CS289A_HW06_NeuralNet

April 14, 2017

1 Neural Network Constructor

This notebook works through the construction of a two-layer neural network. (It will eventually be imported into its own python module)

```
In [108]: %load_ext autoreload

The autoreload extension is already loaded. To reload it, use:
  %reload_ext autoreload


In [109]: %autoreload 2

In [110]: import numpy as np
          import HW06_utils as ut

          import gradients as grad
          import activationfns as af

In [462]: BASE_DIR = '/Users/mitch/Documents/Cal/2_2017_Spring/COMPSCI 289A - Intro
          traindata = np.loadtxt(BASE_DIR+'Data/letters_traindata.csv', dtype=float
          trainlabels = np.array([np.loadtxt(BASE_DIR+'Data/letters_trainlabels.csv

In [365]: class NeuralNet:
              """
              Train and store a neural network, based on supplied training data.
              Use this network to predict classifications.
              """

              def __init__(self,nlayers=3,unitsperlayer=None,actfns=[af.sigmoid,af.
                  """
                  Initialize the neural network
                  - nlayers:       the number of layers in the neural network (incl
                  - unitsperlayer: a list specifying (in order) the number of units
                  - actfns:        a list specifying (in order) the activation func
                  - Gradient:      a class providing optimized gradient calculation
                                   activation functions
                  - verbose:       a boolean for descriptive output
```

```
        """
        if unitsperlayer == None:
            unitsperlayer = 3*np.ones(nlayers)
        elif nlayers == len(unitsperlayer)+1:
            self.nlayers = nlayers-1
            self.unitsperlayer = unitsperlayer
        elif nlayers > len(unitsperlayer)+1:
            print('ERROR: The number of units per layer were not given fo
        elif nlayers < len(unitsperlayer)+1:
            print('ERROR: More layers were given units than were specifie
        if nlayers == len(actfns)+1:
            self.actfns = actfns
        elif nlayers > len(actfns)+1:
            print('ERROR: The activation function was not given for at le
        elif nlayers < len(actfns)+1:
            print('ERROR: More activation functions were provided than sp
        if Gradients == None:
            print('ERROR: A gradient generator class must be included.')
        self.gradients = Gradients
        self.weight_matrices = []


    def initialize_weights(self,shape,mu=0,var=1):
        """
        Initialize weight matrix from normal distribution.
        - shape: tuple specifying desired shape of weight matrix
        - mu:    mean value of normal distribution
        - var:   variance of normal distribution
        """
        weight_matrix = np.random.normal(loc=mu,scale=np.sqrt(var),size=s

        return weight_matrix


    def weight_matrix_shape(self,layer_n,nfeatures):
        """
        Create weight matrix with the proper number of rows and columns f
        - n:         the layer which will employ an activation function o
                     product of the weight matrix and values
        - nfeatures: an integer specifying the number of features in the
        """
        if layer_n != 0 and layer_n != range(self.nlayers)[-1]:
            WM_nrows = self.unitsperlayer[layer_n]-1
            WM_ncols = self.unitsperlayer[layer_n-1]
        elif layer_n == 0:
            WM_nrows = self.unitsperlayer[layer_n]-1
            WM_ncols = nfeatures
        else:
```

```
            WM_nrows = self.unitsperlayer[layer_n]
            WM_ncols = self.unitsperlayer[layer_n-1]
        return WM_nrows,WM_ncols


    def forward(self,data):
        """
        Perform forward pass through neural network by multiplying data b
        and enforcing a nonlinear activation function for each layer.
        - data:           Nxd numpy array with N sample points and d feat
        - weightmatrices: ordered list of sequential weight matrices corr
        - actfns:         ordered list of sequential activation functions
                         (functions are defined in activationfuncs.py)
        Returns layeroutputs, a list of the outputs from each layer. The
        is an CxN numpy array with hypotheses for each sample N_i being i
        """
        H = data.T
        layeroutputs = []
        for i in range(self.nlayers):
            W = self.weight_matrices[i]
            actfn = self.actfns[i]
            H = actfn(np.dot(W,H))
            # If the layer is not the output layer, add a fictitious unit
            if i != self.nlayers-1:
                fictu = np.array([np.ones_like(H[0])])
                H = np.concatenate((H,fictu),axis=0)
            layeroutputs.append(H)
        return layeroutputs


    def backward(self,layeroutputs,labelrange,gradients=None):
        """
        Perform backward pass through neural network by computing gradien
        input weight matrices with respect to the loss function comparing
        to true values. Classes for gradients are provided in gradients.p
        (a unique gradient class is required for neural networks with di
        numbers of layers and/or different activation functions)
        """
        if gradients == None:
            Gradients = self.gradients
        gradients = Gradients.calculate(self.weight_matrices,layeroutputs

        return gradients


    def classify_outputs(self,finaloutputs):
        """
        Convert final outputs into classifications
```

```
        -finaloutputs: a CxN numpy array with hypotheses for each sample
                       class C_j.
        Returns a 1D, length-N array with values corresponding to point c
        """
        if len(finaloutputs) == 1:
            classifications = np.around(finaloutputs[0]).astype(int)
        if len(finaloutputs) > 1:
            # Add one for 1-indexing in classification labels
            classifications = (np.argmax(finaloutputs,axis=0)+np.ones(len
        return classifications


    def stoch_grad_descent_prep(self,layeroutputs,wrongclass):
        """
        For stochastic gradient descent, choose one misclassified point f
        (index i) for performing backprop algorithm and reduce datasets a
        - layeroutputs: a list of the outputs from each layer
        - predictions:  1D, length-N numpy array with predictions for the
        - labels:       1D, length-N numpy array with true labels for the
        """
        diffclass = True
        tested_i = []

        while counter < len(wrongclass):
            i = np.random.randint(len(labels))
            if i not in tested_i:
                tested_i.append(i)
            if len(tested_i) == len(labels):
                print('All points classified correctly')
                return True,True
            if labels[i]!=classifications[i]:
                # Improperly classified point, so use it for gradient des
                return layeroutputs_i,i


    def train(self,data,labels,epsilon=0.1):
        """
        Train the neural network on input data
        - data:   Nxd numppy array with N sample points and d features
        - labels: 1D, length-N numpy array with labels for the N sample p
        """
        # Ensure labels are integers and that data and labels are the sam
        labels = labels.astype(int)
        if len(data) != len(labels):
            print('ERROR: Data and labels must be the same length.')

        # Add fictitious unit for bias terms
        fictu = np.array([np.ones(len(data))]).T
```

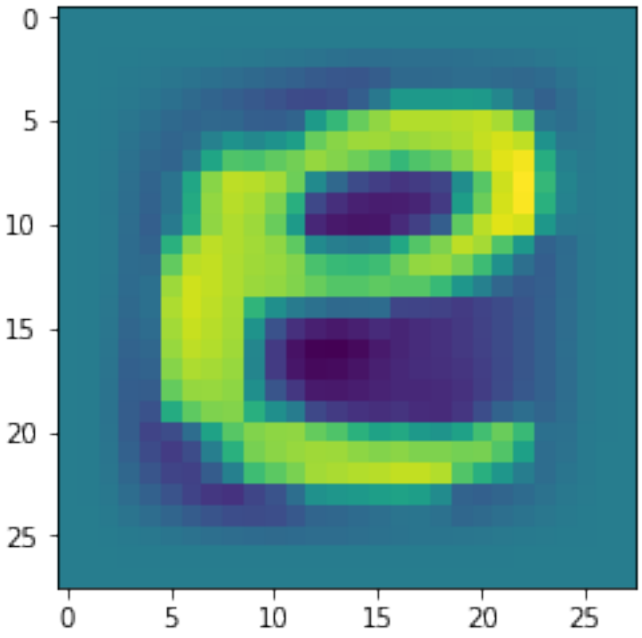
```
        data = np.concatenate((data,fictu),axis=1)

        # Initialize Weights
        nfeatures = len(data[0])
        for layer_n in range(self.nlayers):
            WM_nrows,WM_ncols = self.weight_matrix_shape(layer_n,nfeature
            # Variance of weight matrix determined by fan-in (eta), the n
            # (or the number of data features when initializing the first
            eta = WM_ncols
            weight_matrix = self.initialize_weights((WM_nrows,WM_ncols),n
            self.weight_matrices.append(weight_matrix)

        # Begin loop
        layeroutputs = self.forward(data)
        classifications = self.classify_outputs(layeroutputs[-1])
        trainAccs = [ut.score_accuracy(classifications,labels)]
        epochcounter = 0
        while epochcounter < 20:
            # Stochastic gradient descent: Loop over points randomly, one
            # (Execute gradient class overhead before beginning)
            self.gradients.prepare(data,labels,self.unitsperlayer[-1])

            for datapoint_i in range(len(data)):
                X_i = np.array([data[datapoint_i]])
                layeroutput_i = self.forward(X_i)

                gradients = self.backward(layeroutput_i,[datapoint_i,data

                for n in range(self.nlayers):
                    self.weight_matrices[n]=self.weight_matrices[n]-epsil

            layeroutputs = self.forward(data)
            classifications = self.classify_outputs(layeroutputs[-1])
            trainAcc = ut.score_accuracy(classifications,labels)
            trainAccs.append(trainAcc)

            epochcounter+=1
            print('%.2f%% accuracy after %i epoch(s).' %(100*trainAcc,epo
            DL = np.concatenate((data,labels),axis=1)
            np.random.shuffle(DL)
            data = DL[:,:-1]
            labels = np.array([DL[:,-1]]).T
            epsilon *=0.75
        print(trainAccs)


    def predict(self,testdata):
        """
```

```
        Predict classfications for unlabeled data points using the previo
        trained neural network.
        - testdata: Nxd numpy array with N sample points and d features
                    *Note, dimension d must match that used for the data
        Returns a 1D, length-N numpy array of predictions (one prediction
        """

        # Add fictitious unit to input to match dimensions
        fictu = np.array([np.ones(len(testdata))]).T
        testdata = np.concatenate((testdata,fictu),axis=1)

        npoints = len(testdata)
        predictions = np.empty(npoints)
        layeroutputs = self.forward(testdata)
        predictions = self.classify_outputs(layeroutputs[-1])


        return predictions.astype(int)
```

