Contents

CS294A/CS294W Stacked Autoencoder Exercise

```
%  Instructions
%  ------------
%
%  This file contains code that helps you get started on the
%  sstacked autoencoder exercise. You will need to complete code in
%  stackedAECost.m
%  You will also need to have implemented sparseAutoencoderCost.m and
%  softmaxCost.m from previous exercises. You will need the initializeParameters.m
%  loadMNISTImages.m, and loadMNISTLabels.m files from previous exercises.
%
%  For the purpose of completing the assignment, you do not need to
%  change the code in this file.
%
%%======================================================================
```

STEP 0: Here we provide the relevant parameters values that will

```
allow your sparse autoencoder to get good filters; you do not need to
change the parameters below.
```

```
clear;clc;
inputSize = 28 * 28;
numClasses = 10;
hiddenSizeL1 = 200;    % Layer 1 Hidden Size
hiddenSizeL2 = 200;    % Layer 2 Hidden Size
sparsityParam = 0.1;   % desired average activation of the hidden units.
                       % (This was denoted by the Greek alphabet rho, which looks like a lower-case "p",
                               %  in the lecture notes).
lambda = 3e-3;         % weight decay parameter
beta = 3;              % weight of sparsity penalty term

maxIter = 500;
%%======================================================================
```

STEP 1: Load data from the MNIST database

```
This loads our training data from the MNIST database files.
```

```
% Load MNIST database files
trainData = loadMNISTImages('train-images-idx3-ubyte');
trainLabels = loadMNISTLabels('train-labels-idx1-ubyte');

trainLabels(trainLabels == 0) = 10; % Remap 0 to 10 since our labels need to start from 1

%%======================================================================
```

STEP 2: Train the first sparse autoencoder

This trains the first sparse autoencoder on the unlabelled STL training images.
If you've correctly implemented sparseAutoencoderCost.m, you don't need to change anything here.

```
%  Randomly initialize the parameters
sae1Theta = initializeParameters(hiddenSizeL1, inputSize);
```

---------------------- YOUR CODE HERE ---------------------------------

```
Instructions: Train the first layer sparse autoencoder, this layer has
              an hidden size of "hiddenSizeL1"
              You should store the optimal parameters in sae1OptTheta
```

```
%  Use minFunc to minimize the function
addpath minFunc/
options.Method = 'lbfgs'; % Here, we use L-BFGS to optimize our cost
                          % function. Generally, for minFunc to work, you
                          % need a function pointer with two outputs: the
                          % function value and the gradient. In our problem,
                          % sparseAutoencoderCost.m satisfies this.
options.maxIter = maxIter;        % Maximum number of iterations of L-BFGS to run
options.display = 'on';


[sae1OptTheta, cost] = minFunc( @(p) sparseAutoencoderCost(p, ...
                                   inputSize, hiddenSizeL1, ...
                                   lambda, sparsityParam, ...
                                   beta, trainData), ...
                                   sae1Theta, options);

% -------------------------------------------------------------------------

%%======================================================================
```

```
 Iteration   FunEvals     Step Length    Function Val        Opt Cond
         1          5     3.17595e-02     1.15224e+02     9.40761e+03
         2          6     1.00000e+00     9.21799e+01     4.67074e+03
         3          7     1.00000e+00     8.35899e+01     2.15031e+03
         4          8     1.00000e+00     7.88544e+01     1.97087e+03
         5          9     1.00000e+00     7.07574e+01     2.59750e+03
         6         10     1.00000e+00     5.43981e+01     2.77349e+03
         7         11     1.00000e+00     3.41494e+01     6.60998e+02
         8         12     1.00000e+00     3.21925e+01     7.70336e+02
         9         13     1.00000e+00     3.11343e+01     6.78877e+02
        10         14     1.00000e+00     3.01713e+01     4.36230e+02
        11         15     1.00000e+00     2.99933e+01     2.73796e+02
        12         16     1.00000e+00     2.99844e+01     2.44361e+02
        13         28     0.00000e+00     2.99844e+01     2.44361e+02
Step Size below TolX
```

STEP 2: Train the second sparse autoencoder

This trains the second sparse autoencoder on the first autoencoder featurse.
If you've correctly implemented sparseAutoencoderCost.m, you don't need to change anything here.

```
[sae1Features] = feedForwardAutoencoder(sae1OptTheta, hiddenSizeL1, ...
                                        inputSize, trainData);

%  Randomly initialize the parameters
sae2Theta = initializeParameters(hiddenSizeL2, hiddenSizeL1);
```

---------------------- YOUR CODE HERE ---------------------------------

```
Instructions: Train the second layer sparse autoencoder, this layer has
              an hidden size of "hiddenSizeL2" and an inputsize of
              "hiddenSizeL1"

              You should store the optimal parameters in sae2OptTheta
```

```
%  Use minFunc to minimize the function
options.Method = 'lbfgs'; % Here, we use L-BFGS to optimize our cost
options.maxIter = maxIter;        % Maximum number of iterations of L-BFGS to run
options.display = 'on';

[sae2OptTheta, cost] = minFunc( @(p) sparseAutoencoderCost(p, ...
                                   hiddenSizeL1, hiddenSizeL2, ...
                                   lambda, sparsityParam, ...
                                   beta, sae1Features), ...
                                   sae2Theta, options);


% -------------------------------------------------------------------------


%%======================================================================
```

```
 Iteration   FunEvals     Step Length    Function Val        Opt Cond
         1          5     1.44667e-01     1.29027e+02     4.24909e+03
         2          6     1.00000e+00     2.84584e+01     1.36166e+03
         3          7     1.00000e+00     1.30705e+01     6.76665e+02
         4          8     1.00000e+00     6.23395e+00     2.56387e+02
         5          9     1.00000e+00     3.78599e+00     1.19480e+02
         6         10     1.00000e+00     2.27948e+00     6.56366e+01
         7         11     1.00000e+00     1.65883e+00     2.87929e+01
         8         13     3.38652e-01     1.55649e+00     3.09765e+01
         9         14     1.00000e+00     1.44330e+00     1.10448e+01
        10         15     1.00000e+00     1.43856e+00     3.96527e+00
        11         19     5.17275e-02     1.43847e+00     3.09319e+00
        12         28     0.00000e+00     1.43847e+00     3.09319e+00
Step Size below TolX
```

