))  # scores of the t
#          targets = targets.view(-1,1)
#          ones = torch.Tensor([1])
#          loss = torch.sum(torch.max(zero, logits - score_target_class + 1.0), dim =1)
#          loss = loss - ones
#          loss = torch.mean(loss) # Getting the mean loss
#          return loss
        targets = targets.long()
        loss= torch.max(torch.tensor([0.]),logits-logits.gather(1, targets.unsqueeze(1
        dim1 = torch.arange(0, targets.shape[0], out=torch.LongTensor())
        labels=targets.long()
        idx=(dim1,labels)
        loss.index_put_(idx, torch.tensor([0.]))
        #loss=torch.pow(loss,2)
        return torch.mean(torch.sum(loss,dim=1))

    def fit_and_evaluate(self, model, train_dataset, test_data, test_labels):

        optimizer = self.optimizer(model.parameters(), lr=self.learning_rate)

        train_loader = torch.utils.data.DataLoader(dataset=train_dataset,
                                                   batch_size=self.batch_size,
                                                   shuffle=True)

        for epoch in range(self.num_epochs):
```

```python
            for images, labels in train_loader:
                images = Variable(images.view(-1, 28*28))
                labels = Variable(labels)

                # Clear gradients w.r.t. parameters
                optimizer.zero_grad()

                # Forward pass to get output/logits
                outputs = self.forward(images)

                # Calculate Loss: softmax --> cross entropy loss
                loss = self.criterion(outputs, labels)

                # Getting gradients w.r.t. parameters
                loss.backward()

                # Updating parameters
                optimizer.step()

            test_images = Variable(test_data.view(-1, 28*28))
            outputs = self.forward(test_images.type(torch.FloatTensor))

            accuracy = self.get_accuracy(outputs, test_labels)

            # Print Loss
            print('Epoch: {}. Training Loss: {}. Test Accuracy: {}'.format(
                            epoch+1, loss.data, accuracy))

    def get_accuracy(self, outputs, labels, get_pred_conf=False):

        _, predicted = torch.max(outputs.data, 1)
        accuracy = 100. * float((predicted.cpu() ==
                             labels.cpu()).sum()) / len(labels)

        if get_pred_conf:
            raw_preds = outputs.data.numpy()
            return accuracy, predicted.numpy(), np.max(raw_preds, axis=1)

        return accuracy

    def generate_adversarial(self, model, image_tensor, image_labels,
                             epsilon=0.1):

        images = image_tensor.type(torch.FloatTensor)/255
        images = Variable(images.view(-1, 28*28),
                              requires_grad=True)

        outputs = self.forward(images)
```

```
        loss = self.criterion(outputs, image_labels)
        loss.backward()
        gradients   = torch.sign(images.grad.data)
        adversarial_images = torch.clamp(images.data + epsilon * gradients, 0., 1.)

        return images, adversarial_images

    def plot(self, image, adversarial, img_title, adv_title):
        fig = plt.figure()
        fig.add_subplot(121)
        image = np.reshape(image, (28, 28)) * 255
        plt.imshow(image, cmap= plt.cm.binary)
        plt.title(img_title)
        fig.add_subplot(122)
        adversarial = np.reshape(adversarial, (28, 28)) * 255
        plt.imshow(adversarial, cmap= plt.cm.binary)
        plt.title(adv_title)
        plt.tight_layout()
        plt.show()

    def visualize_image_and_adversarial(self, **kwargs):

        results = kwargs['results']
        if results is None:
            image_array = kwargs['image_array']
            adversarial_array = kwargs['adversarial_array']
            for image, adversarial in zip(image_array, adversarial_array):
                self.plot(image, adversarial, img_title='Image',
                          adv_title='Adversarial')
        else:
            for index, (image, adversarial) in enumerate(zip(
                                    results['image'], results['adversarial'])):
                if index == kwargs['num_visualize']:
                    break
                img_title = 'Image \n Prediction: {} \n Score: {}'.format(
                                    results['pred_img'][index], results['conf_img'][index]
                adv_title = 'Adversarial \n Prediction: {} \n Score: {}'.format(
                                    results['pred_adv'][index], results['conf_adv'][index]
                self.plot(image, adversarial, img_title=img_title,
                          adv_title=adv_title)

    def evaluate_adversarial_effect(self, model, image_tensor, adversarial_tensor,
                                       image_labels):

        results = {}
        results['image'] = image_tensor.detach().numpy()
        results['adversarial'] = adversarial_tensor.detach().numpy()
```

```
                outputs = self.forward(image_tensor)
                results['acc_img'], results['pred_img'], results['conf_img'] = self.get_accura
                                                outputs, image_labels, get_pred_conf=True)

                outputs = self.forward(adversarial_tensor)
                results['acc_adv'], results['pred_adv'], results['conf_adv'] = self.get_accura
                                                outputs, image_labels, get_pred_conf=True)

                return results
```

```
In [4]: input_dim = 28*28
        output_dim = 10
```

0.3 Task 2: The selected models are Logistic Regression and SVM

0.4 Task 3: Obtaining above 90 percent accuracy on Logistic Regression:

```
In [5]: print ('..........Logistic Regression.............\n')

        model_logisticReg = LinearModel(input_dim, output_dim, algorithm_name='LogisticRegressi
        model_logisticReg.fit_and_evaluate(model_logisticReg, train_dataset,
                                           test_dataset.test_data, test_dataset.test_labels)
```

```
...Logistic Regression...

Epoch: 1. Training Loss: 0.8672741651535034. Test Accuracy: 83.02
Epoch: 2. Training Loss: 0.6605766415596008. Test Accuracy: 87.0
Epoch: 3. Training Loss: 0.5138049721717834. Test Accuracy: 88.55
Epoch: 4. Training Loss: 0.4657759964466095. Test Accuracy: 89.38
Epoch: 5. Training Loss: 0.4272240102291107. Test Accuracy: 89.92
Epoch: 6. Training Loss: 0.4208531677722931. Test Accuracy: 90.48
Epoch: 7. Training Loss: 0.3497934341430664. Test Accuracy: 90.49
Epoch: 8. Training Loss: 0.327832967042923. Test Accuracy: 90.82
Epoch: 9. Training Loss: 0.3460347354412079. Test Accuracy: 90.87
Epoch: 10. Training Loss: 0.31379234790802. Test Accuracy: 91.26
```

0.5 Task 3: Obtaining above 90 percent accuracy on SVM:

```
In [6]: print ('..........Support Vector Machine.............\n')

        model_SVM = LinearModel(input_dim, output_dim, algorithm_name='SVM')
        model_SVM.fit_and_evaluate(model_SVM, train_dataset,
                                   test_dataset.test_data, test_dataset.test_labels)
```

```
...Support Vector Machine...