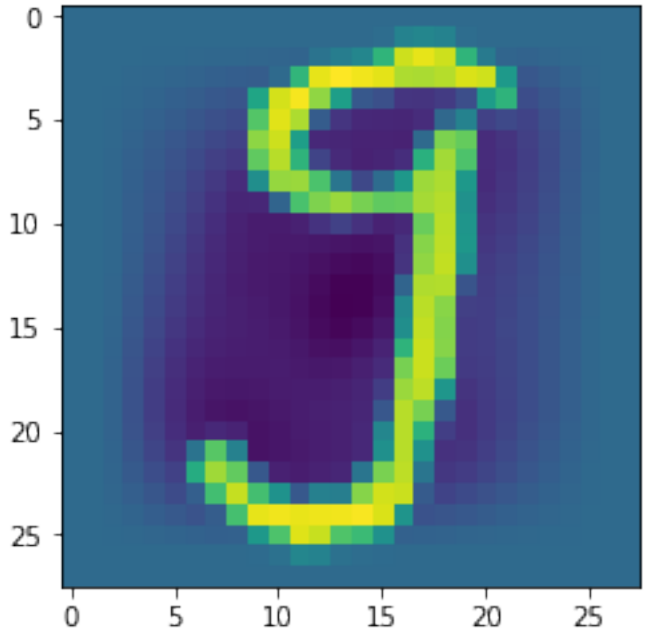
1.0.1 Implementation

```
In [366]: classifier = NeuralNet(nlayers=3,unitsperlayer=[201,26],actfns=[af.tanh,a

In [367]: classifier.train(traindata,trainlabels)

73.91% accuracy after 1 epoch(s).
79.92% accuracy after 2 epoch(s).
83.10% accuracy after 3 epoch(s).
83.48% accuracy after 4 epoch(s).
85.09% accuracy after 5 epoch(s).
86.20% accuracy after 6 epoch(s).
86.69% accuracy after 7 epoch(s).
87.58% accuracy after 8 epoch(s).
88.06% accuracy after 9 epoch(s).
88.04% accuracy after 10 epoch(s).
88.44% accuracy after 11 epoch(s).
88.55% accuracy after 12 epoch(s).
88.64% accuracy after 13 epoch(s).
88.75% accuracy after 14 epoch(s).
88.79% accuracy after 15 epoch(s).
88.82% accuracy after 16 epoch(s).
88.91% accuracy after 17 epoch(s).
88.91% accuracy after 18 epoch(s).
88.93% accuracy after 19 epoch(s).
88.94% accuracy after 20 epoch(s).
[0.03782051282051282, 0.7390725160256411, 0.7991686698717949, 0.8310196314102564, 0
```

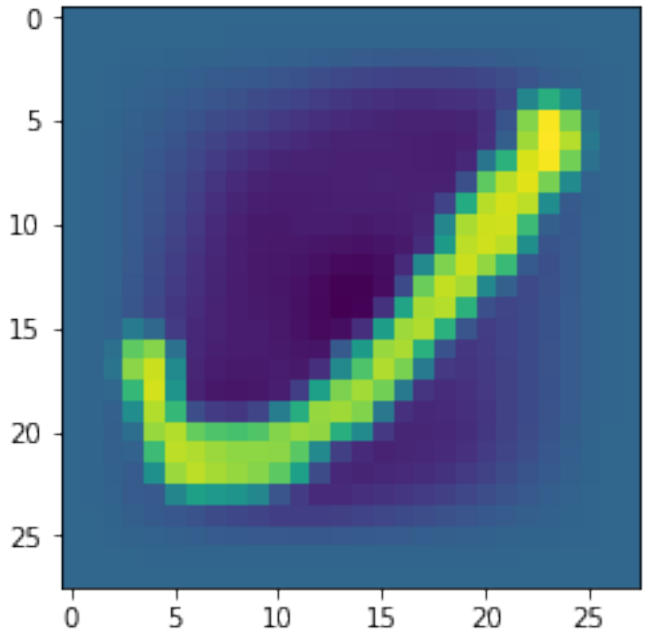
```
In [445]: valdata = np.loadtxt(BASE_DIR+'Data/letters_valdata.csv', dtype=float, de
          vallabels = np.array([np.loadtxt(BASE_DIR+'Data/letters_vallabels.csv', c

In [446]: valpredictions = classifier.predict(valdata)

In [447]: valAcc = ut.score_accuracy(valpredictions,vallabels)
          print(valAcc)

0.8662660256410256


In [448]: import matplotlib.pyplot as plt

In [472]: for num in range(40,60):
              plt.imshow(valdata[num,:784].reshape((28,28)))
              plt.show()
              alphabet = 'abcdefghijklmnopqrstuvwxyz'
              print('Guess:  \t',alphabet[valpredictions[num]-1])
              print('Actually:\t',alphabet[vallabels[num,0]-1])
```



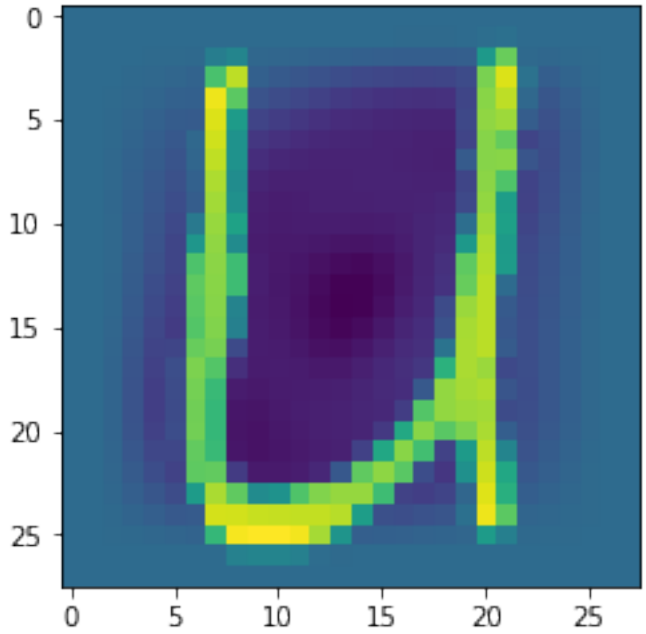

```
Guess:          e
Actually:        e
```