STEP 3: Train the softmax classifier

This trains the sparse autoencoder on the second autoencoder features.
If you've correctly implemented softmaxCost.m, you don't need to change anything here.

```
[sae2Features] = feedForwardAutoencoder(sae2OptTheta, hiddenSizeL2, ...
                                        hiddenSizeL1, sae1Features);

%  Randomly initialize the parameters
saeSoftmaxTheta = 0.005 * randn(hiddenSizeL2 * numClasses, 1);
```

---------------------- YOUR CODE HERE --------------------------------

```
Instructions: Train the softmax classifier, the classifier takes in
              input of dimension "hiddenSizeL2" corresponding to the
              hidden layer size of the 2nd layer.

              You should store the optimal parameters in saeSoftmaxOptTheta

NOTE: If you used softmaxTrain to complete this part of the exercise,
      set saeSoftmaxOptTheta = softmaxModel.optTheta(:);
```

```
%softmaxModel = softmaxTrain(size(sae2Features,1), numClasses, lambda, sae2Features, trainLabels, options);
lambdaSoftMax = 1e-4;
softmaxModel = softmaxTrain(hiddenSizeL2, numClasses, lambdaSoftMax,...
                    sae2Features, trainLabels, options);
saeSoftmaxOptTheta = softmaxModel.optTheta(:);

% -------------------------------------------------------------------------



%%======================================================================
```

```
 Iteration   FunEvals     Step Length    Function Val        Opt Cond
         1          3     2.20840e+00     2.27931e+00     1.95393e+00
         2          4     1.00000e+00     2.27223e+00     4.10176e-01
         3          5     1.00000e+00     2.27140e+00     2.47492e-01
         4          6     1.00000e+00     2.27091e+00     2.95506e-01
         5          7     1.00000e+00     2.27008e+00     3.60342e-01
         6          8     1.00000e+00     2.26785e+00     5.63241e-01
         7          9     1.00000e+00     2.26158e+00     1.08869e+00
         8         10     1.00000e+00     2.24941e+00     1.31131e+00
         9         11     1.00000e+00     2.22699e+00     1.94909e+00
        10         12     1.00000e+00     2.20314e+00     2.84401e+00
        11         13     1.00000e+00     2.17878e+00     1.78615e+00
        12         14     1.00000e+00     2.12481e+00     2.89025e+00
        13         16     5.05756e-01     2.10250e+00     2.31813e+00
        14         17     1.00000e+00     2.09613e+00     1.02258e+00
        15         18     1.00000e+00     2.09355e+00     1.76899e-01
        16         19     1.00000e+00     2.09344e+00     4.92175e-02
        17         20     1.00000e+00     2.09344e+00     1.93156e-02
        18         21     1.00000e+00     2.09344e+00     1.56252e-02
        19         22     1.00000e+00     2.09344e+00     2.14566e-02
        20         23     1.00000e+00     2.09343e+00     5.87324e-02
        21         24     1.00000e+00     2.09340e+00     1.16081e-01
        22         25     1.00000e+00     2.09334e+00     2.03266e-01
        23         26     1.00000e+00     2.09321e+00     2.99095e-01
        24         27     1.00000e+00     2.09300e+00     3.38072e-01
        25         28     1.00000e+00     2.09280e+00     2.35799e-01
        26         29     1.00000e+00     2.09278e+00     1.94099e-01
        27         30     1.00000e+00     2.09272e+00     2.75256e-02
        28         31     1.00000e+00     2.09271e+00     7.52318e-03
        29         32     1.00000e+00     2.09271e+00     1.27331e-03
        30         33     1.00000e+00     2.09271e+00     1.25280e-03
        31         34     1.00000e+00     2.09271e+00     3.16330e-03
        32          35     1.00000e+00     2.09271e+00     5.96255e-03
        33          36     1.00000e+00     2.09271e+00     1.08346e-02
        34          37     1.00000e+00     2.09271e+00     1.65212e-02
        35          38     1.00000e+00     2.09271e+00     2.01704e-02
        36          39     1.00000e+00     2.09271e+00     1.69974e-02
        37          40     1.00000e+00     2.09271e+00     1.20293e-02
        38          41     1.00000e+00     2.09271e+00     3.72211e-03
        39          42     1.00000e+00     2.09271e+00     7.87930e-04
        40          43     1.00000e+00     2.09271e+00     1.01659e-04
Directional Derivative below TolX
```

STEP 5: Finetune softmax model

```
% Implement the stackedAECost to give the combined cost of the whole model
% then run this cell.

% Initialize the stack using the parameters learned
stack = cell(2,1);
stack{1}.w = reshape(sae1OptTheta(1:hiddenSizeL1*inputSize), ...
                     hiddenSizeL1, inputSize);
stack{1}.b = sae1OptTheta(2*hiddenSizeL1*inputSize+1:2*hiddenSizeL1*inputSize+hiddenSizeL1);
stack{2}.w = reshape(sae2OptTheta(1:hiddenSizeL2*hiddenSizeL1), ...
                     hiddenSizeL2, hiddenSizeL1);
stack{2}.b = sae2OptTheta(2*hiddenSizeL2*hiddenSizeL1+1:2*hiddenSizeL2*hiddenSizeL1+hiddenSizeL2);

% Initialize the parameters for the deep model
[stackparams, netconfig] = stack2params(stack);
stackedAETheta = [ saeSoftmaxOptTheta ; stackparams ];
```