Epoch: 1. Training Loss: 1.1074693202972412. Test Accuracy: 85.0
Epoch: 2. Training Loss: 0.8011562824249268. Test Accuracy: 88.65
```

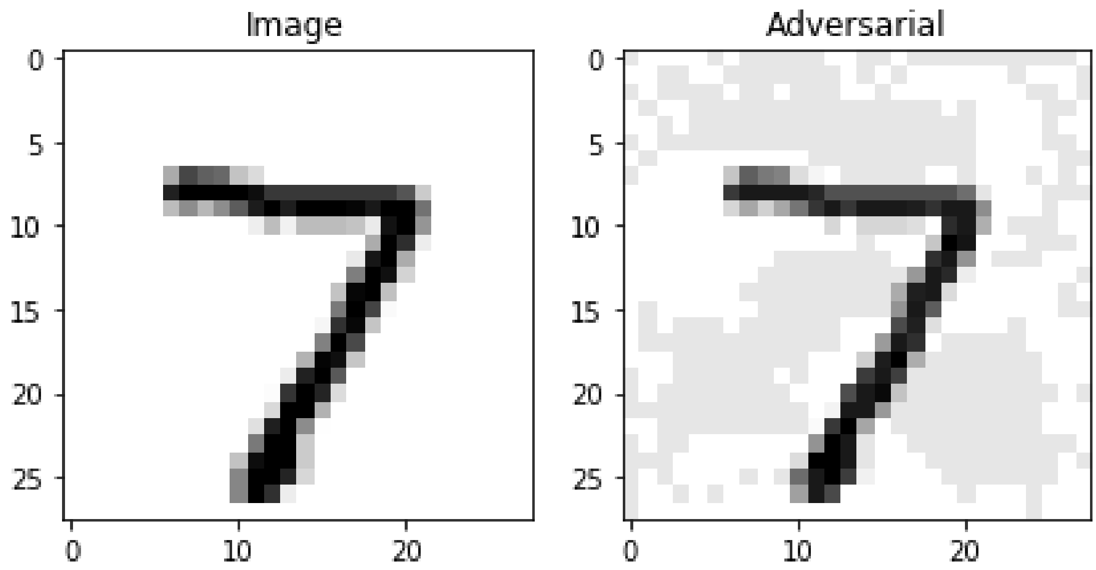
```
Epoch: 3. Training Loss: 0.7575165033340454. Test Accuracy: 89.65
Epoch: 4. Training Loss: 0.5674992203712463. Test Accuracy: 90.14
Epoch: 5. Training Loss: 0.5898672938346863. Test Accuracy: 90.28
Epoch: 6. Training Loss: 0.6022735238075256. Test Accuracy: 90.57
Epoch: 7. Training Loss: 0.550260603427887. Test Accuracy: 90.58
Epoch: 8. Training Loss: 0.4232252538204193. Test Accuracy: 90.83
Epoch: 9. Training Loss: 0.5049446821212769. Test Accuracy: 90.71
Epoch: 10. Training Loss: 0.45765921473503113. Test Accuracy: 90.92
```

0.6 Task 4: Generating 100 adversarial images for Logistic Regression:

```
In [7]: num_adversarials = 100
        image_logReg, adver_logReg = model_logisticReg.generate_adversarial(
                                                         model_logisticReg,
                                                         test_dataset.test_data[0:num_adversaria
                                                         test_dataset.test_labels[0:num_adversar

        print ('..........Visualize 5 sample images and corresponding adversarials...........\n
        model_logisticReg.visualize_image_and_adversarial(image_array=image_logReg[0:5].detach
                                                          adversarial_array=adver_logReg[0:5].de
                                                          results=None)
```

