ECE 1513 Introduction to Machine Learning

Assignment 5

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Load the boilerplate code:

```
[1] import array
    import gzip
    import itertools
    import numpy
    import numpy.random as npr
    import os
    import struct
    import time
    from os import path
    import urllib.request

    import jax.numpy as np
    from jax.api import jit, grad
    from jax.config import config
    from jax.scipy.special import logsumexp
    from jax import random
```

The following cell contains boilerplate code to download and load MNIST data.

```
[2] _DATA = "/tmp/"

    def _download(url, filename):
      """Download a url to a file in the JAX data temp directory."""
      if not path.exists(_DATA):
        os.makedirs(_DATA)
      out_file = path.join(_DATA, filename)
      if not path.isfile(out_file):
        urllib.request.urlretrieve(url, out_file)
        print("downloaded {} to {}".format(url, _DATA))


    def _partial_flatten(x):
      """Flatten all but the first dimension of an ndarray."""
      return numpy.reshape(x, (x.shape[0], -1))


    def _one_hot(x, k, dtype=numpy.float32):
      """Create a one-hot encoding of x of size k."""
      return numpy.array(x[:, None] == numpy.arange(k), dtype)


    def mnist_raw():
      """Download and parse the raw MNIST dataset."""
      # CVDF mirror of http://yann.lecun.com/exdb/mnist/
      base_url = "https://storage.googleapis.com/cvdf-datasets/mnist/"

      def parse_labels(filename):
        with gzip.open(filename, "rb") as fh:
          _ = struct.unpack(">II", fh.read(8))
          return numpy.array(array.array("B", fh.read()), dtype=numpy.uint8)
```

[2]

```
    def parse_images(filename):
      with gzip.open(filename, "rb") as fh:
        _, num_data, rows, cols = struct.unpack(">IIII", fh.read(16))
        return numpy.array(array.array("B", fh.read()),
                        dtype=numpy.uint8).reshape(num_data, rows, cols)

    for filename in ["train-images-idx3-ubyte.gz", "train-labels-idx1-ubyte.gz",
                     "t10k-images-idx3-ubyte.gz", "t10k-labels-idx1-ubyte.gz"]:
      _download(base_url + filename, filename)

    train_images = parse_images(path.join(_DATA, "train-images-idx3-ubyte.gz"))
    train_labels = parse_labels(path.join(_DATA, "train-labels-idx1-ubyte.gz"))
    test_images = parse_images(path.join(_DATA, "t10k-images-idx3-ubyte.gz"))
    test_labels = parse_labels(path.join(_DATA, "t10k-labels-idx1-ubyte.gz"))

    return train_images, train_labels, test_images, test_labels


  def mnist(create_outliers=False):
    """Download, parse and process MNIST data to unit scale and one-hot labels."""
    train_images, train_labels, test_images, test_labels = mnist_raw()

    train_images = _partial_flatten(train_images) / numpy.float32(255.)
    test_images = _partial_flatten(test_images) / numpy.float32(255.)
    train_labels = _one_hot(train_labels, 10)
    test_labels = _one_hot(test_labels, 10)

    if create_outliers:
      mum_outliers = 30000
      perm = numpy.random.RandomState(0).permutation(mum_outliers)
      train_images[:mum_outliers] = train_images[:mum_outliers][perm]

    return train_images, train_labels, test_images, test_labels

  def shape_as_image(images, labels, dummy_dim=False):
    target_shape = (-1, 1, 28, 28, 1) if dummy_dim else (-1, 28, 28, 1)
    return np.reshape(images, target_shape), labels

  train_images, train_labels, test_images, test_labels = mnist(create_outliers=False)
  num_train = train_images.shape[0]
```