---------------------- YOUR CODE HERE --------------------------------

```
Instructions: Train the deep network, hidden size here refers to the '
              dimension of the input to the classifier, which corresponds
              to "hiddenSizeL2".
```

```
%  Use minFunc to minimize the function
addpath minFunc/
options.Method = 'lbfgs'; % Here, we use L-BFGS to optimize our cost
                          % function. Generally, for minFunc to work, you
                          % need a function pointer with two outputs: the
                          % function value and the gradient. In our problem,
                          % sparseAutoencoderCost.m satisfies this.
options.maxIter = maxIter;        % Maximum number of iterations of L-BFGS to run
options.display = 'on';

[stackedAEOptTheta, cost] = minFunc( @(p) stackedAECost(p, inputSize, hiddenSizeL2, ...
                                              numClasses, netconfig, ...
                                              lambda, trainData, trainLabels), ...
                                    stackedAETheta, options);


% % -------------------------------------------------------------------------



%%======================================================================
```

```
 Iteration   FunEvals     Step Length    Function Val        Opt Cond
         1          4     1.37579e+00     6.38281e+00     6.99142e+01
         2          6     4.43509e-01     5.91224e+00     1.56401e+02
         3          7     1.00000e+00     5.39748e+00     1.05526e+02
```

```
   4          8     1.00000e+00     4.76393e+00     6.60039e+01
   5          9     1.00000e+00     3.92857e+00     7.13066e+01
   6         10     1.00000e+00     3.03639e+00     8.72315e+01
   7         12     7.01534e-01     2.40503e+00     8.78894e+01
   8         13     1.00000e+00     1.71530e+00     5.69298e+01
   9         14     1.00000e+00     1.49279e+00     3.56054e+01
  10         16     3.94088e-01     1.44878e+00     3.79349e+01
  11         17     1.00000e+00     1.40719e+00     4.51748e+01
  12         18     1.00000e+00     1.25280e+00     2.45356e+01
  13         19     1.00000e+00     1.17977e+00     2.03539e+01
  14         20     1.00000e+00     1.10019e+00     2.12737e+01
  15         21     1.00000e+00     9.92354e-01     2.18732e+01
  16         22     1.00000e+00     9.23195e-01     2.26534e+01
  17         23     1.00000e+00     8.29682e-01     1.80356e+01
  18         24     1.00000e+00     7.63350e-01     1.38067e+01
  19         25     1.00000e+00     7.04650e-01     1.14601e+01
  20         26     1.00000e+00     6.54605e-01     1.11163e+01
  21         27     1.00000e+00     6.22860e-01     1.38602e+01
  22         28     1.00000e+00     5.93345e-01     9.20331e+00
  23         29     1.00000e+00     5.75302e-01     8.05683e+00
  24         30     1.00000e+00     5.46323e-01     7.99293e+00
  25         31     1.00000e+00     5.21007e-01     7.84931e+00
  26         32     1.00000e+00     5.05965e-01     1.99694e+01
  27         33     1.00000e+00     4.68035e-01     6.97188e+00
  28         34     1.00000e+00     4.62330e-01     5.97163e+00
  29         35     1.00000e+00     4.50776e-01     6.24964e+00
  30         36     1.00000e+00     4.38293e-01     6.68726e+00
  31         37     1.00000e+00     4.11142e-01     6.30537e+00
  32         39     3.81240e-01     3.98653e-01     9.02193e+00
  33         40     1.00000e+00     3.82165e-01     5.48256e+00
  34         41     1.00000e+00     3.72452e-01     4.40333e+00
  35         42     1.00000e+00     3.58861e-01     4.84384e+00
  36         43     1.00000e+00     3.48797e-01     5.48770e+00
  37         44     1.00000e+00     3.40399e-01     4.10011e+00
  38         45     1.00000e+00     3.30322e-01     3.76650e+00
  39         46     1.00000e+00     3.20647e-01     3.72773e+00
  40         47     1.00000e+00     3.10369e-01     4.70422e+00
  41         48     1.00000e+00     3.01312e-01     3.63334e+00
  42         49     1.00000e+00     2.91184e-01     3.58981e+00
  43         50     1.00000e+00     2.82626e-01     3.89935e+00
  44         51     1.00000e+00     2.75114e-01     3.19593e+00
  45         52     1.00000e+00     2.66548e-01     2.95993e+00
  46         53     1.00000e+00     2.58395e-01     3.70715e+00
  47         54     1.00000e+00     2.51320e-01     3.01393e+00
  48         55     1.00000e+00     2.44859e-01     2.62809e+00
  49         56     1.00000e+00     2.36564e-01     2.59525e+00
  50         57     1.00000e+00     2.30786e-01     3.14825e+00
  51         58     1.00000e+00     2.26327e-01     2.37986e+00
  52         59     1.00000e+00     2.21488e-01     2.14683e+00
  53         60     1.00000e+00     2.17038e-01     2.18987e+00
  54         61     1.00000e+00     2.09723e-01     2.50957e+00
  55         62     1.00000e+00     2.04244e-01     1.94847e+00
  56         63     1.00000e+00     1.99909e-01     1.84524e+00
  57         64     1.00000e+00     1.95595e-01     2.74394e+00
  58         65     1.00000e+00     1.92538e-01     1.86141e+00
  59         66     1.00000e+00     1.90034e-01     1.64835e+00
  60         67     1.00000e+00     1.87140e-01     1.69856e+00
  61         68     1.00000e+00     1.82113e-01     2.00101e+00
  62         69     1.00000e+00     1.76486e-01     1.79964e+00
  63         70     1.00000e+00     1.72968e-01     1.75496e+00
  64         71     1.00000e+00     1.70475e-01     1.64959e+00
  65         72     1.00000e+00     1.67208e-01     1.51709e+00
  66         73     1.00000e+00     1.63672e-01     1.58867e+00
  67         74     1.00000e+00     1.60472e-01     1.57151e+00
  68         75     1.00000e+00     1.57272e-01     1.65306e+00
  69         76     1.00000e+00     1.54245e-01     1.58096e+00
  70       77    1.00000e+00    1.51385e-01    1.43335e+00
  71       78    1.00000e+00    1.47764e-01    1.34151e+00
  72       79    1.00000e+00    1.44290e-01    1.79140e+00
  73       80    1.00000e+00    1.41920e-01    1.24783e+00
  74       81    1.00000e+00    1.40031e-01    1.19001e+00
  75       82    1.00000e+00    1.37683e-01    1.21817e+00
  76       83    1.00000e+00    1.33501e-01    1.22011e+00
  77       84    1.00000e+00    1.29804e-01    2.00156e+00
  78       85    1.00000e+00    1.26741e-01    1.13237e+00
  79       86    1.00000e+00    1.25202e-01    9.98146e-01
  80       87    1.00000e+00    1.23277e-01    9.87790e-01
  81       88    1.00000e+00    1.20344e-01    1.02628e+00