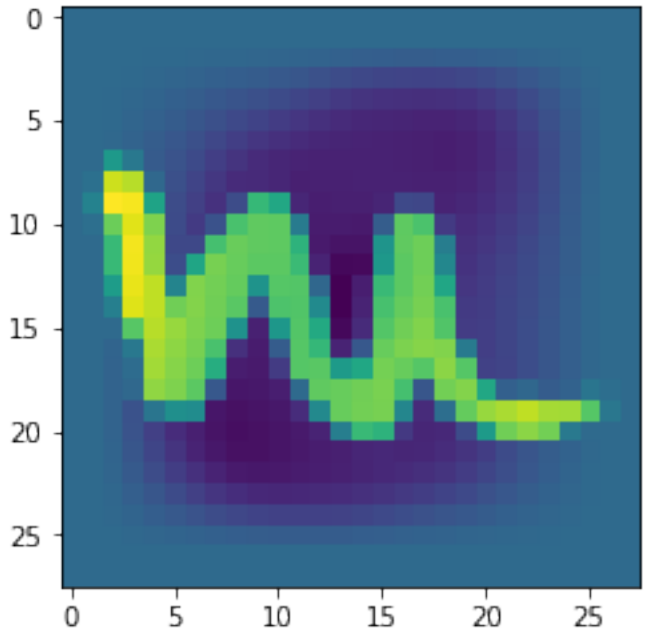

```
Guess:          g
Actually:        g
```



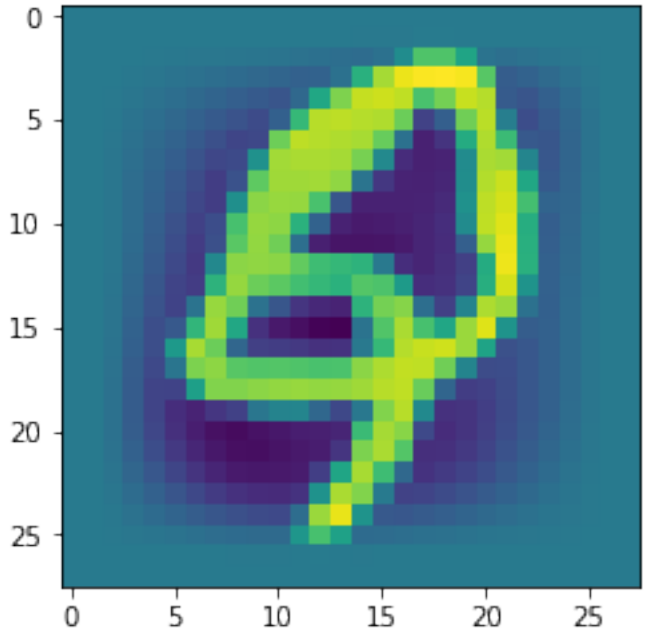
```
Guess:          j
Actually:        j
```



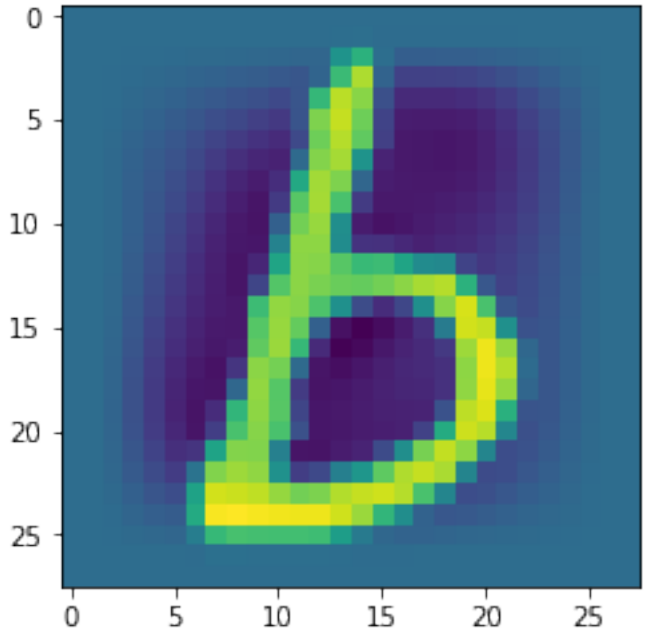

```
Guess:          u
Actually:        u
```



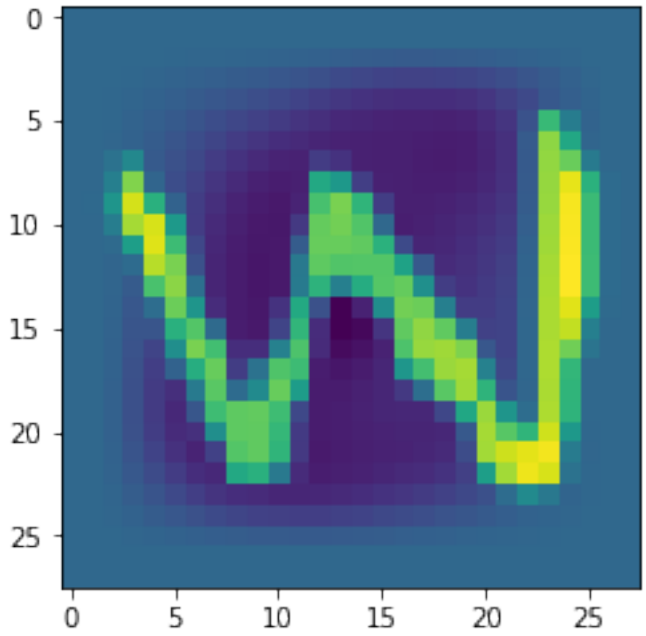
```
Guess:          u
Actually:        m
```



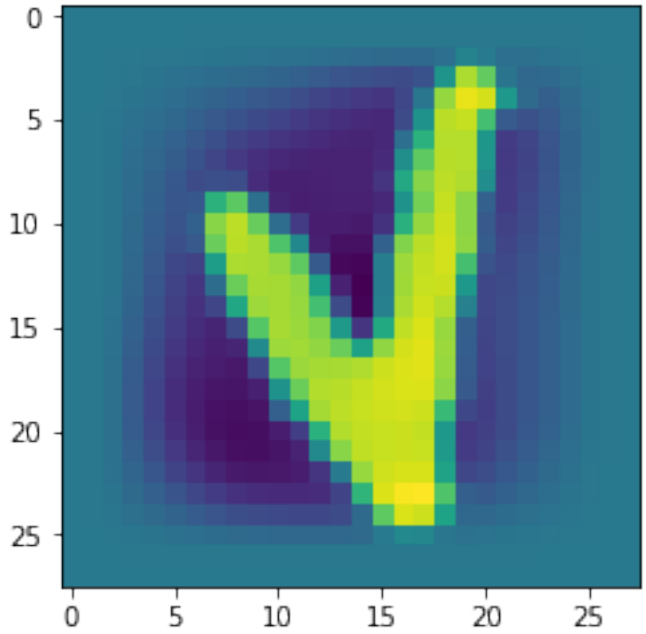

```
Guess:          q
Actually:        q
```



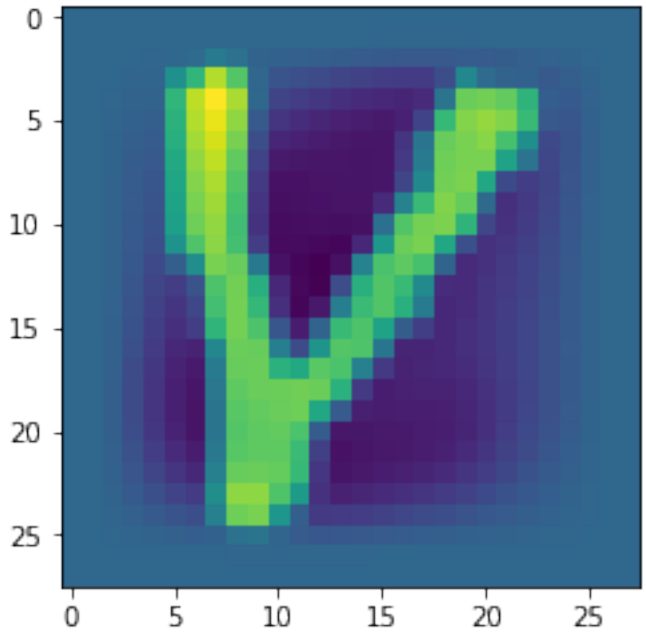

```
Guess:          b
Actually:        b
```



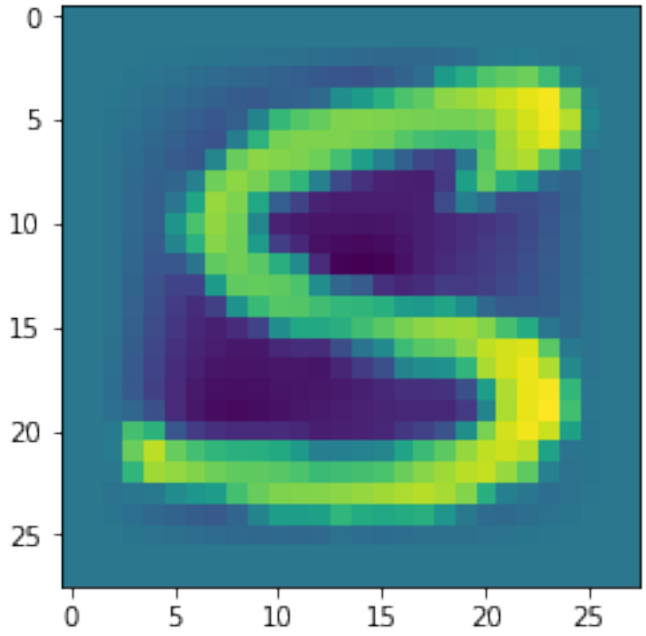
```
Guess:          w
Actually:        w
```