```
...Visualize 5 sample images and corresponding adversarials...
```



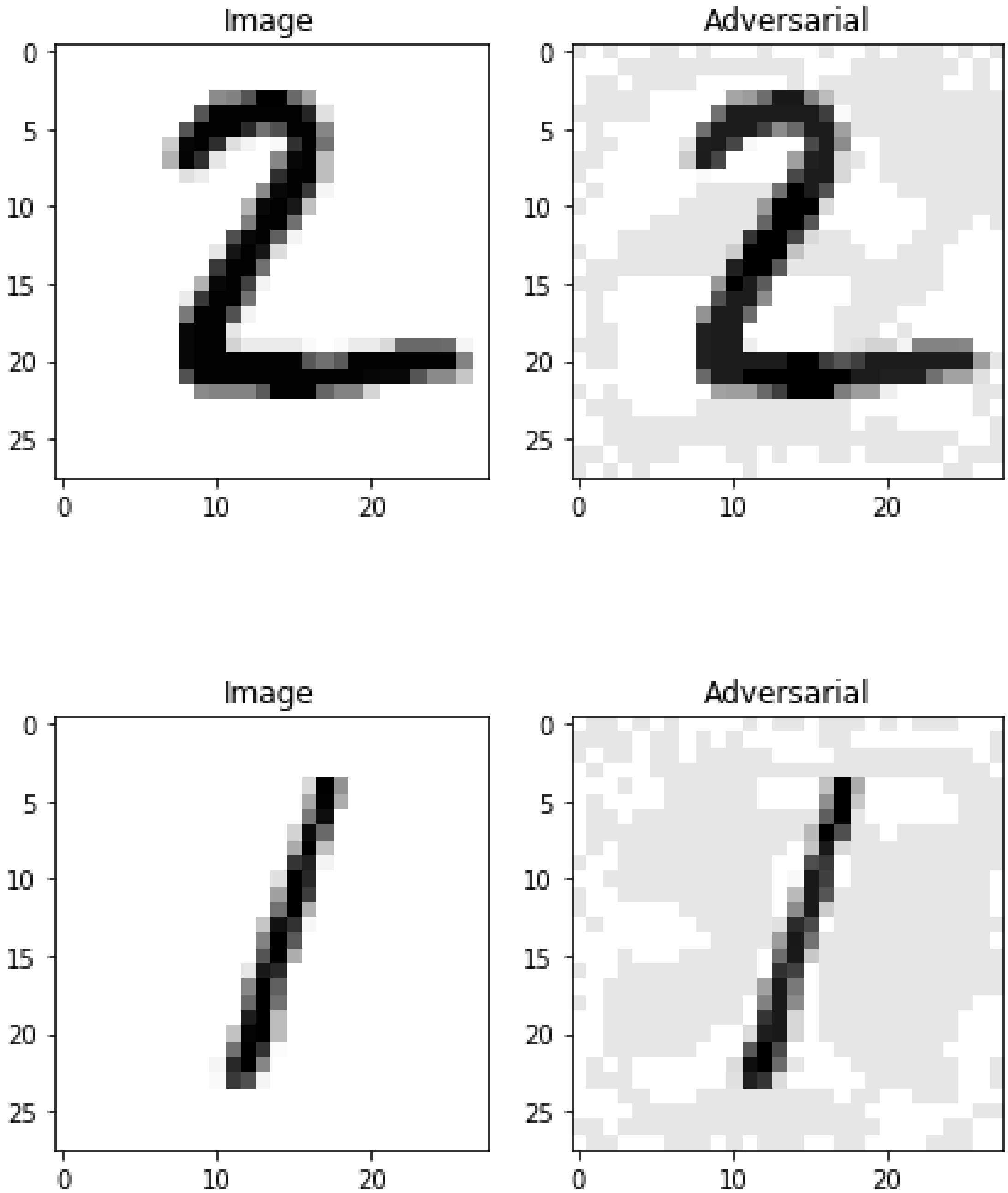
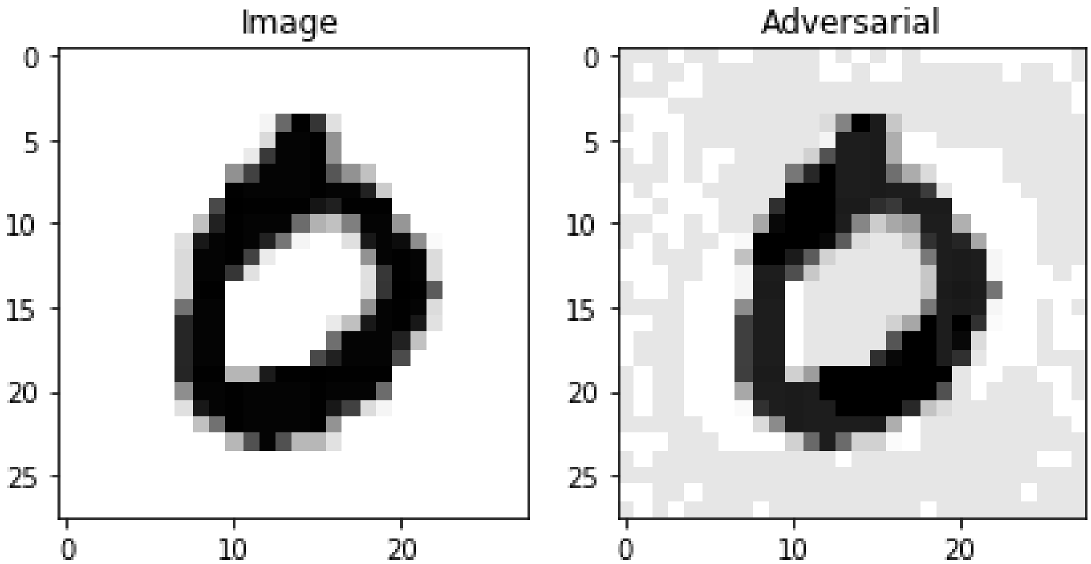
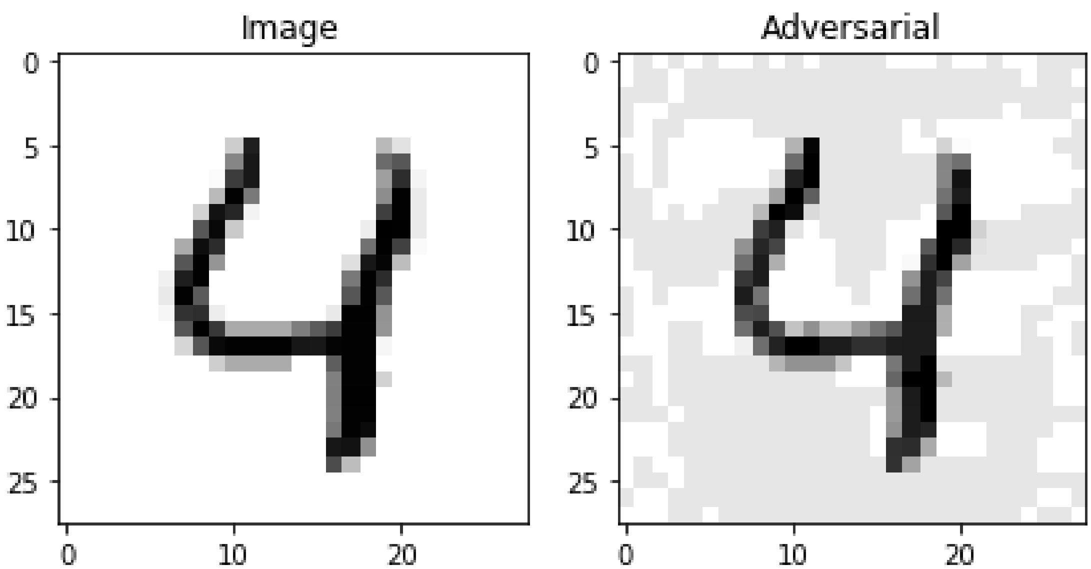