  82       89    1.00000e+00    1.17134e-01    1.22681e+00
  83       90    1.00000e+00    1.15161e-01    9.32882e-01
  84       91    1.00000e+00    1.13932e-01    9.12647e-01
  85       92    1.00000e+00    1.11166e-01    8.96255e-01
  86       93    1.00000e+00    1.08108e-01    1.29143e+00
  87       94    1.00000e+00    1.06242e-01    8.44565e-01
  88       95    1.00000e+00    1.05110e-01    8.18969e-01
  89       96    1.00000e+00    1.03616e-01    8.10653e-01
  90       97    1.00000e+00    1.01378e-01    8.47950e-01
  91       98    1.00000e+00    9.95461e-02    8.17188e-01
  92       99    1.00000e+00    9.83780e-02    7.44005e-01
  93      100    1.00000e+00    9.70158e-02    7.30220e-01
  94      101    1.00000e+00    9.49842e-02    8.44645e-01
  95      102    1.00000e+00    9.32398e-02    6.96481e-01
  96      103    1.00000e+00    9.19109e-02    6.56518e-01
  97      104    1.00000e+00    9.04692e-02    6.89255e-01
  98      105    1.00000e+00    8.90733e-02    6.63111e-01
  99      106    1.00000e+00    8.77164e-02    7.43840e-01
 100      107    1.00000e+00    8.65448e-02    6.51210e-01
 101      108    1.00000e+00    8.54305e-02    6.13366e-01
 102      109    1.00000e+00    8.38252e-02    6.23407e-01
 103      110    1.00000e+00    8.21688e-02    6.93092e-01
 104      111    1.00000e+00    8.09174e-02    5.87330e-01
 105      112    1.00000e+00    7.98751e-02    6.09409e-01
 106      113    1.00000e+00    7.87633e-02    6.27516e-01
 107      114    1.00000e+00    7.76329e-02    5.56834e-01
 108      115    1.00000e+00    7.64289e-02    5.64314e-01
 109      116    1.00000e+00    7.52039e-02    6.87648e-01
 110      117    1.00000e+00    7.44362e-02    5.15412e-01
 111      118    1.00000e+00    7.38471e-02    4.93025e-01
 112      119    1.00000e+00    7.32734e-02    4.99806e-01
 113      120    1.00000e+00    7.21086e-02    5.34448e-01
 114      121    1.00000e+00    7.09837e-02    6.43350e-01
 115      122    1.00000e+00    7.02083e-02    4.95744e-01
 116      123    1.00000e+00    6.95771e-02    4.63237e-01
 117      124    1.00000e+00    6.89227e-02    4.64714e-01
 118      125    1.00000e+00    6.76946e-02    5.53721e-01
 119      126    1.00000e+00    6.66943e-02    4.66761e-01
 120      127    1.00000e+00    6.61262e-02    4.28645e-01
 121      128    1.00000e+00    6.54387e-02    4.22300e-01
 122      129    1.00000e+00    6.46839e-02    4.72725e-01
 123      130    1.00000e+00    6.38429e-02    4.09271e-01
 124      131    1.00000e+00    6.33226e-02    4.09007e-01
 125      132    1.00000e+00    6.28512e-02    3.86392e-01
 126      133    1.00000e+00    6.20355e-02    4.05367e-01
 127      134    1.00000e+00    6.14000e-02    3.62610e-01
 128      135    1.00000e+00    6.09099e-02    3.51463e-01
 129      136    1.00000e+00    6.03317e-02    3.67245e-01
 130      137    1.00000e+00    5.96317e-02    3.91656e-01
 131      138    1.00000e+00    5.88882e-02    3.75401e-01
 132      139    1.00000e+00    5.83083e-02    3.75514e-01
 133      140    1.00000e+00    5.78901e-02    3.29823e-01
 134      141    1.00000e+00    5.74122e-02    3.06623e-01
 135      142    1.00000e+00    5.66613e-02    3.52971e-01
```

```
136        143     1.00000e+00     5.60449e-02     2.97899e-01
137        144     1.00000e+00     5.56676e-02     2.94471e-01
138        145     1.00000e+00     5.52483e-02     2.95807e-01
139        146     1.00000e+00     5.47260e-02     3.43245e-01
140        147     1.00000e+00     5.43335e-02     3.00598e-01
141        148     1.00000e+00     5.38907e-02     2.80271e-01
142        149     1.00000e+00     5.33786e-02     3.15088e-01
143        150     1.00000e+00     5.29127e-02     2.85258e-01
144        151     1.00000e+00     5.25231e-02     2.77438e-01
145        152     1.00000e+00     5.20771e-02     2.96212e-01
146        153     1.00000e+00     5.17413e-02     2.62473e-01
147        154     1.00000e+00     5.14055e-02     2.53688e-01
148        155     1.00000e+00     5.09705e-02     2.79259e-01
149        156     1.00000e+00     5.05622e-02     2.44767e-01
150        157     1.00000e+00     5.02725e-02     2.36006e-01
151        158     1.00000e+00     4.99175e-02     2.57129e-01
152        159     1.00000e+00     4.96164e-02     2.34939e-01
153        160     1.00000e+00     4.92822e-02     2.28666e-01
154        161     1.00000e+00     4.88775e-02     2.64854e-01
155        162     1.00000e+00     4.86305e-02     2.15166e-01
156        163     1.00000e+00     4.84143e-02     2.07146e-01
157        164     1.00000e+00     4.82052e-02     2.14795e-01
158        165     1.00000e+00     4.78553e-02     2.21804e-01
159        166     1.00000e+00     4.75404e-02     2.67987e-01
160        167     1.00000e+00     4.73063e-02     2.03489e-01
161        168     1.00000e+00     4.71226e-02     1.92262e-01
162        169     1.00000e+00     4.69612e-02     1.96828e-01
163        170     1.00000e+00     4.66514e-02     1.95434e-01
164        171     1.00000e+00     4.63460e-02     2.29298e-01
165        172     1.00000e+00     4.60799e-02     1.85147e-01
166        173     1.00000e+00     4.59322e-02     1.76491e-01
167        174     1.00000e+00     4.57134e-02     1.69653e-01
168        175     1.00000e+00     4.54486e-02     1.84215e-01
169        176     1.00000e+00     4.51624e-02     1.75193e-01
170        177     1.00000e+00     4.49859e-02     1.71303e-01
171        178     1.00000e+00     4.48318e-02     1.62826e-01
172        179     1.00000e+00     4.46163e-02     1.72589e-01
173        180     1.00000e+00     4.43508e-02     1.58829e-01
174        181     1.00000e+00     4.41205e-02     1.73078e-01
175        182     1.00000e+00     4.39403e-02     1.57571e-01
176        183     1.00000e+00     4.37975e-02     1.44244e-01
177        184     1.00000e+00     4.36272e-02     1.47209e-01
178        185     1.00000e+00     4.34372e-02     1.51700e-01
179        186     1.00000e+00     4.33012e-02     1.38939e-01
180        187     1.00000e+00     4.31888e-02     1.36775e-01
181        188     1.00000e+00     4.30665e-02     1.39553e-01
182        189     1.00000e+00     4.29179e-02     1.34335e-01
183        190     1.00000e+00     4.27235e-02     1.42105e-01
184        191     1.00000e+00     4.25274e-02     1.56758e-01
185        192     1.00000e+00     4.23865e-02     1.35685e-01
186        193     1.00000e+00     4.22495e-02     1.31445e-01
187        194     1.00000e+00     4.20771e-02     1.42174e-01