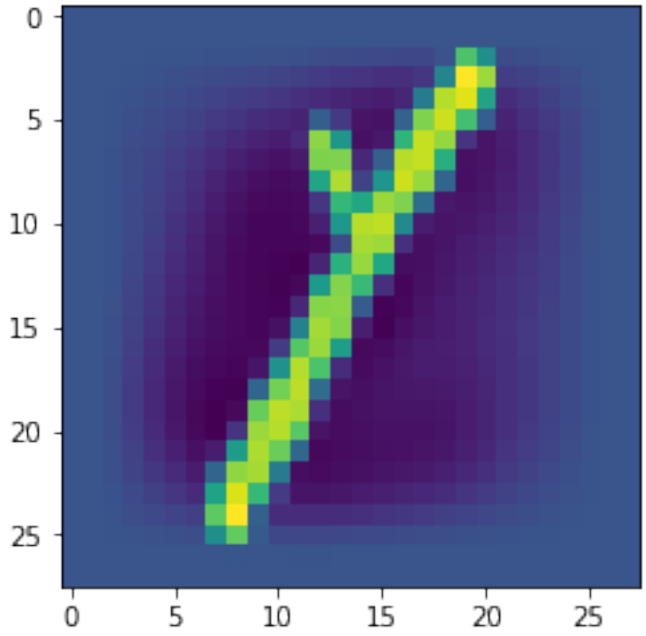

```
Guess:          v
Actually:        v
```



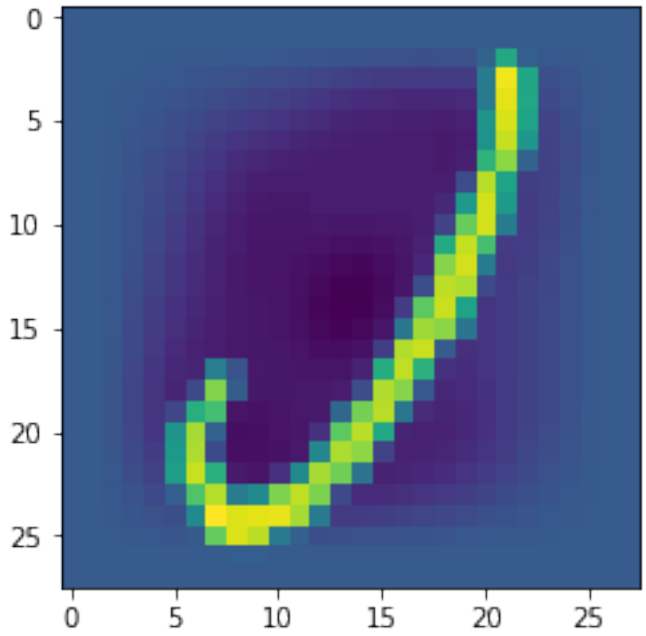
```
Guess:          v
Actually:        v
```



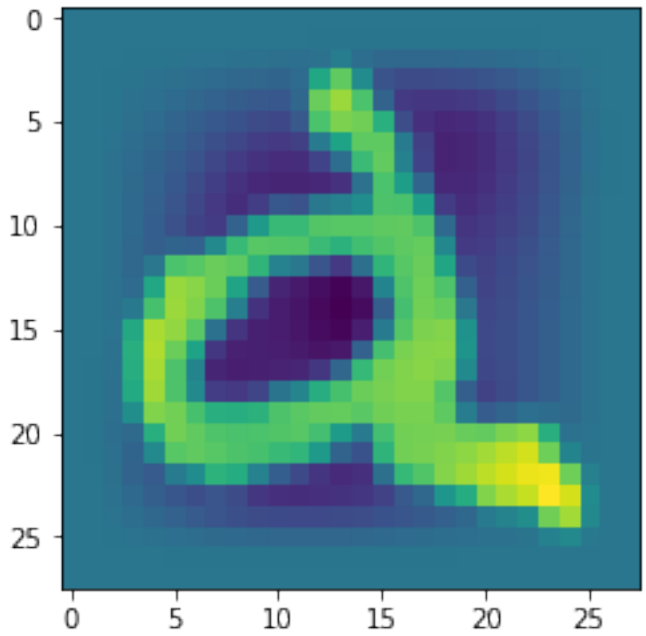

```
Guess:          s
Actually:        s
```



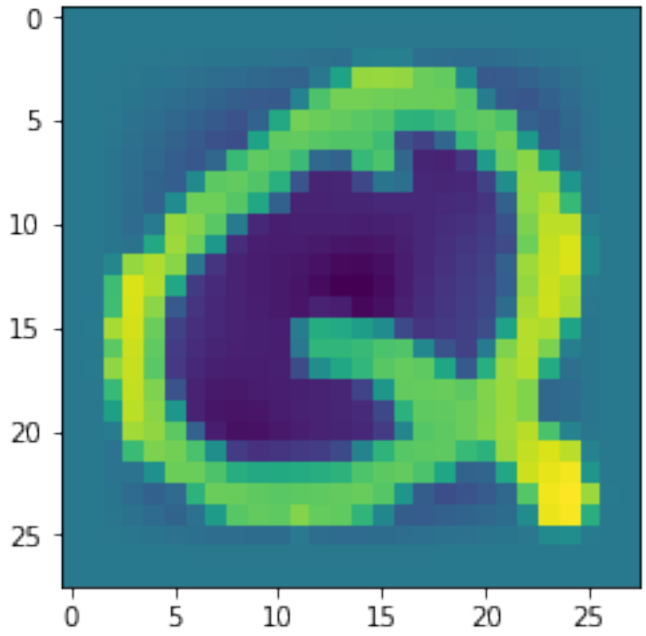

```
Guess:              l
Actually:           y
```



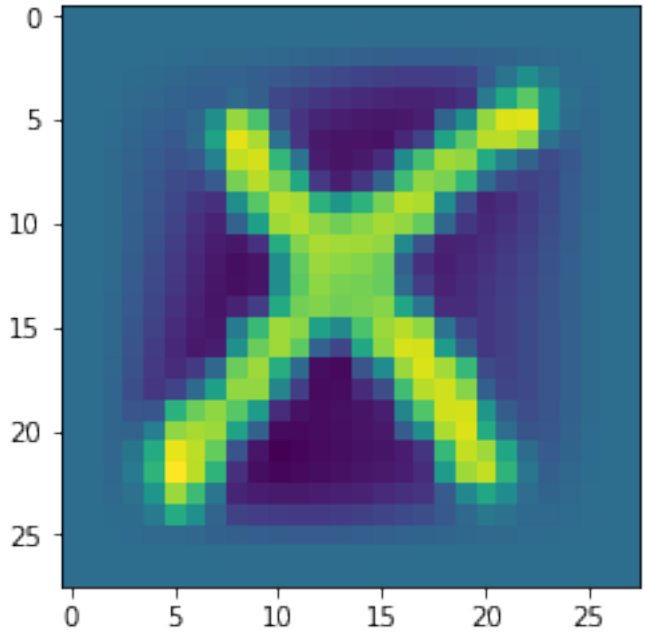
```
Guess:          j
Actually:        j
```



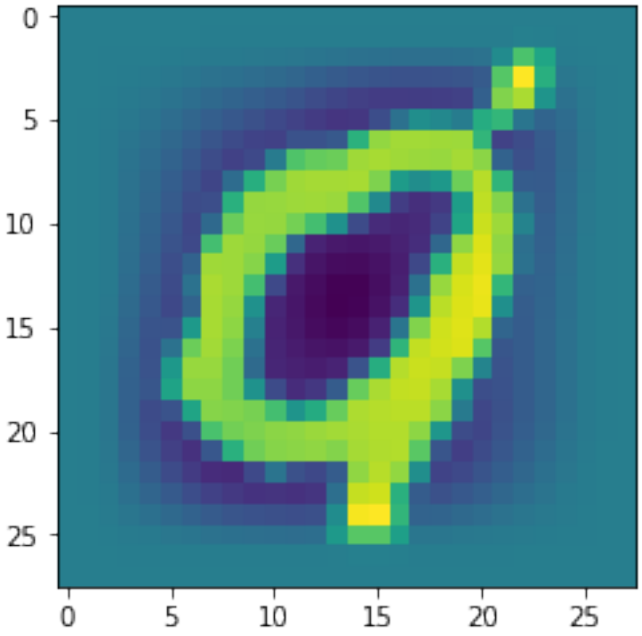

```
Guess:          d
Actually:        a
```