Image
Adversarial
Image
Adversarial
0
5
10
15
20
25
0
10
20



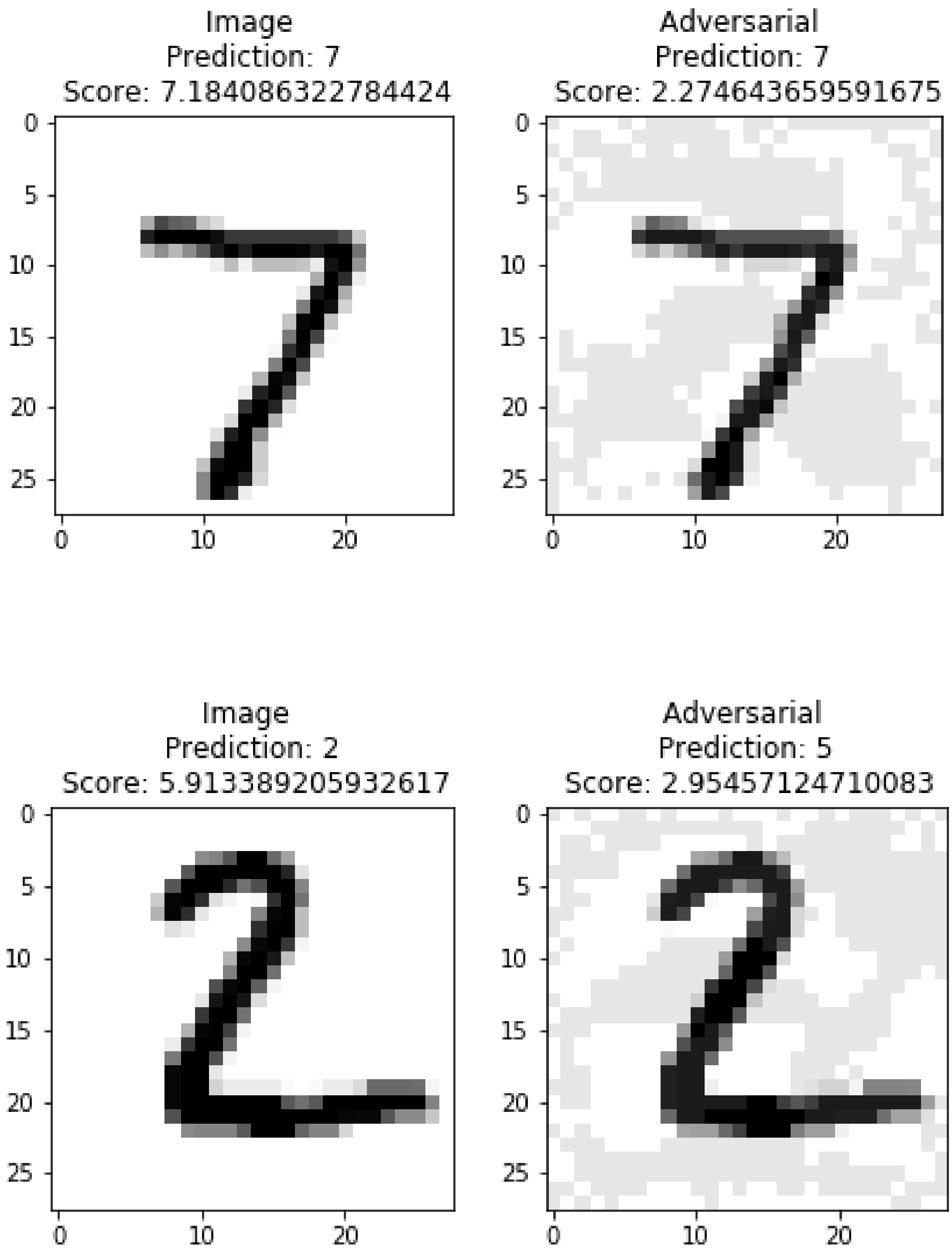


0.7 Task 4: Evaluating the effects of the adversarial images on Logistic Regression:

```
In [8]: results = model_logisticReg.evaluate_adversarial_effect(
                                                     model_logisticReg, image_logReg,
                                                     adver_logReg,
                                                     test_dataset.test_labels[0:num_adversarials
        print ('..............Adversarial attack on Logistic Regression...........\n')
        model_logisticReg.visualize_image_and_adversarial(results=results, num_visualize=5)
```

```
print ('------------------------------------------------------------------')
print ('Accuracy on actual images: {}'.format(results['acc_img']))
print ('Accuracy on adversarial images: {}'.format(results['acc_adv']))
```

```
...Adversarial attack on Logistic Regression...
```



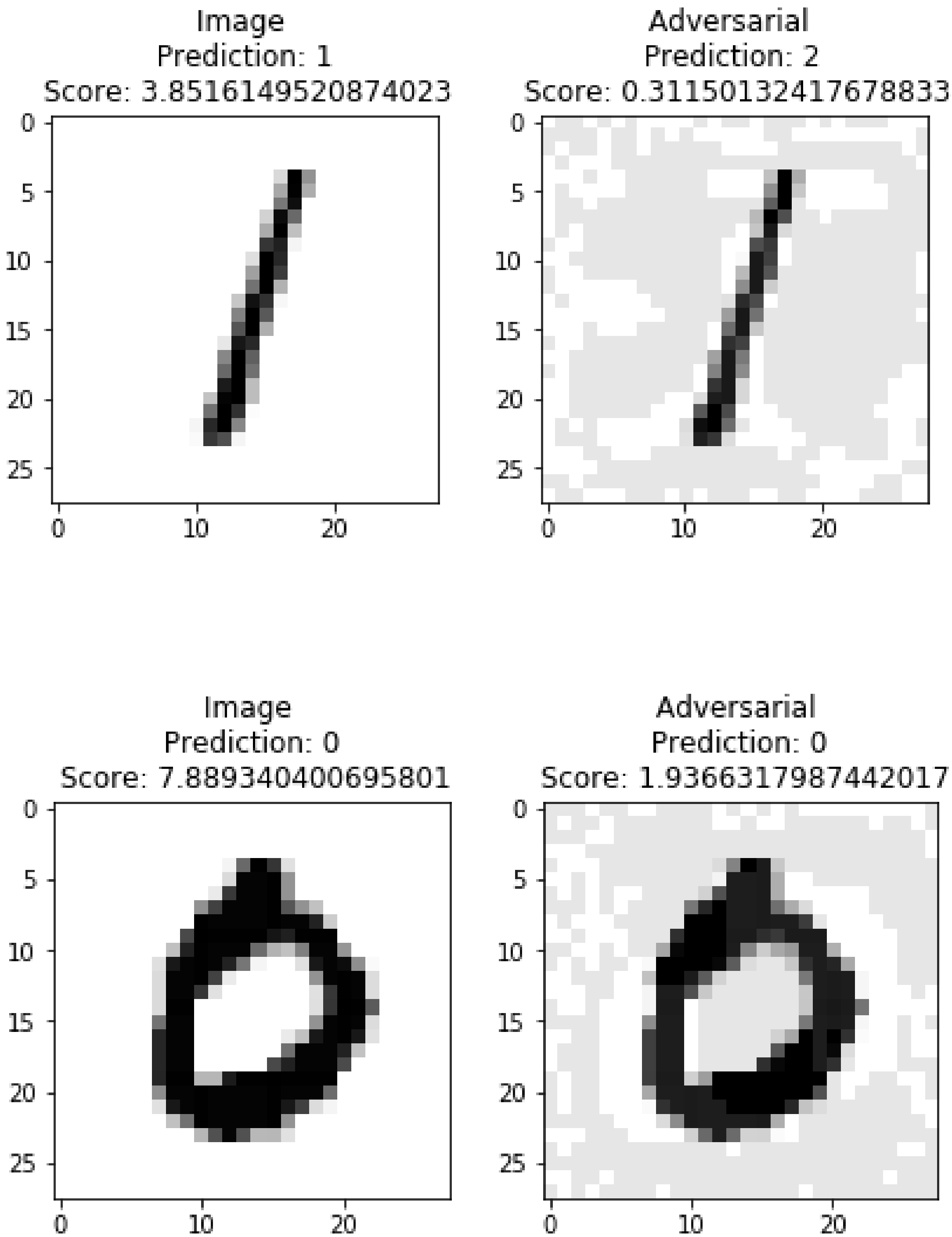
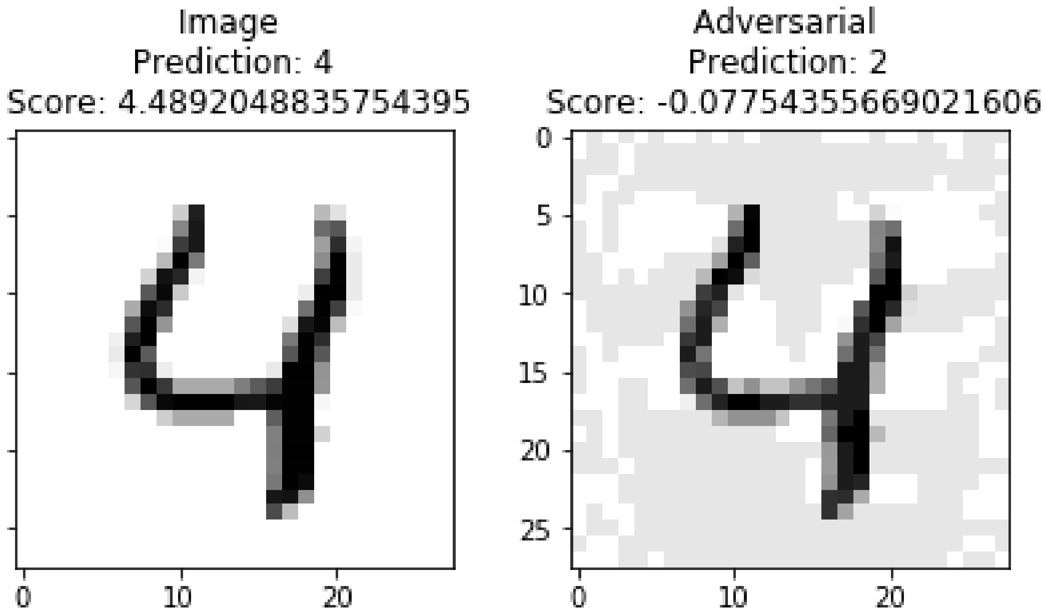


Image
Prediction: 1
Score: 3.8516149520874023
Adversarial
Prediction: 2
Score: 0.31150132417678833
Image
Prediction: 0
Score: 7.889340400695801
Adversarial
Prediction: 0
Score: 1.9366317987442017