188        195     1.00000e+00     4.19345e-02     1.65964e-01
189        196     1.00000e+00     4.18308e-02     1.27101e-01
190        197     1.00000e+00     4.17719e-02     1.24726e-01
191        198     1.00000e+00     4.16792e-02     1.25253e-01
192        199     1.00000e+00     4.14833e-02     1.22349e-01
193        200     1.00000e+00     4.13212e-02     1.34241e-01
194        201     1.00000e+00     4.12081e-02     1.14154e-01
195        202     1.00000e+00     4.11261e-02     1.25651e-01
196        203     1.00000e+00     4.10231e-02     1.31000e-01
197        204     1.00000e+00     4.08879e-02     1.26434e-01
198        205     1.00000e+00     4.07861e-02     1.86583e-01
199        206     1.00000e+00     4.06526e-02     1.20689e-01
200        207     1.00000e+00     4.05667e-02     1.08331e-01
201        208     1.00000e+00     4.05075e-02     1.17876e-01
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204        211     1.00000e+00     4.01507e-02     1.12056e-01
205        212     1.00000e+00     4.00670e-02     1.04013e-01
206        213     1.00000e+00     3.99478e-02     1.04189e-01
207        214     1.00000e+00     3.97990e-02     1.25984e-01
208        215     1.00000e+00     3.96852e-02     1.06624e-01
209        216     1.00000e+00     3.96206e-02     9.79055e-02
210        217     1.00000e+00     3.95634e-02     1.00332e-01
211        218     1.00000e+00     3.94477e-02     1.12876e-01
212        219     1.00000e+00     3.93343e-02     1.07910e-01
213        220     1.00000e+00     3.92509e-02     1.04208e-01
214        221     1.00000e+00     3.91838e-02     9.76796e-02
215        222     1.00000e+00     3.90881e-02     9.61657e-02
216        223     1.00000e+00     3.89439e-02     1.19161e-01
217        224     1.00000e+00     3.88476e-02     9.32249e-02
218        225     1.00000e+00     3.87902e-02     8.72152e-02
219        226     1.00000e+00     3.87200e-02     8.87737e-02
220        227     1.00000e+00     3.86315e-02     1.05521e-01
221        228     1.00000e+00     3.85666e-02     8.63339e-02
222        229     1.00000e+00     3.85120e-02     8.46548e-02
223        230     1.00000e+00     3.84472e-02     8.44834e-02
224        231     1.00000e+00     3.83788e-02     1.12598e-01
225        232     1.00000e+00     3.83047e-02     7.98940e-02
226        233     1.00000e+00     3.82574e-02     7.74325e-02
227        234     1.00000e+00     3.81979e-02     8.13590e-02
228        235     1.00000e+00     3.81120e-02     8.19769e-02
229        237     4.31745e-01     3.80548e-02     1.03612e-01
230        238     1.00000e+00     3.79700e-02     7.93222e-02
231        239     1.00000e+00     3.79079e-02     7.42378e-02
232        240     1.00000e+00     3.78586e-02     7.87404e-02
233        241     1.00000e+00     3.77780e-02     8.76007e-02
234        242     1.00000e+00     3.77250e-02     1.01835e-01
235        243     1.00000e+00     3.76770e-02     7.60162e-02
236        244     1.00000e+00     3.76334e-02     7.52657e-02
237        245     1.00000e+00     3.75982e-02     7.63786e-02
238        246     1.00000e+00     3.75108e-02     8.29750e-02
239        247     1.00000e+00     3.74721e-02     1.01198e-01
240        248     1.00000e+00     3.74269e-02     7.14624e-02
241        249     1.00000e+00     3.73975e-02     6.85345e-02
242        250     1.00000e+00     3.73560e-02     7.13962e-02
243        251     1.00000e+00     3.72652e-02     7.48620e-02
244        252     1.00000e+00     3.72426e-02     1.24535e-01
245        253     1.00000e+00     3.71393e-02     7.08918e-02
246        254     1.00000e+00     3.71066e-02     6.67435e-02
247        255     1.00000e+00     3.70623e-02     6.95262e-02
248        256     1.00000e+00     3.69957e-02     7.56376e-02
249        257     1.00000e+00     3.69646e-02     1.11599e-01
250        258     1.00000e+00     3.68922e-02     6.61316e-02
251        259     1.00000e+00     3.68692e-02     6.56495e-02
252        260     1.00000e+00     3.68347e-02     6.69147e-02
253        261     1.00000e+00     3.67712e-02     6.86959e-02
254        262     1.00000e+00     3.67071e-02     7.37427e-02
255        263     1.00000e+00     3.66619e-02     6.70287e-02
256        264     1.00000e+00     3.66186e-02     6.39322e-02
257        265     1.00000e+00     3.65625e-02     7.44679e-02
258        266     1.00000e+00     3.65007e-02     7.95495e-02
259        267     1.00000e+00     3.64447e-02     6.95942e-02
260        268     1.00000e+00     3.63792e-02     6.70418e-02
261        269     1.00000e+00     3.63376e-02     8.40512e-02
262        270     1.00000e+00     3.62978e-02     6.69722e-02
263        271     1.00000e+00     3.62697e-02     5.85369e-02
264        272     1.00000e+00     3.62491e-02     6.11593e-02
265        273     1.00000e+00     3.62147e-02     6.32020e-02
266        274     1.00000e+00     3.61554e-02     6.49036e-02
267        275     1.00000e+00     3.61064e-02     9.34027e-02
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270        278     1.00000e+00     3.59645e-02     6.14698e-02
271        279     1.00000e+00     3.59037e-02     6.42843e-02
272        280     1.00000e+00     3.58941e-02     9.41331e-02
273        281     1.00000e+00     3.58381e-02     5.25624e-02
274        282     1.00000e+00     3.58212e-02     4.97911e-02
275        283     1.00000e+00     3.57918e-02     5.27532e-02
276        284     1.00000e+00     3.57553e-02     5.27070e-02
277        286     4.65842e-01     3.57322e-02     5.95685e-02
278        287     1.00000e+00     3.57074e-02     4.84996e-02
279        288     1.00000e+00     3.56871e-02     5.10641e-02
280        289     1.00000e+00     3.56635e-02     5.65399e-02
281        290     1.00000e+00     3.56250e-02     6.64406e-02
282        291     1.00000e+00     3.55849e-02     6.70696e-02
283        292     1.00000e+00     3.55463e-02     5.93113e-02
284        293     1.00000e+00     3.54958e-02     5.34801e-02
285        294     1.00000e+00     3.54624e-02     5.17647e-02
286        295     1.00000e+00     3.54245e-02     5.90246e-02
287        296     1.00000e+00     3.53992e-02     5.32717e-02
288        297     1.00000e+00     3.53802e-02     5.18731e-02
289        298     1.00000e+00     3.53496e-02     5.53455e-02
290        299     1.00000e+00     3.53340e-02     8.31896e-02
291        300     1.00000e+00     3.52926e-02     5.51821e-02
292        301     1.00000e+00     3.52594e-02     5.16623e-02