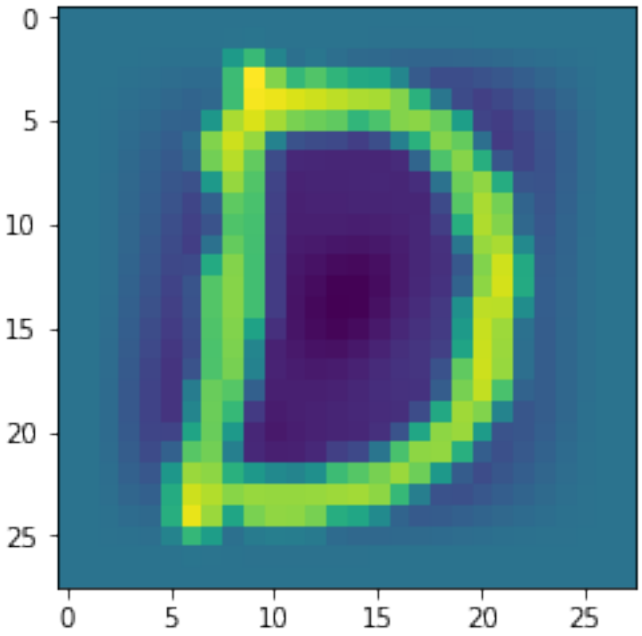
```
Guess:          q
Actually:        q
```



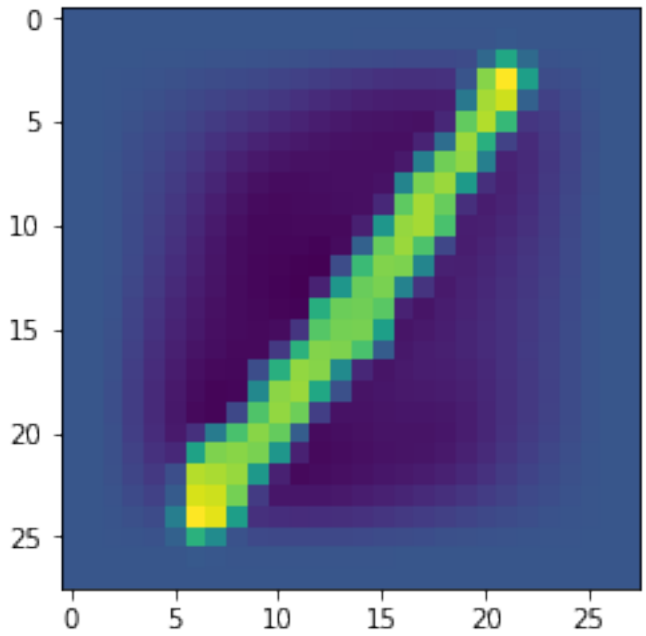

```
Guess:          x
Actually:        x
```



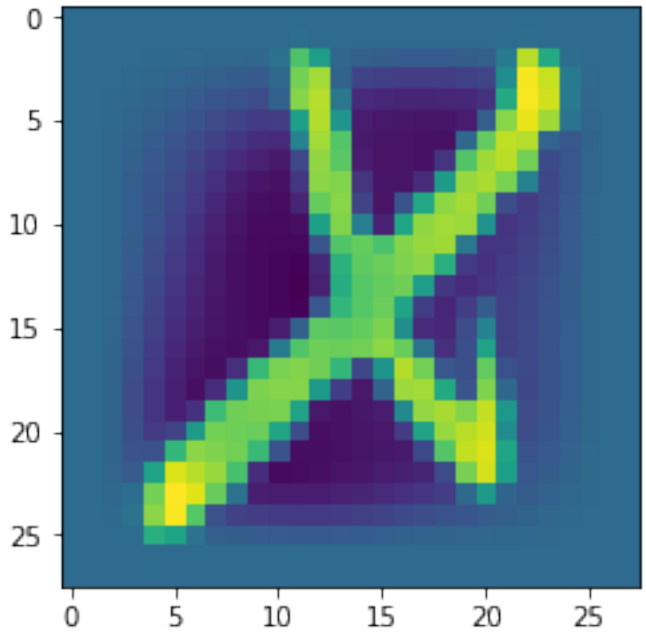

```
Guess:          o
Actually:        q
```



```
Guess:          d
Actually:        d
```




```
Guess:          l
Actually:        l
```

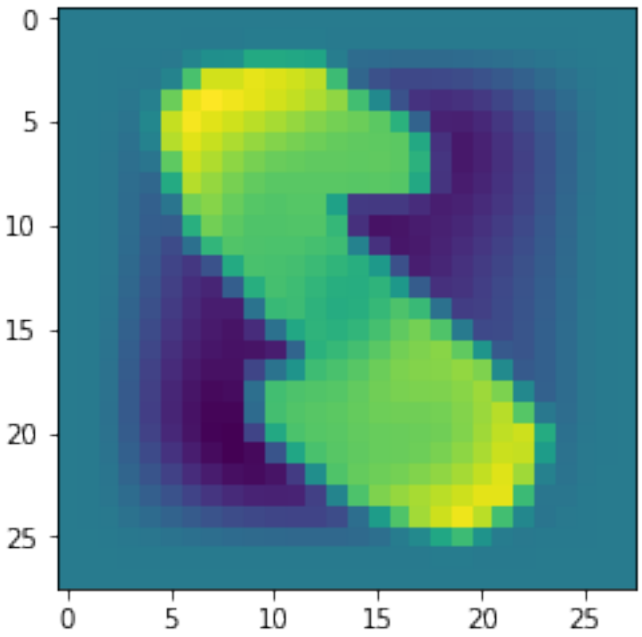


```
Guess:           x
Actually:         x
```

```
In [465]: testdata = np.loadtxt(BASE_DIR+'Data/letters_testdata.csv', dtype=float,
```

```
In [466]: testpredictions = classifier.predict(testdata)
```

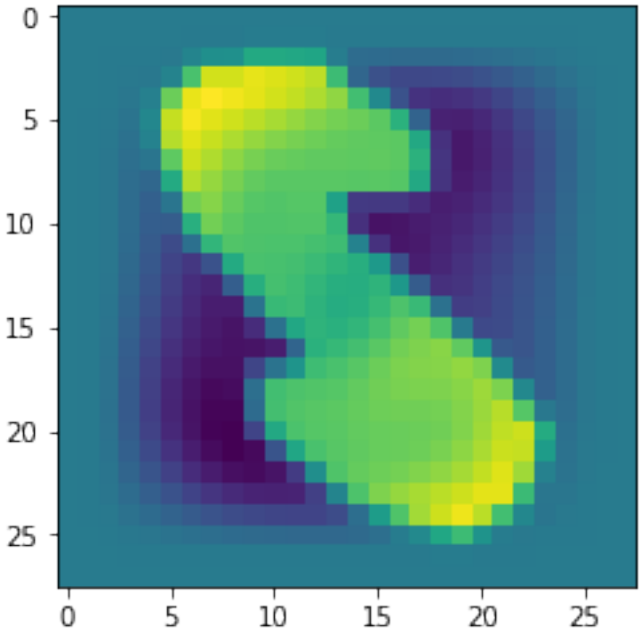
```
In [467]: plt.imshow(testdata[0,:784].reshape((28,28)))
          plt.show()
```