```
--------------------------------------------------------------------
Accuracy on actual images: 93.0
Accuracy on adversarial images: 11.0
```

0.8 Task 4: Generating 100 adversarial images for SVM:

```
In [9]: num_adversarials = 100
        image_svm, adver_svm = model_SVM.generate_adversarial(
                                                       model_SVM,
                                                       test_dataset.test_data[0:num_adversaria
                                                       test_dataset.test_labels[0:num_adversar
                                                       epsilon=0.5)

        print ('..........Visualize 5 sample images and corresponding adversarials...........\n
        model_SVM.visualize_image_and_adversarial(image_array=image_svm[0:5].detach().numpy(),
                                                        adversarial_array=adver_svm[0:5].detac
                                                        results=None)
```

```
...Visualize 5 sample images and corresponding adversarials...
```

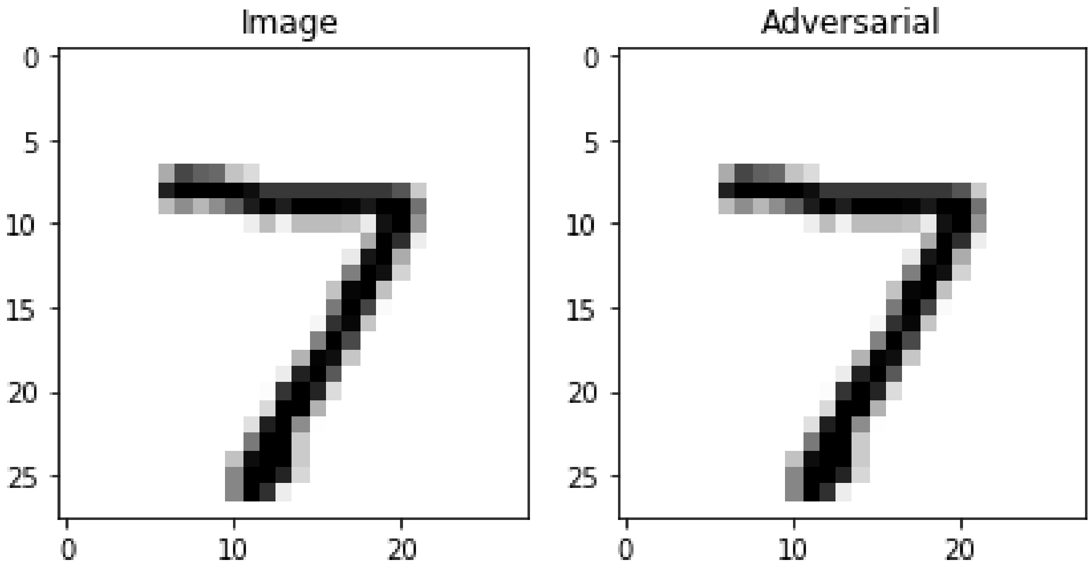


Image
Adversarial
0
5
10
15
20
25
0
10
20

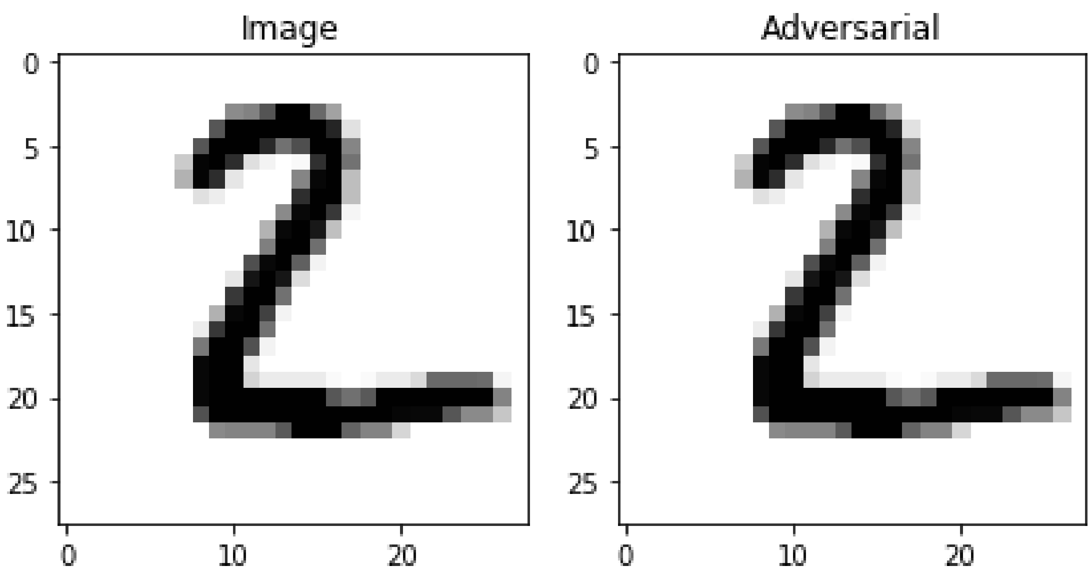


Image
Adversarial
0
5
10
15
20
25
0
10
20

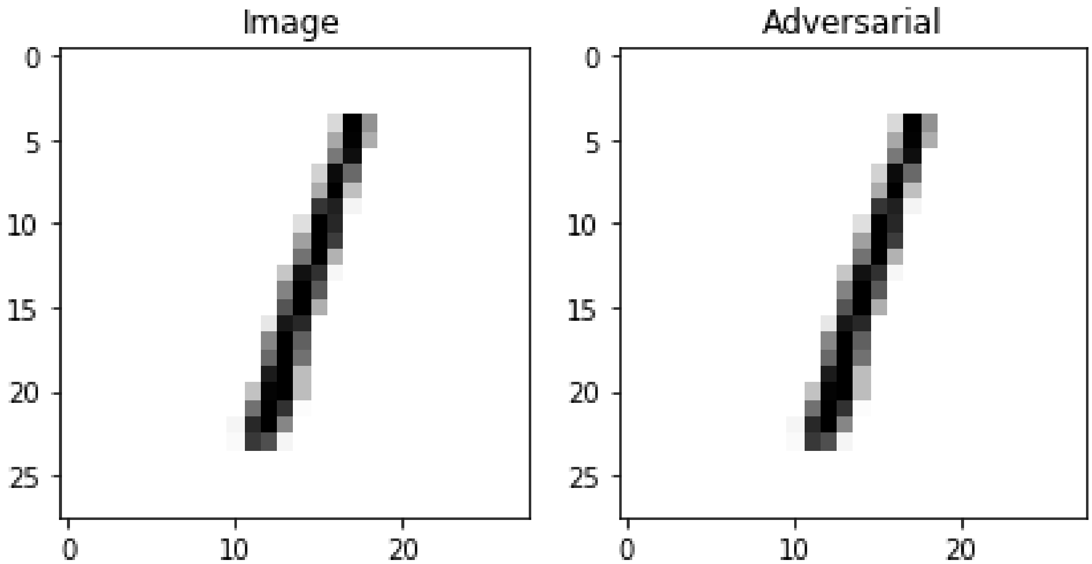


Image
Adversarial
0
5
10
15
20
25
0
10
20

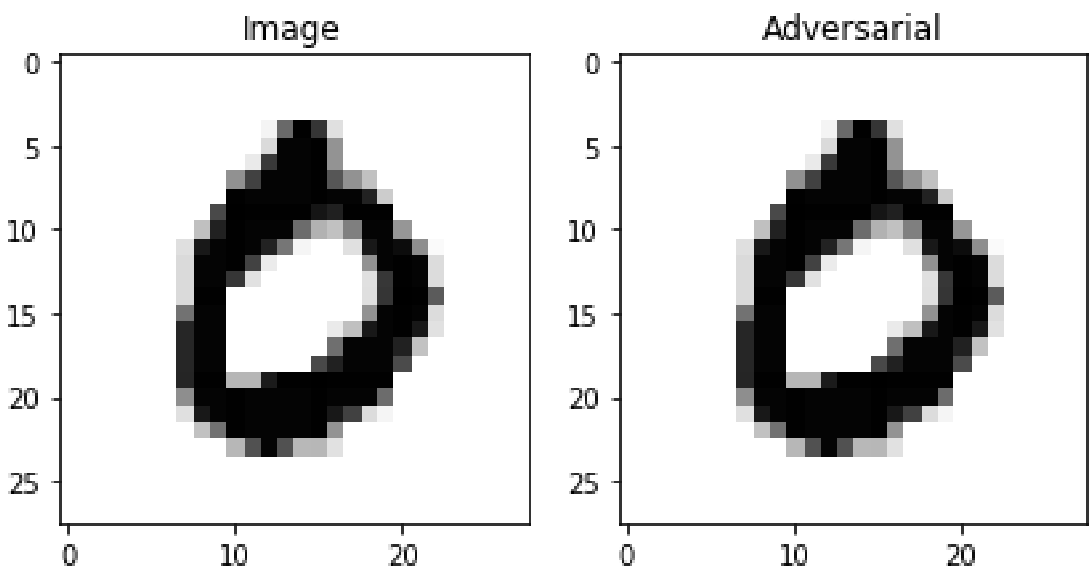
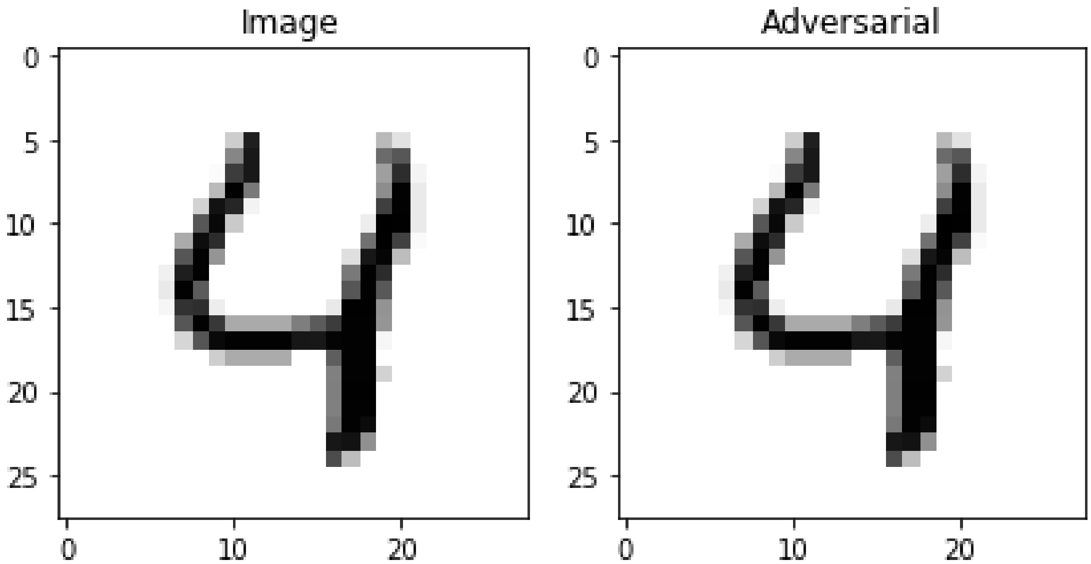


Image
Adversarial
0
5
10
15
20
25
0
10
20



0.9 Task 4: Evaluating the effects of the adversarial images on SVM:

```
In [10]: results = model_SVM.evaluate_adversarial_effect(
                                                   model_SVM, image_svm,
                                                   adver_svm,
                                                   test_dataset.test_labels[0:num_adversarial
         print ('..............Adversarial attack on Support Vector Machine............\n')
         model_SVM.visualize_image_and_adversarial(results=results, num_visualize=5)
         print ('-------------------------------------------------------------------')
         print ('Accuracy on actual images: {}'.format(results['acc_img']))
         print ('Accuracy on adversarial images: {}'.format(results['acc_adv']))
```

```
...Adversarial attack on Support Vector Machine...
```

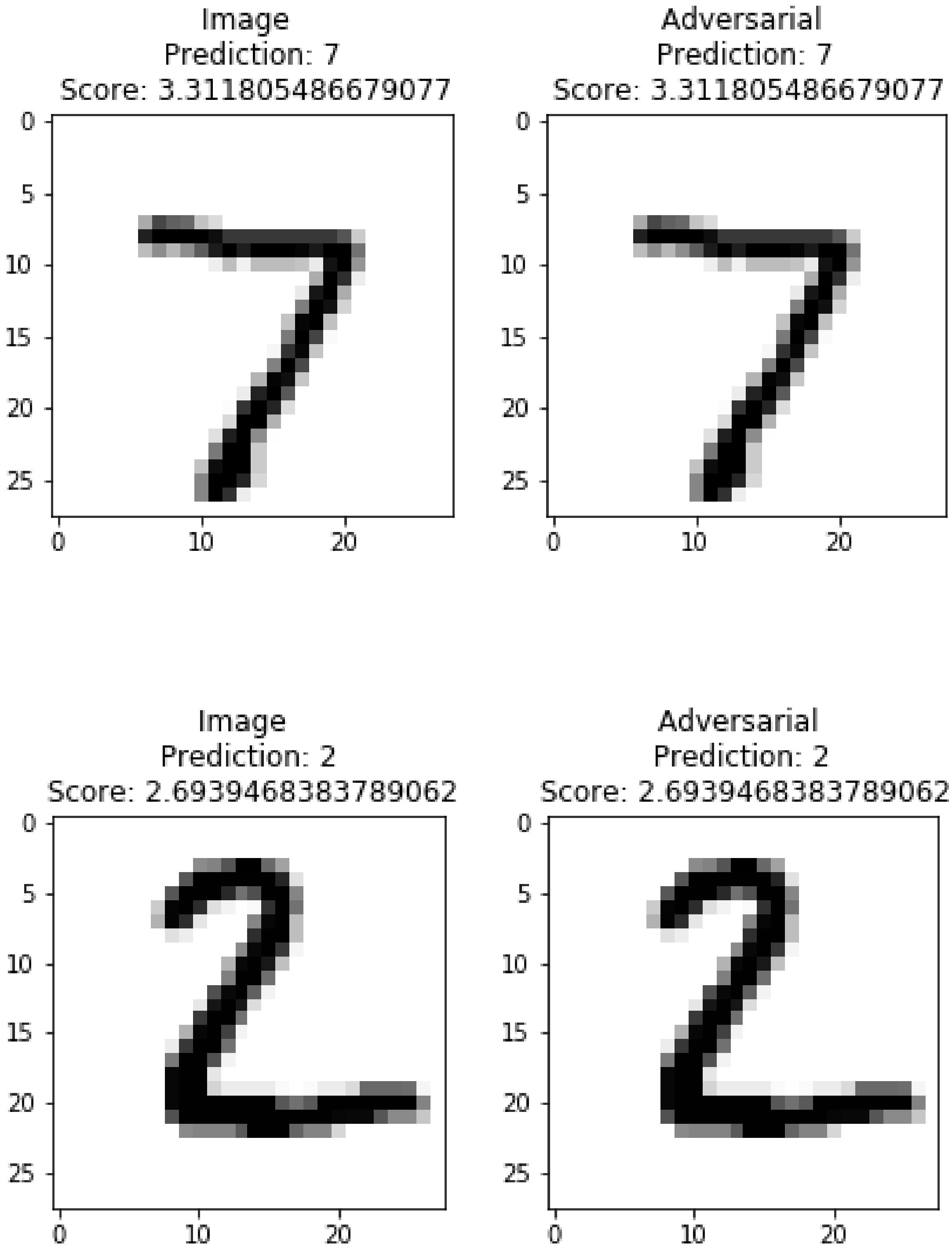


Image
Prediction: 7
Score: 3.311805486679077
Adversarial
Prediction: 7
Score: 3.311805486679077
Image
Prediction: 2
Score: 2.6939468383789062
Adversarial
Prediction: 2
Score: 2.6939468383789062
0
5
10
15
20
25
0
10
20

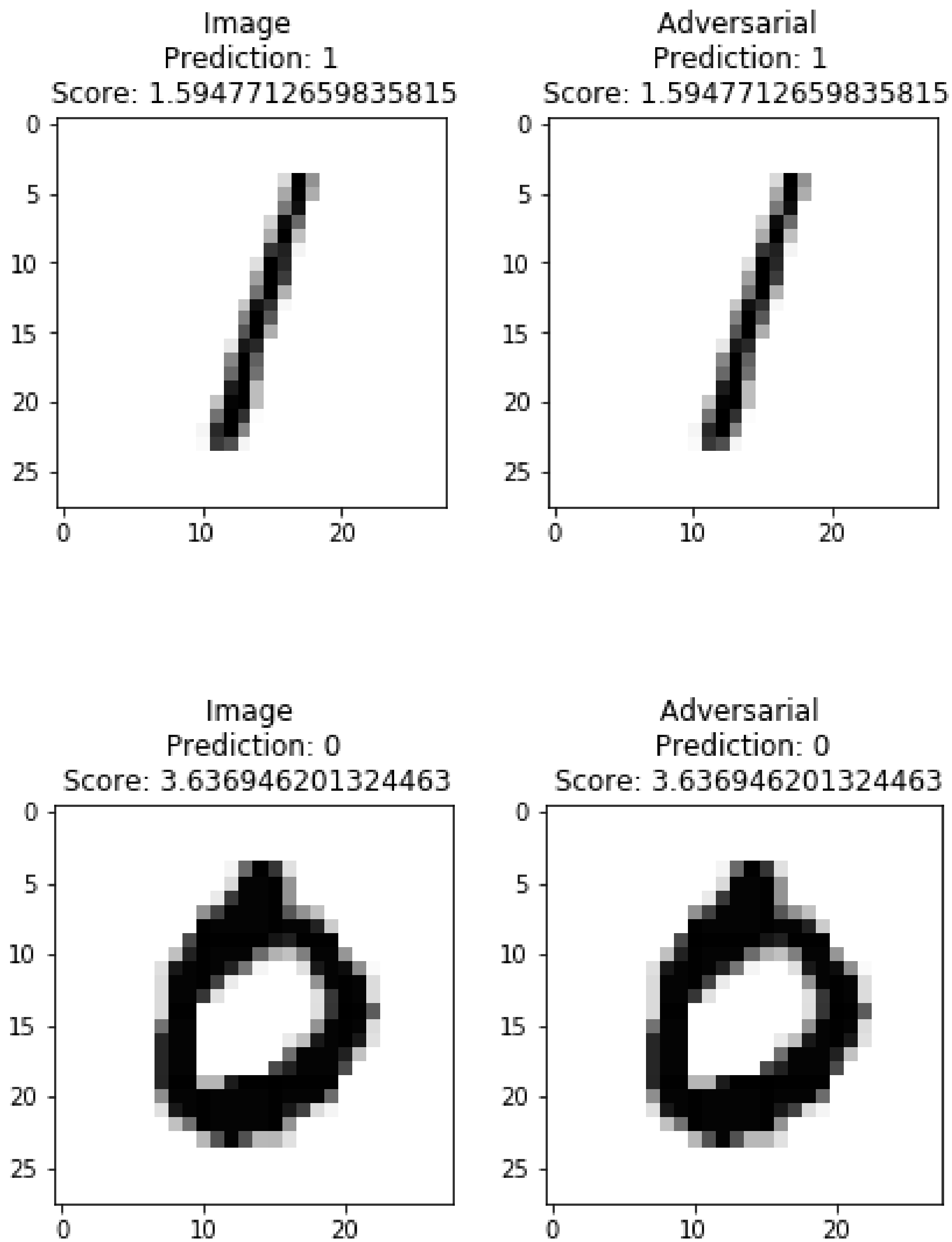
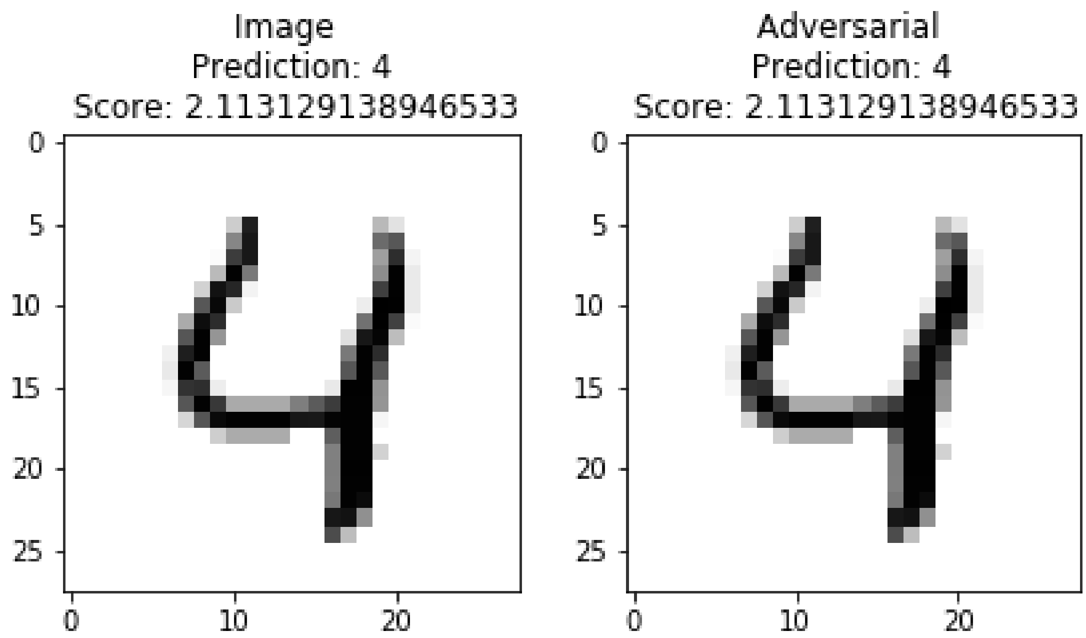


Image
Prediction: 1
Score: 1.5947712659835815
Adversarial
Prediction: 1
Score: 1.5947712659835815
Image
Prediction: 0
Score: 3.636946201324463
Adversarial
Prediction: 0
Score: 3.636946201324463