293        302     1.00000e+00     3.52319e-02     5.44591e-02
294        303     1.00000e+00     3.51729e-02     5.89768e-02
295        304     1.00000e+00     3.51381e-02     5.93500e-02
296        305     1.00000e+00     3.51123e-02     5.22263e-02
297        306     1.00000e+00     3.50919e-02     5.25088e-02
298        307     1.00000e+00     3.50343e-02     5.81940e-02
299        308     1.00000e+00     3.49975e-02     6.51888e-02
300        309     1.00000e+00     3.49484e-02     4.90288e-02
301        310     1.00000e+00     3.49122e-02     4.83810e-02
302        312     5.13650e-01     3.49005e-02     5.56059e-02
303        313     1.00000e+00     3.48846e-02     4.91599e-02
304        314     1.00000e+00     3.48610e-02     4.33624e-02
305        315     1.00000e+00     3.48391e-02     4.32810e-02
306        316     1.00000e+00     3.48068e-02     4.50260e-02
307        317     1.00000e+00     3.47535e-02     5.54864e-02
308        318     1.00000e+00     3.47033e-02     5.81539e-02
309        319     1.00000e+00     3.46634e-02     5.22703e-02
310        320     1.00000e+00     3.46384e-02     4.27256e-02
311        321     1.00000e+00     3.46176e-02     3.95387e-02
312        322     1.00000e+00     3.45875e-02     4.26777e-02
313        323     1.00000e+00     3.45571e-02     4.56087e-02
314        324     1.00000e+00     3.45373e-02     5.99977e-02
315        325     1.00000e+00     3.45152e-02     4.20557e-02
316        326     1.00000e+00     3.45010e-02     4.14777e-02
317        327     1.00000e+00     3.44841e-02     4.34006e-02
318        328     1.00000e+00     3.44508e-02     4.51865e-02
319        329     1.00000e+00     3.44233e-02     6.22508e-02
320        330     1.00000e+00     3.43813e-02     4.24499e-02
321        331     1.00000e+00     3.43527e-02     4.23616e-02
322        332     1.00000e+00     3.43206e-02     4.30308e-02
323        333     1.00000e+00     3.42916e-02     4.50341e-02
324        335     4.00243e-01     3.42808e-02     4.61128e-02
325        336     1.00000e+00     3.42686e-02     3.93564e-02
326        337     1.00000e+00     3.42559e-02     3.83971e-02
327        338     1.00000e+00     3.42410e-02     4.20332e-02
328        339     1.00000e+00     3.42193e-02     4.71803e-02
329        340     1.00000e+00     3.42087e-02     6.45439e-02
330        341     1.00000e+00     3.41854e-02     4.53759e-02
331        342     1.00000e+00     3.41649e-02     4.10914e-02
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333        344     1.00000e+00     3.41038e-02     4.55761e-02
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338        350     1.00000e+00     3.39698e-02     3.84145e-02
339        351     1.00000e+00     3.39632e-02     3.60596e-02
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342        354     1.00000e+00     3.39227e-02     4.31783e-02
343        355     1.00000e+00     3.39021e-02     5.58233e-02
344        356     1.00000e+00     3.38709e-02     4.64437e-02
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346        358     1.00000e+00     3.37826e-02     4.57768e-02
347        360     4.60751e-01     3.37572e-02     6.23126e-02
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349        362     1.00000e+00     3.36951e-02     3.75569e-02
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351        364     1.00000e+00     3.36535e-02     3.83805e-02
352        366     4.01082e-01     3.36423e-02     4.70963e-02
353        367     1.00000e+00     3.36192e-02     3.49059e-02
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355        369     1.00000e+00     3.35903e-02     3.25051e-02
356        370     1.00000e+00     3.35727e-02     3.22397e-02
357        371     1.00000e+00     3.35488e-02     3.46890e-02
358        372     1.00000e+00     3.35283e-02     4.22270e-02
359        373     1.00000e+00     3.35092e-02     3.43500e-02
360        374     1.00000e+00     3.34906e-02     3.23435e-02
361        375     1.00000e+00     3.34804e-02     3.71782e-02
362        376     1.00000e+00     3.34701e-02     3.07407e-02
363        377     1.00000e+00     3.34588e-02     3.38878e-02
364        378     1.00000e+00     3.34506e-02     3.86816e-02
365        379     1.00000e+00     3.34415e-02     3.38772e-02
366        380     1.00000e+00     3.34147e-02     3.34653e-02
367        381     1.00000e+00     3.33992e-02     3.59344e-02
368        382     1.00000e+00     3.33655e-02     3.79476e-02
369        383     1.00000e+00     3.33460e-02     4.33099e-02
370        384     1.00000e+00     3.33292e-02     4.26469e-02
371        385     1.00000e+00     3.33132e-02     3.41075e-02
372        386     1.00000e+00     3.32935e-02     3.24960e-02
373        387     1.00000e+00     3.32739e-02     3.33575e-02
374        388     1.00000e+00     3.32456e-02     3.70866e-02
375        390     2.89401e-01     3.32377e-02     3.52015e-02
376        391     1.00000e+00     3.32270e-02     2.99966e-02
377        392     1.00000e+00     3.32163e-02     2.97675e-02
378        393     1.00000e+00     3.32049e-02     3.06676e-02
379        394     1.00000e+00     3.31902e-02     4.33076e-02
380        395     1.00000e+00     3.31719e-02     3.08665e-02
381        396     1.00000e+00     3.31598e-02     2.95973e-02
382        397     1.00000e+00     3.31373e-02     3.19962e-02
383        398     1.00000e+00     3.31149e-02     3.41926e-02
384        400     4.88312e-01     3.30997e-02     4.29325e-02
385        401     1.00000e+00     3.30793e-02     3.13696e-02
386        402     1.00000e+00     3.30639e-02     3.00682e-02
387        403     1.00000e+00     3.30438e-02     3.25694e-02
388        404     1.00000e+00     3.30138e-02     3.56601e-02
389        406     4.98992e-01     3.29986e-02     4.27766e-02
390        407     1.00000e+00     3.29743e-02     3.06596e-02
391        408     1.00000e+00     3.29537e-02     3.28918e-02
392        409     1.00000e+00     3.29352e-02     3.67420e-02
393        411     3.37676e-01     3.29289e-02     4.15481e-02
394        412     1.00000e+00     3.29160e-02     3.20536e-02
395        413     1.00000e+00     3.29066e-02     2.72061e-02
396        414     1.00000e+00     3.29000e-02     2.77657e-02
397        415     1.00000e+00     3.28905e-02     2.98418e-02
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399        417     1.00000e+00     3.28728e-02     2.93001e-02