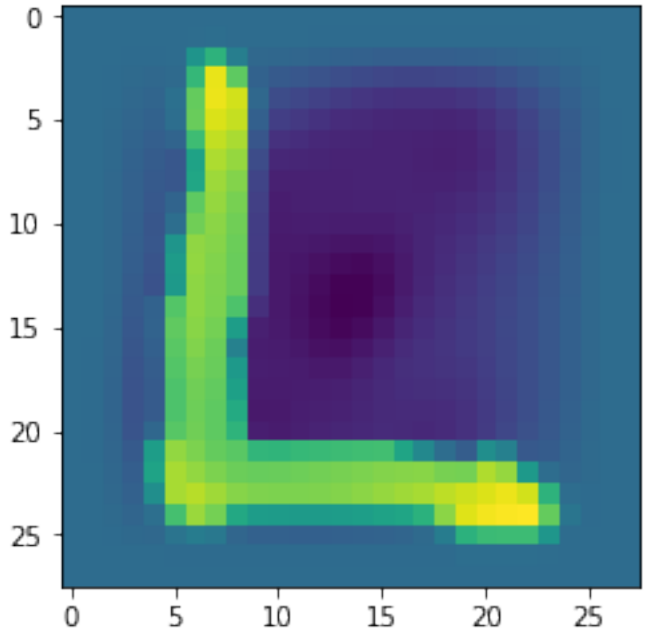

```
In [468]: def make_kaggle(predictions,kagglecsvfilename,indexing=0):
              # Use this optimal classifier on the test data
              if indexing == 0:
                  ids = np.arange(len(predictions))
              elif indexing == 1:
                  ids = np.arange(1,len(predictions)+1)
              predictions_csv = np.concatenate(([ids],[predictions]),axis=0).T
              np.savetxt(kagglecsvfilename,predictions_csv,fmt='%i',delimiter=',',h
              return predictions_csv
```

```
In [469]: kagglepreds = make_kaggle(testpredictions,BASE_DIR+'Kaggle/neuralnet_mneq
```

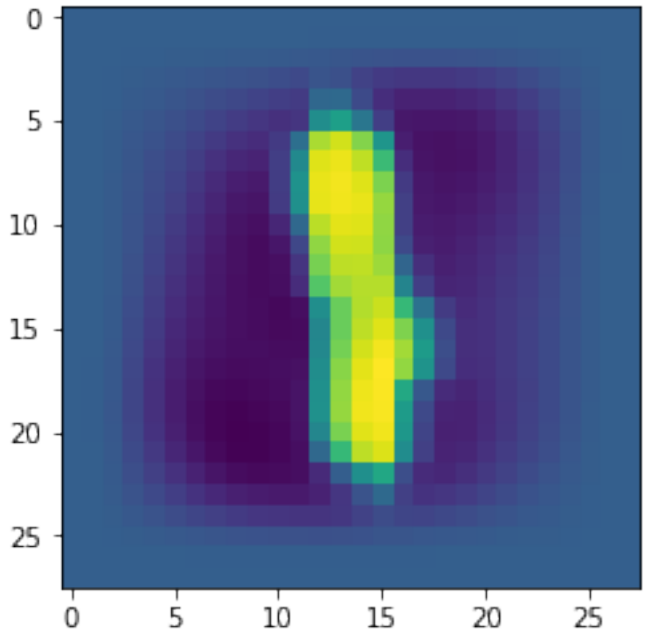
```
In [461]: for num in range(20):
              plt.imshow(testdata[num,:784].reshape((28,28)))
              plt.show()
              alphabet = 'abcdefghijklmnopqrstuvwxyz'
              print('Guess:\t',alphabet[testpredictions[num]-1])
```