The following cell defines the accuracy of our model and how to initialize its parameters.

```
[3] def accuracy(params, batch):
      inputs, targets = batch
      target_class = np.argmax(targets, axis=1)
      predicted_class = np.argmax(predict(params, inputs), axis=1)
      return np.mean(predicted_class == target_class)

    def init_random_params(layer_sizes, rng=npr.RandomState(0)):
      scale = 0.1
      return [(scale * rng.randn(m, n), scale * rng.randn(n))
              for m, n, in zip(layer_sizes[:-1], layer_sizes[1:])]
```

```
[4] batch_size = 50
    num_complete_batches, leftover = divmod(num_train, batch_size)
    num_batches = num_complete_batches + bool(leftover)

    def data_stream():
      rng = npr.RandomState(0)
      while True:
        perm = rng.permutation(num_train)
        for i in range(num_batches):
          batch_idx = perm[i * batch_size:(i + 1) * batch_size]
          yield train_images[batch_idx], train_labels[batch_idx]
    batches = data_stream()
```

```
[5] from jax.experimental import optimizers
    from jax.experimental import stax
```

```
init_random_params, predict = stax.serial(
    stax.Conv(256, (5,5),strides = (2,2)),
    stax.Relu,
    stax.Conv(128, (3,3)),
    stax.Relu,
    stax.Conv(32, (3,3)),
    stax.Relu,
    stax.MaxPool((2,2)),
    stax.Flatten,
    stax.Dense(1024),
    stax.Relu,
    stax.Dense(128),
    stax.Relu,
    stax.Dense(10),
)
```

We redefine the cross-entropy loss for this model. As done in Problem 1, complete the return line below (it's identical).

```
[7] def loss(params, batch):
      inputs, targets = batch
      logits = predict(params, inputs)
      preds  = stax.logsoftmax(logits)
      return -np.sum(targets*preds)/len(targets)
```

Next, we define the mini-batch SGD optimizer, this time with the optimizers library in JAX.

```
[8] learning_rate = 0.08
    opt_init, opt_update, get_params = optimizers.sgd(learning_rate)

    @jit
    def update(_, i, opt_state, batch):
      params = get_params(opt_state)
      return opt_update(i, grad(loss)(params, batch), opt_state)
```

The next cell contains our training loop, very similar to Problem 1.

learning rate, batch size, number of epochs

```
[9] num_epochs = 20

    key = random.PRNGKey(123)
    _, init_params = init_random_params(key, (-1, 28, 28, 1))
    opt_state = opt_init(init_params)
    itercount = itertools.count()

    acc_list=[]
    for epoch in range(1, num_epochs + 1):
      for _ in range(num_batches):
        opt_state = update(key, next(itercount), opt_state, shape_as_image(*next(batches)))

      params = get_params(opt_state)
      test_acc = accuracy(params, shape_as_image(test_images, test_labels))
      test_loss = loss(params, shape_as_image(test_images, test_labels))
      print('Test set loss, accuracy (%): ({:.2f}, {:.2f})'.format(test_loss, 100 * test_acc))
      acc_list.append(test_acc)
```

```
Test set loss, accuracy (%): (0.05, 98.46)
Test set loss, accuracy (%): (0.04, 98.80)
Test set loss, accuracy (%): (0.03, 98.95)
Test set loss, accuracy (%): (0.03, 98.99)
Test set loss, accuracy (%): (0.04, 98.94)
Test set loss, accuracy (%): (0.03, 99.04)
Test set loss, accuracy (%): (0.03, 99.16)
Test set loss, accuracy (%): (0.04, 98.96)
Test set loss, accuracy (%): (0.04, 98.89)
Test set loss, accuracy (%): (0.04, 99.02)
Test set loss, accuracy (%): (0.04, 99.11)
Test set loss, accuracy (%): (0.04, 99.05)
Test set loss, accuracy (%): (0.04, 98.99)
Test set loss, accuracy (%): (0.05, 98.93)
Test set loss, accuracy (%): (0.04, 99.12)
Test set loss, accuracy (%): (0.04, 99.18)
Test set loss, accuracy (%): (0.04, 99.17)
Test set loss, accuracy (%): (0.04, 99.17)
Test set loss, accuracy (%): (0.04, 99.16)
Test set loss, accuracy (%): (0.04, 99.18)
```