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404        422     1.00000e+00     3.27978e-02     4.80177e-02
405        423     1.00000e+00     3.27800e-02     3.65228e-02
406        424     1.00000e+00     3.27622e-02     3.30322e-02
407        425     1.00000e+00     3.27425e-02     3.18012e-02
408        426     1.00000e+00     3.27259e-02     3.13434e-02
409        427     1.00000e+00     3.27141e-02     3.32371e-02
410        428     1.00000e+00     3.27048e-02     3.42524e-02
411        429     1.00000e+00     3.26961e-02     3.05383e-02
412        430     1.00000e+00     3.26780e-02     2.87539e-02
413        431     1.00000e+00     3.26618e-02     2.96530e-02
414        432     1.00000e+00     3.26367e-02     2.79558e-02
415        433     1.00000e+00     3.26280e-02     3.54041e-02
416        434     1.00000e+00     3.26168e-02     2.74007e-02
417        435     1.00000e+00     3.26099e-02     2.33025e-02
418        436     1.00000e+00     3.26036e-02     2.55282e-02
419        437     1.00000e+00     3.25961e-02     2.88666e-02
420        438     1.00000e+00     3.25900e-02     2.15637e-02
421        439     1.00000e+00     3.25844e-02     2.19874e-02
422        440     1.00000e+00     3.25781e-02     2.42341e-02
423        441     1.00000e+00     3.25758e-02     4.02343e-02
424        442     1.00000e+00     3.25621e-02     2.28089e-02
425        443     1.00000e+00     3.25568e-02     2.21995e-02
426        444     1.00000e+00     3.25461e-02     2.63353e-02
427        445     1.00000e+00     3.25338e-02     2.74400e-02
428        446     1.00000e+00     3.25145e-02     3.98895e-02
429        447     1.00000e+00     3.24975e-02     3.70186e-02
430        448     1.00000e+00     3.24827e-02     2.61094e-02
431        449     1.00000e+00     3.24691e-02     2.33096e-02
432        450     1.00000e+00     3.24581e-02     2.42895e-02
433        451     1.00000e+00     3.24519e-02     3.99599e-02
434        452     1.00000e+00     3.24379e-02     2.33592e-02
435        453     1.00000e+00     3.24335e-02     2.15514e-02
436        454     1.00000e+00     3.24246e-02     2.14622e-02
437        455     1.00000e+00     3.24134e-02     3.17522e-02
438        456     1.00000e+00     3.24030e-02     2.70006e-02
439        457     1.00000e+00     3.23951e-02     2.25414e-02
440        458     1.00000e+00     3.23862e-02     2.55859e-02
441        459     1.00000e+00     3.23836e-02     3.58482e-02
442        460     1.00000e+00     3.23769e-02     2.55011e-02
443        461     1.00000e+00     3.23689e-02     2.20967e-02
444        462     1.00000e+00     3.23624e-02     2.54013e-02
445        463     1.00000e+00     3.23517e-02     2.67975e-02
446        464     1.00000e+00     3.23390e-02     3.64330e-02
447        465     1.00000e+00     3.23321e-02     4.10109e-02
448        466     1.00000e+00     3.23151e-02     2.50662e-02
449        467     1.00000e+00     3.23084e-02     2.36575e-02
450        468     1.00000e+00     3.23011e-02     2.62217e-02
451        469     1.00000e+00     3.22975e-02     3.37088e-02
452        470     1.00000e+00     3.22898e-02     2.36101e-02
453        471     1.00000e+00     3.22850e-02     2.20256e-02
454        472     1.00000e+00     3.22804e-02     2.32151e-02
455        473     1.00000e+00     3.22741e-02     2.95513e-02
456        474     1.00000e+00     3.22668e-02     2.36881e-02
457        475     1.00000e+00     3.22619e-02     2.13093e-02
458        476     1.00000e+00     3.22533e-02     2.13845e-02
459        477     1.00000e+00     3.22436e-02     2.27675e-02
460        478     1.00000e+00     3.22191e-02     2.85073e-02
461        479     1.00000e+00     3.22111e-02     4.43047e-02
462        480     1.00000e+00     3.21759e-02     2.68375e-02
463        481     1.00000e+00     3.21596e-02     2.34917e-02
464        482     1.00000e+00     3.21444e-02     2.59757e-02
465        484     5.12016e-01     3.21350e-02     2.72097e-02
```

```
       466         485     1.00000e+00     3.21277e-02     2.30648e-02
       467         486     1.00000e+00     3.21231e-02     2.09493e-02
       468         487     1.00000e+00     3.21180e-02     2.18079e-02
       469         488     1.00000e+00     3.21122e-02     2.07378e-02
       470         489     1.00000e+00     3.21055e-02     2.00178e-02
       471         490     1.00000e+00     3.20965e-02     2.44968e-02
       472         491     1.00000e+00     3.20933e-02     3.33069e-02
       473         492     1.00000e+00     3.20805e-02     2.21352e-02
       474         493     1.00000e+00     3.20718e-02     2.18124e-02
       475         494     1.00000e+00     3.20608e-02     2.28089e-02
       476         495     1.00000e+00     3.20499e-02     2.89170e-02
       477         496     1.00000e+00     3.20398e-02     2.37550e-02
       478         497     1.00000e+00     3.20336e-02     2.17993e-02
       479         498     1.00000e+00     3.20215e-02     2.16495e-02
       480         499     1.00000e+00     3.20092e-02     2.52938e-02
       481         500     1.00000e+00     3.19984e-02     3.02527e-02
       482         501     1.00000e+00     3.19857e-02     2.30141e-02
       483         502     1.00000e+00     3.19745e-02     2.19005e-02
       484         503     1.00000e+00     3.19631e-02     2.32406e-02
       485         504     1.00000e+00     3.19530e-02     3.23579e-02
       486         505     1.00000e+00     3.19445e-02     2.24021e-02
       487         506     1.00000e+00     3.19408e-02     1.86230e-02
       488         507     1.00000e+00     3.19356e-02     1.79061e-02
       489         508     1.00000e+00     3.19288e-02     1.96504e-02
       490         509     1.00000e+00     3.19209e-02     2.22691e-02
       491         510     1.00000e+00     3.19157e-02     2.32013e-02
       492         511     1.00000e+00     3.19101e-02     1.85614e-02
       493         512     1.00000e+00     3.19051e-02     1.84350e-02
       494         513     1.00000e+00     3.18989e-02     2.60394e-02
       495         514     1.00000e+00     3.18897e-02     2.11602e-02
       496         515     1.00000e+00     3.18817e-02     2.11537e-02
       497         516     1.00000e+00     3.18695e-02     2.35272e-02
       498         517     1.00000e+00     3.18605e-02     2.32841e-02
       499         518     1.00000e+00     3.18507e-02     1.94532e-02
       500         519     1.00000e+00     3.18392e-02     2.02408e-02
 Exceeded Maximum Number of Iterations
```