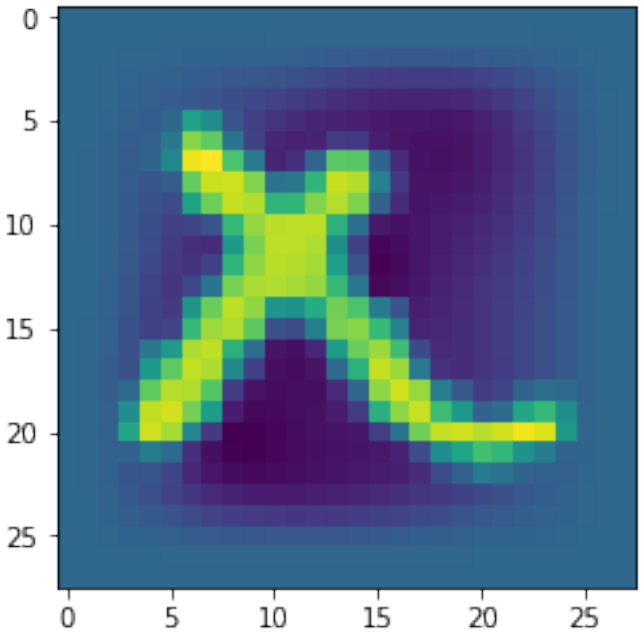

```
Guess:          q
```



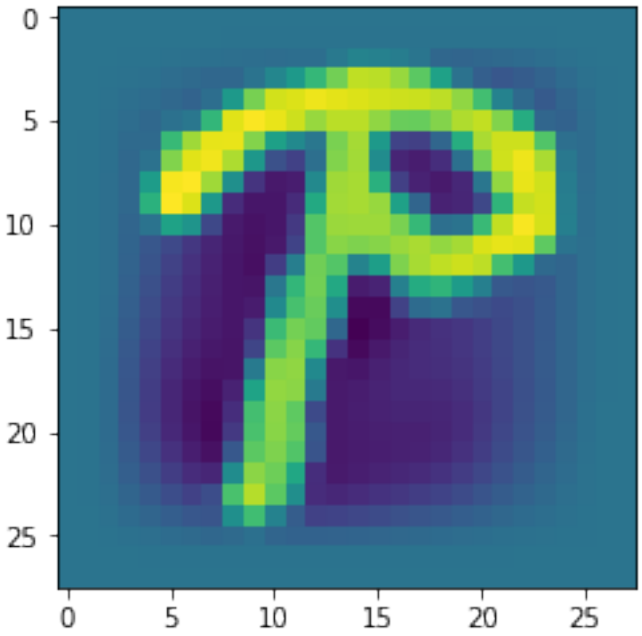

```
Guess:          l
```



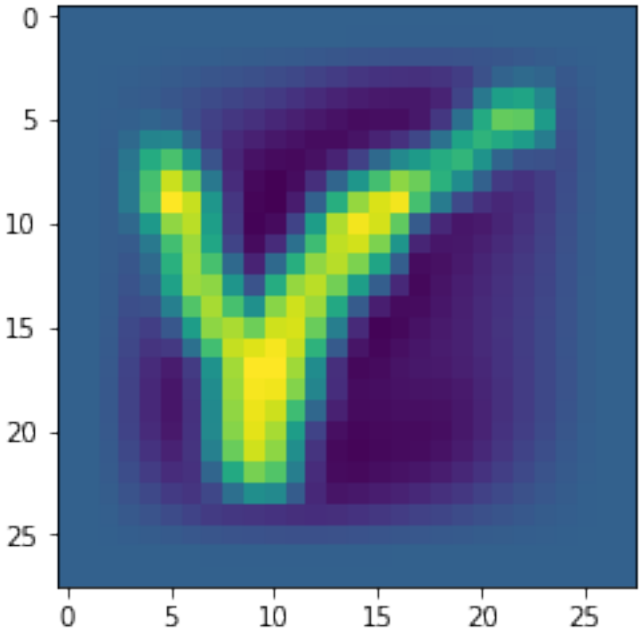
```
Guess:          i
```



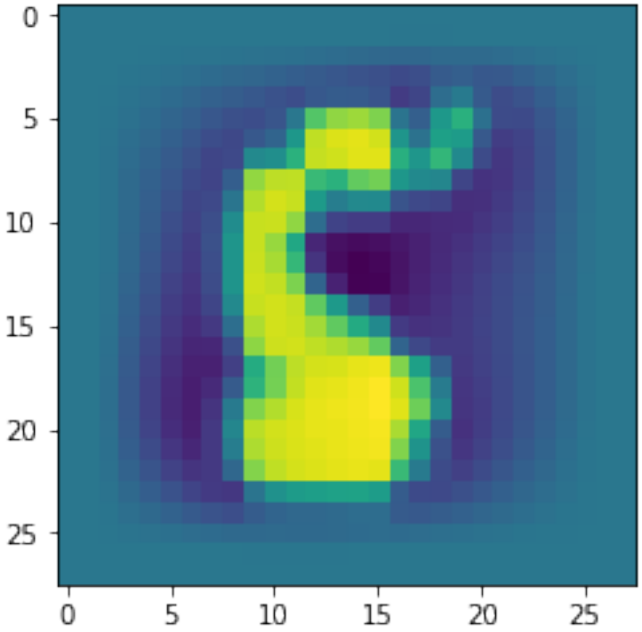

```
Guess:          x
```



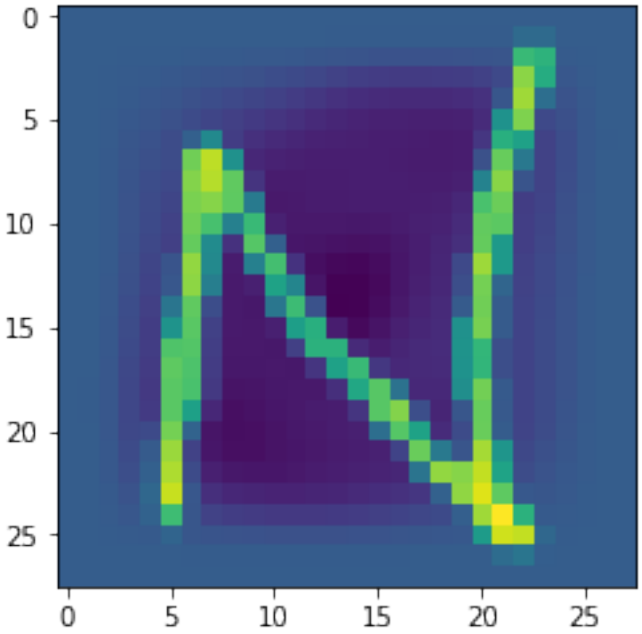
```
Guess:          p
```



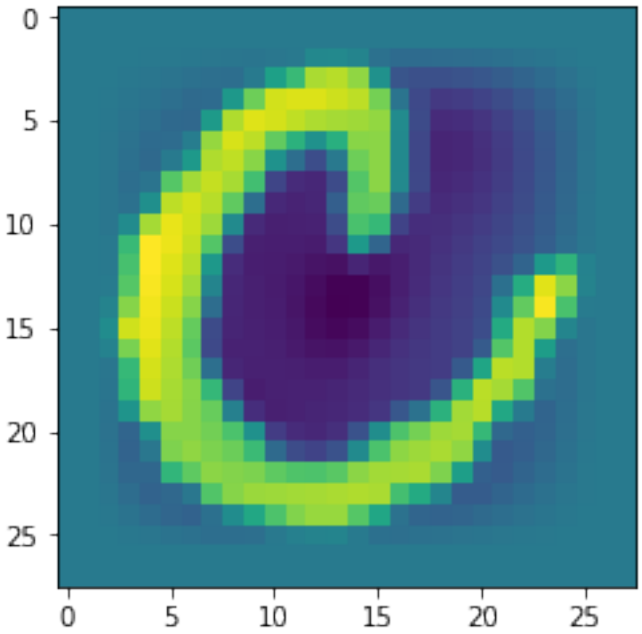

```
Guess:          v
```



```
Guess:          e
```




```
Guess:          n
```



```
Guess:          o
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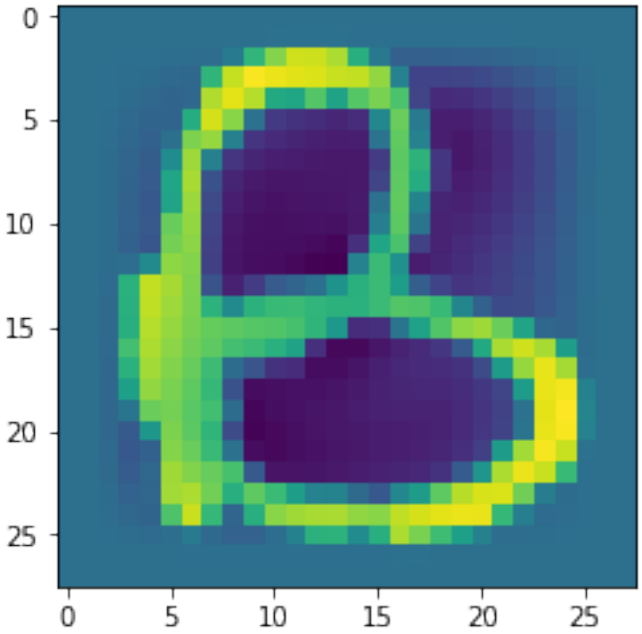
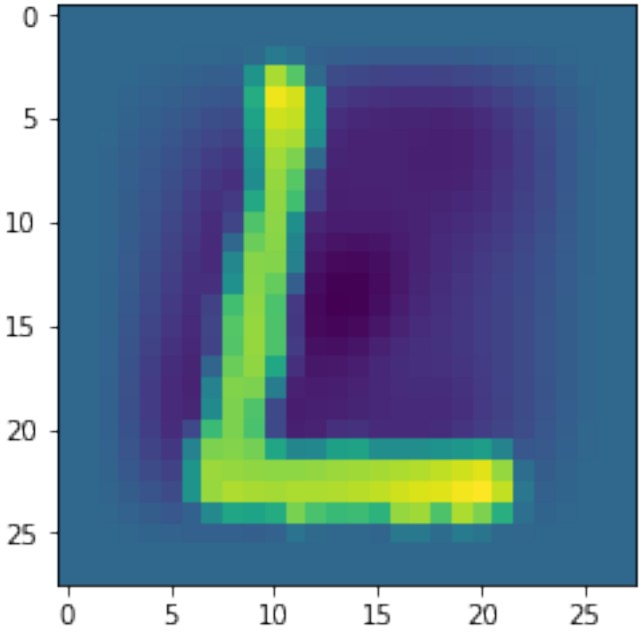



```
Guess:          b
```



```
Guess:          l
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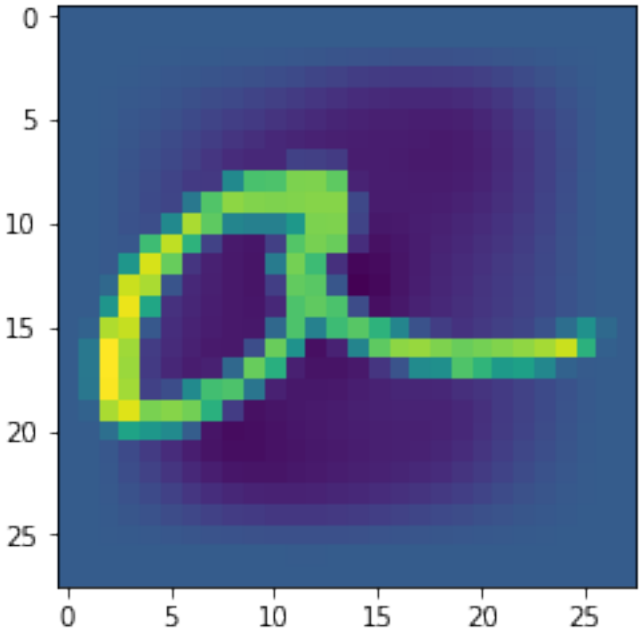


```
Guess:          a
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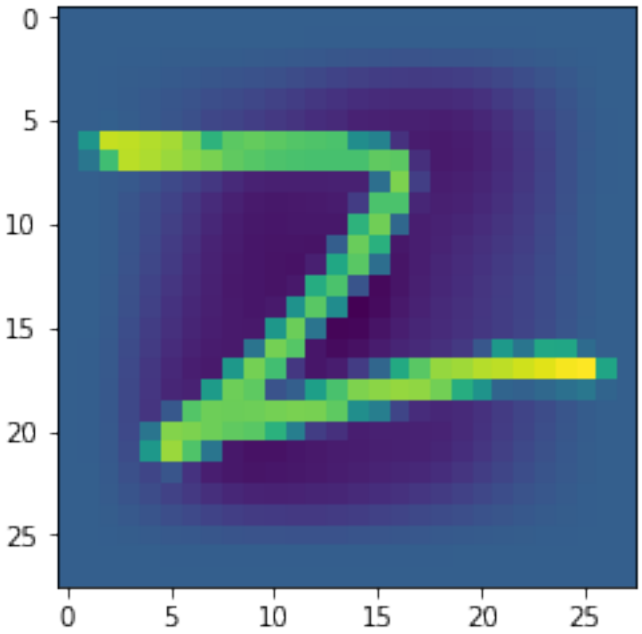