Assignment 5 code:

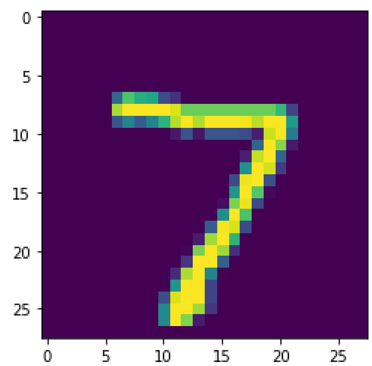
Assignment 5

question1

```
[10] class_7_label = [0.,0.,0.,0.,0.,0.,0.,1.,0.,0.]
     index_class7 = test_labels.tolist().index(class_7_label)
     input_image, input_label = shape_as_image(test_images[index_class7], test_labels[index_class7])
```

```
[11] #original image visulization
     from matplotlib import pyplot as plt
     visualize_image = input_image
     visualize_image = np.reshape(visualize_image, (28,28))
     plt.imshow(visualize_image, interpolation='nearest')
```

```
<matplotlib.image.AxesImage at 0x7fe09c047c88>
```



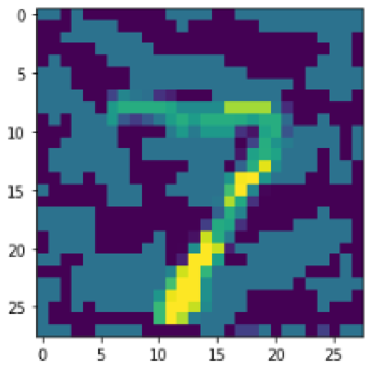

```
[12] epsilon = 0.3
```

```
[13] from jax.experimental.stax import logsoftmax
     def loss_adversarial(params, inputs, target):
       logits = predict(params, inputs)
       preds = logsoftmax(logits)
       return -np.mean(target*preds)
```

```
[14] #finding perturbation
     grad_inputx = grad(loss_adversarial,1)(params, input_image, input_label)
     x_star = input_image + epsilon * np.sign(grad_inputx)
```

```
[15] #visualization of the perturbed image
     visualize_image = x_star
     visualize_image = np.reshape(visualize_image, (28,28))
     plt.imshow(visualize_image, interpolation='nearest')
```

```
<matplotlib.image.AxesImage at 0x7fe09c1950b8>
```




```
[16] #prediction vector on original image
     original_vector = predict(params, input_image)
     print("original image prediction vector:",original_vector)
     print("original image prediction class is:",np.argmax(input_label))
```

```
original image prediction vector: [[ -9.696826     0.40136307  -3.2809608    3.9565678    4.725864
   -6.593747   -16.60616     28.114473    -4.3066363    5.435471  ]]
original image prediction class is: 7
```

```
[17] #prediction vector on perturbed image
     prediction=predict(params, x_star)
     print("perturbed image prediction vector:\n",prediction)
     print("\n")
     print("perturbed image prediction class is:",np.argmax(prediction))
```

```
perturbed image prediction vector:
 [[ -3.9941251  -4.731851   -2.8022878   9.94996     1.798103   -3.2056277
  -12.401413    3.2338426   1.4470123   9.714881 ]]


perturbed image prediction class is: 3
```