STEP 6: Test

```
Instructions: You will need to complete the code in stackedAEPredict.m
              before running this part of the code
```

```
% Get labelled test images
% Note that we apply the same kind of preprocessing as the training set
testData = loadMNISTImages('t10k-images-idx3-ubyte');
testLabels = loadMNISTLabels('t10k-labels-idx1-ubyte');

testLabels(testLabels == 0) = 10; % Remap 0 to 10


[pred] = stackedAEPredict(stackedAETheta, inputSize, hiddenSizeL2, ...
                          numClasses, netconfig, testData);

acc = mean(testLabels(:) == pred(:));
fprintf('Before Finetuning Test Accuracy: %0.3f%%\n', acc * 100);

[pred] = stackedAEPredict(stackedAEOptTheta, inputSize, hiddenSizeL2, ...
                          numClasses, netconfig, testData);

acc = mean(testLabels(:) == pred(:));
fprintf('After Finetuning Test Accuracy: %0.3f%%\n', acc * 100);

% Accuracy is the proportion of correctly classified images
% The results for our implementation were:
```

```
%
% Before Finetuning Test Accuracy: 87.7%
% After Finetuning Test Accuracy:  97.6%
%
% If your values are too low (accuracy less than 95%), you should check
% your code for errors, and make sure you are training on the
% entire data set of 60000 28x28 training images
% (unless you modified the loading code, this should be the case)
```

```
Before Finetuning Test Accuracy: 64.280%
After Finetuning Test Accuracy: 97.280%
```

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