```
------------------------------------------------------------------
Accuracy on actual images: 95.0
Accuracy on adversarial images: 72.0
```

0.10 Task 5: Testing models by interchanging generated adversarials:

```
In [11]: print ('.....Testing Logistic Regression on adversarial images generated from SVM...\n

         results = model_logisticReg.evaluate_adversarial_effect(
                                                             model_logisticReg, image_svm,
                                                             adver_svm,
                                                             test_dataset.test_labels[0:num_adversaria
         print ('Accuracy on actual images: {}'.format(results['acc_img']))
         print ('Accuracy on adversarial images: {}'.format(results['acc_adv']))
```

```
...Testing Logistic Regression on adversarial images generated from SVM...

Accuracy on actual images: 93.0
Accuracy on adversarial images: 72.0
```

```
In [12]: print ('.....Testing SVM on adversarial images generated from Logistic Regression...\n

         results = model_SVM.evaluate_adversarial_effect(
                                                             model_SVM, image_logReg,
```

```
                                                     adver_logReg,
                                                     test_dataset.test_labels[0:num_adversarial
        print ('Accuracy on actual images: {}'.format(results['acc_img']))
        print ('Accuracy on adversarial images: {}'.format(results['acc_adv']))
```

```
...Testing SVM on adversarial images generated from Logistic Regression...

Accuracy on actual images: 95.0
Accuracy on adversarial images: 6.0
```

0.11 Task 6: Generating 60000 adversarials and creating new training set:

```
In [13]: num_adversarials = 60000
         image_logReg, adver_logReg = model_logisticReg.generate_adversarial(
                                                         model_logisticReg,
                                                         train_dataset.train_data[0:num_adversa
                                                         train_dataset.train_labels[0:num_adver

         adver_logReg = torch.reshape(adver_logReg, (-1, 28, 28))
         normalized_train_data = train_dataset.train_data.type(torch.FloatTensor)/255.
         train_dataset.train_data = torch.cat((normalized_train_data, adver_logReg), dim=0) * 2
         train_dataset.train_labels = torch.cat((train_dataset.train_labels[0:num_adversarials]
                                             train_dataset.train_labels[0:num_adversarials]]
         print('Shape of new training data: {}'.format(
                                 train_dataset.train_data.shape))
         print('Shape of new training labels: {}'.format(
                                 train_dataset.train_labels.shape))
```

```
Shape of new training data: torch.Size([120000, 28, 28])
Shape of new training labels: torch.Size([120000])
```

0.12 Task 6: Retraining and evaluating the two models:

```
In [14]: print ('..........Logistic Regression.............\n')

         model_logisticReg = LinearModel(input_dim, output_dim, algorithm_name='LogisticRegress
         model_logisticReg.fit_and_evaluate(model_logisticReg, train_dataset,
                                        test_dataset.test_data, test_dataset.test_labels)
```

```
...Logistic Regression...

Epoch: 1. Training Loss: 1.1657236814498901. Test Accuracy: 14.32
Epoch: 2. Training Loss: 1.1167799234390259. Test Accuracy: 14.81
Epoch: 3. Training Loss: 1.0219694375991821. Test Accuracy: 14.16
Epoch: 4. Training Loss: 0.9923308491706848. Test Accuracy: 13.27
Epoch: 5. Training Loss: 0.839326798915863. Test Accuracy: 12.61
Epoch: 6. Training Loss: 0.8311876058578491. Test Accuracy: 11.69
```

```
Epoch: 7. Training Loss: 0.8361297845840454. Test Accuracy: 11.16
Epoch: 8. Training Loss: 0.7912066578865051. Test Accuracy: 10.77
Epoch: 9. Training Loss: 0.8634053468704224. Test Accuracy: 10.64
Epoch: 10. Training Loss: 0.7733713388442993. Test Accuracy: 10.37
```

```
In [15]: print ('...........Support Vector Machine.............\n')

         model_SVM = LinearModel(input_dim, output_dim, algorithm_name='SVM')
         model_SVM.fit_and_evaluate(model_SVM, train_dataset,
                                    test_dataset.test_data, test_dataset.test_labels)
```

```
...Support Vector Machine...

Epoch: 1. Training Loss: 3.5574769973754883. Test Accuracy: 14.84
Epoch: 2. Training Loss: 2.800982713699341. Test Accuracy: 12.35
Epoch: 3. Training Loss: 2.3519675731658936. Test Accuracy: 10.96
Epoch: 4. Training Loss: 2.1461479663848877. Test Accuracy: 10.42
Epoch: 5. Training Loss: 1.8605360984802246. Test Accuracy: 10.23
Epoch: 6. Training Loss: 1.899336576461792. Test Accuracy: 10.2
Epoch: 7. Training Loss: 1.9729762077331543. Test Accuracy: 10.21
Epoch: 8. Training Loss: 1.819486379623413. Test Accuracy: 10.22
Epoch: 9. Training Loss: 1.580538034439087. Test Accuracy: 10.15
Epoch: 10. Training Loss: 1.8695851564407349. Test Accuracy: 10.15
```

0.13 Task 6: 1) Both the models performed worse on the new dataset.

0.14 Task 6: 2) Adversarial attack on the new trained model: From the accuracy we can see that the new model is more susceptable to the adverserial examples.

0.15 Task 6: 3) Could regularization be used: Yes regularization can be used because the model has less accuracy because of over fitting. The model is trying to in corporate even the smallest of the noise. In order to avoid this, we need to perform regularization.