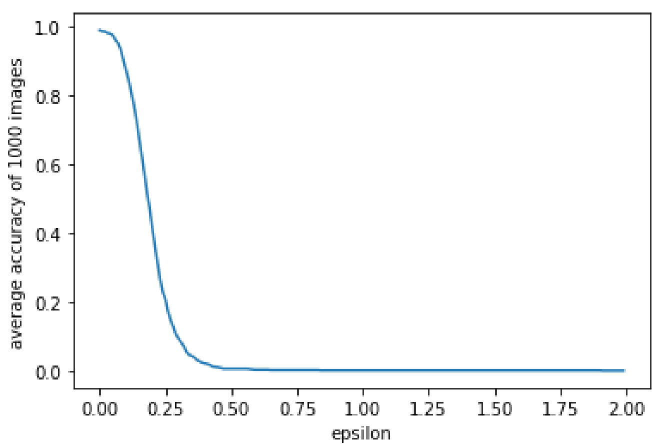
question 2

```
[18] image = test_images[0:1000]
     label = test_labels[0:1000]
     input_image_q2, input_label_q2 = shape_as_image(image, label)
     grad_inputx = grad(loss_adversarial,1)(params, input_image_q2, input_label_q2)
```

```
[29] accuracy_result= []
     epsilon = np.arange(0,2,0.01)
     for i in epsilon:

       #update input
       x_star = input_image_q2 + i * np.sign(grad_inputx)
       #calculate accuracy
       test_acc = accuracy(params, shape_as_image(x_star, label))
       accuracy_result.append(test_acc)
```

```
#plot
plt.plot(epsilon, accuracy_result)
plt.xlabel("epsilon")
plt.ylabel("average accuracy of 1000 images")
plt.show()
```



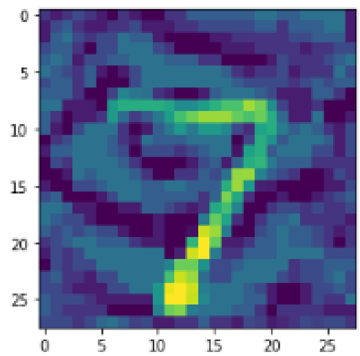
question 3

```
[21] class_7_label = [0.,0.,0.,0.,0.,0.,0.,1.,0.,0.]
     index_class7 = test_labels.tolist().index(class_7_label)
     input_image, input_label = shape_as_image(test_images[index_class7], test_labels[index_class7])
```

```
[22] #finding perturbation
     k=5
     epsilon=0.3
     original_image = input_image
     for _ in range (k):
       grad_inputx = grad(loss_adversarial,1)(params, original_image, input_label)
       original_image = original_image + epsilon/k * np.sign(grad_inputx)
```

```
[23] #visualization of the perturbed image
     visualize_image = original_image
     visualize_image = np.reshape(visualize_image, (28,28))
     plt.imshow(visualize_image, interpolation='nearest')
```

```
<matplotlib.image.AxesImage at 0x7fe0904d4a20>
```




```
[24] #prediction vector on original image
     print("original image prediction class is:",np.argmax(input_label))
     original_vector = predict(params, input_image)
     print("original image prediction vector:",original_vector)
```

```
original image prediction class is: 7
original image prediction vector: [[ -9.696826     0.40136307  -3.2809608    3.9565678    4.725864
   -6.593747   -16.60616     28.114473    -4.3066363    5.435471  ]]
```

```
[25] #prediction vector on perturbed image
     prediction=predict(params, original_image)
     print("perturbed image prediction vector:\n",prediction)
     print("\n")
     print("perturbed image prediction class is:",np.argmax(prediction))
```

```
perturbed image prediction vector:
 [[ -6.182073    -6.845872    -5.0515084    3.6911247    5.2505727    1.700013
  -14.193443     3.522048     1.437608    21.307058 ]]


perturbed image prediction class is: 9
```

question 4

```
[26] image = test_images[0:1000]
     label = test_labels[0:1000]
     input_image_q4, input_label_q4 = shape_as_image(image, label)
```

```
[27] accuracy_result= []
     k=5
     epsilon = np.arange(0,2,0.01).tolist()
     original_image = input_image_q4
     for e in epsilon:

       for _ in range (k):
         grad_inputx = grad(loss_adversarial,1)(params, original_image, input_label_q4)
         original_image = original_image + e/k * np.sign(grad_inputx)

         #calculate accuracy
       test_acc = accuracy(params, shape_as_image(original_image, label))
       accuracy_result.append(test_acc)
```

```
#plot
plt.plot(epsilon, accuracy_result)
plt.xlabel("epsilon")
plt.ylabel("average accuracy of 1000 images")
plt.show()
```