```
Guess:          z
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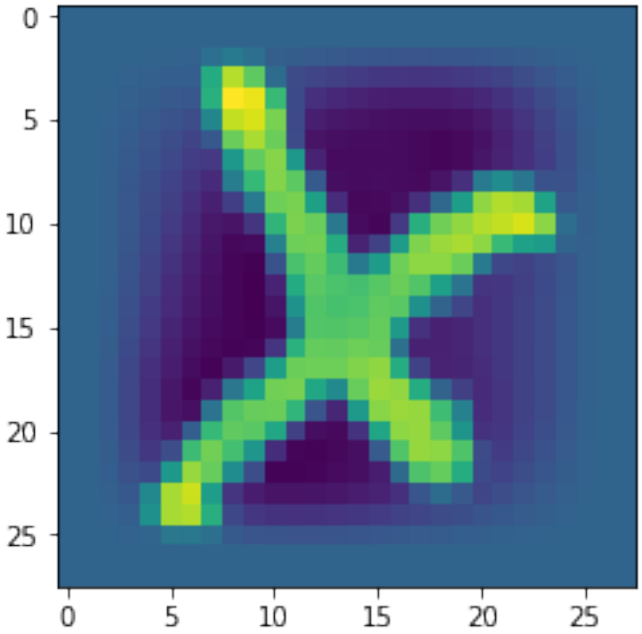
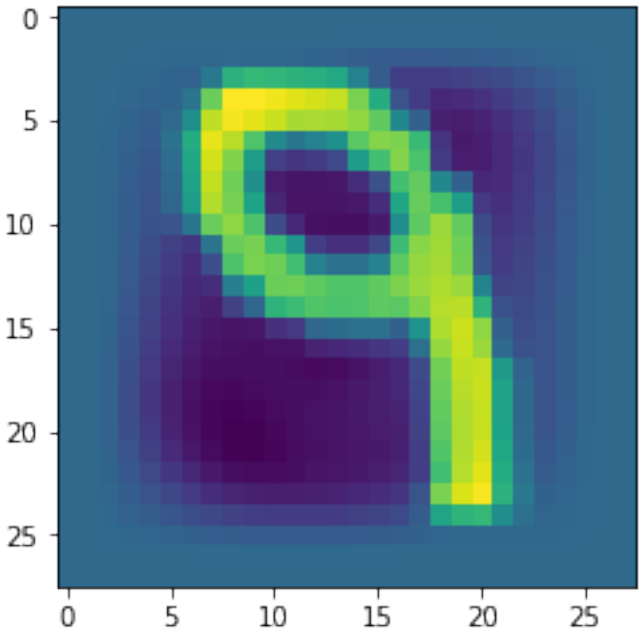
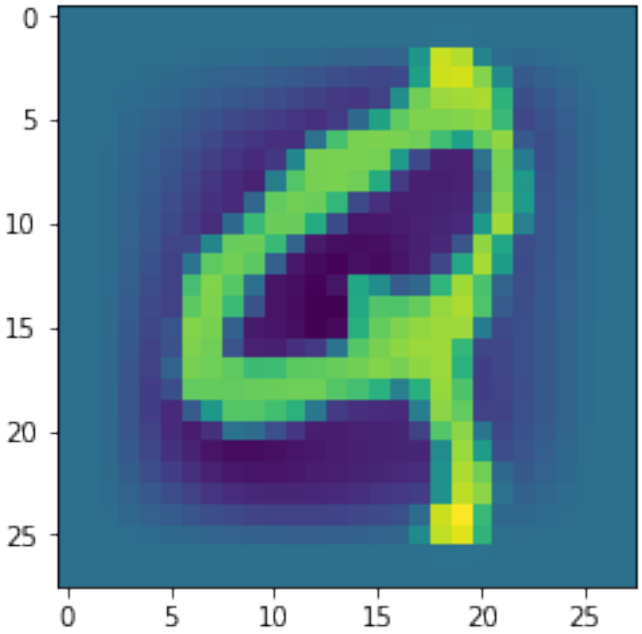



```
Guess:          x
```



```
Guess:          q
```




```
Guess:          q
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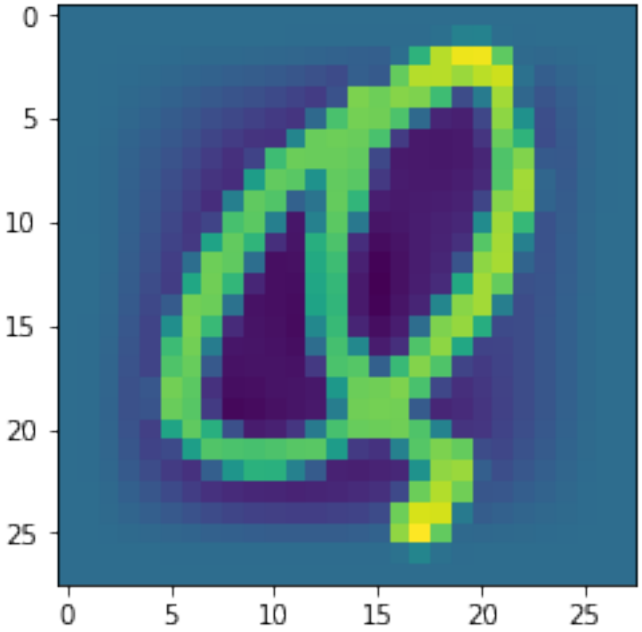

```
Guess:          q
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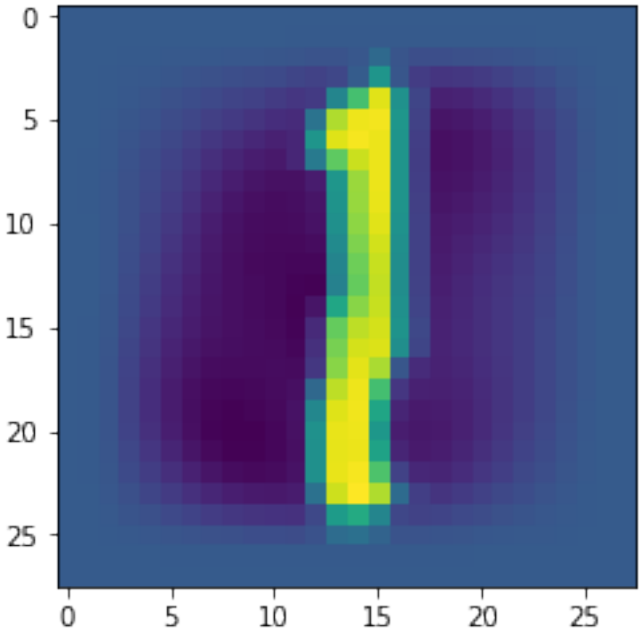


```
Guess:          i
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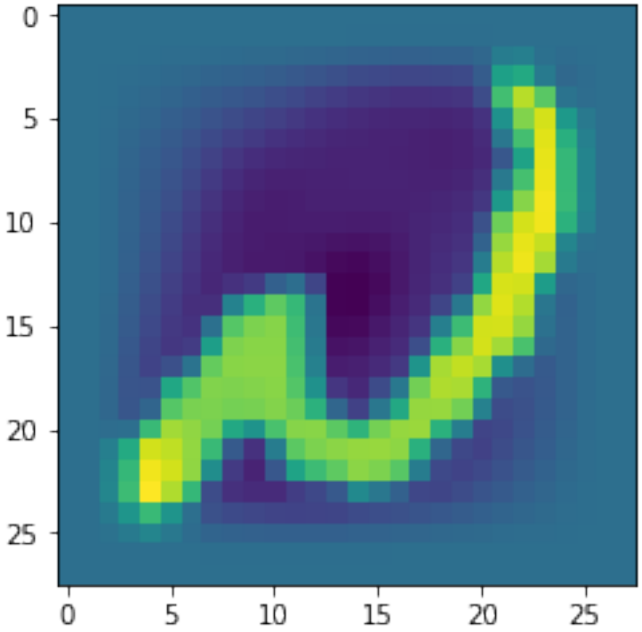
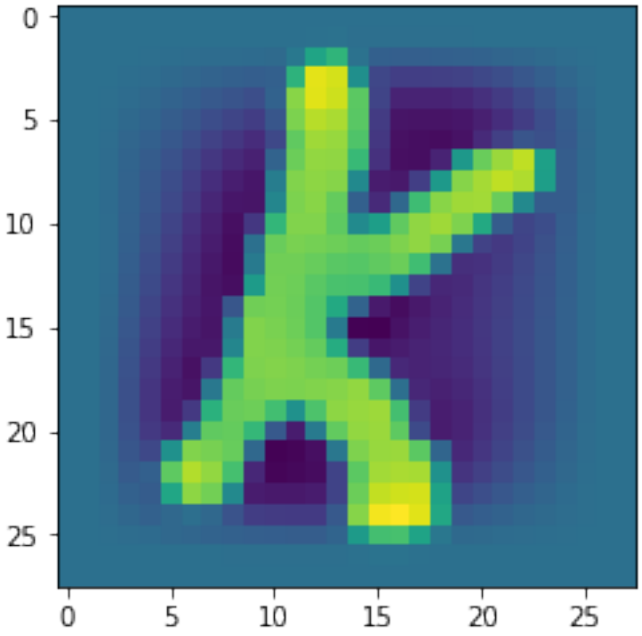


```
Guess:          n
```




```
Guess:          k
```

```
In [ ]:
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