Contents

CS294A/CS294W Self-taught Learning Exercise

```
%  Instructions
%  ------------
%
%  This file contains code that helps you get started on the
%  self-taught learning. You will need to complete code in feedForwardAutoencoder.m
%  You will also need to have implemented sparseAutoencoderCost.m and
%  softmaxCost.m from previous exercises.
%
```

==

```
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.
```

```
inputSize  = 28 * 28;
numLabels  = 5;
hiddenSize = 200;
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 = 400;
```

==

```
STEP 1: Load data from the MNIST database

This loads our training and test data from the MNIST database files.
We have sorted the data for you in this so that you will not have to
change it.
```

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

% Set Unlabeled Set (All Images)
```

```
% Simulate a Labeled and Unlabeled set
labeledSet   = find(mnistLabels >= 0 & mnistLabels <= 4);
unlabeledSet = find(mnistLabels >= 5);

numTrain = round(numel(labeledSet)/2);
trainSet = labeledSet(1:numTrain);
testSet  = labeledSet(numTrain+1:end);

unlabeledData = mnistData(:, unlabeledSet);

trainData   = mnistData(:, trainSet);
trainLabels = mnistLabels(trainSet)' + 1; % Shift Labels to the Range 1-5

testData   = mnistData(:, testSet);
testLabels = mnistLabels(testSet)' + 1;   % Shift Labels to the Range 1-5

% Output Some Statistics
fprintf('# examples in unlabeled set: %d\n', size(unlabeledData, 2));
fprintf('# examples in supervised training set: %d\n\n', size(trainData, 2));
fprintf('# examples in supervised testing set: %d\n\n', size(testData, 2));
```

```
# examples in unlabeled set: 29404
# examples in supervised training set: 15298

# examples in supervised testing set: 15298
```

===

STEP 2: Train the sparse autoencoder
This trains the sparse autoencoder on the unlabeled training
images.

```
%  Randomly initialize the parameters
theta = initializeParameters(hiddenSize, inputSize);
```

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

Find opttheta by running the sparse autoencoder on
unlabeledTrainingImages

```
%[cost,grad] = sparseAutoencoderCost(theta, inputSize, hiddenSize, ...
%                                    lambda, sparsityParam, beta, unlabeledData);

%  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';


[opttheta, cost] = minFunc( @(p) sparseAutoencoderCost(p, ...
                                   inputSize, hiddenSize, ...
                                   lambda, sparsityParam, ...
                                   beta, unlabeledData), ...
                              theta, options);
```

Iteration	FunEvals	Step Length	Function Val	Opt Cond
1	5	3.17144e-02	1.09441e+02	8.39860e+03
2	6	1.00000e+00	9.13105e+01	4.33276e+03
3	7	1.00000e+00	8.38682e+01	1.95811e+03
4	8	1.00000e+00	7.95454e+01	2.04678e+03
5	9	1.00000e+00	7.11217e+01	2.73423e+03
6	10	1.00000e+00	5.40402e+01	2.96698e+03
7	11	1.00000e+00	3.26609e+01	7.77808e+02
8	12	1.00000e+00	3.06043e+01	6.83039e+02
9	13	1.00000e+00	2.97733e+01	6.03632e+02
10	14	1.00000e+00	2.90295e+01	4.11155e+02
11	15	1.00000e+00	2.85348e+01	2.28426e+02
12	16	1.00000e+00	2.83625e+01	2.08767e+02
13	17	1.00000e+00	2.83021e+01	1.55551e+02
14	18	1.00000e+00	2.81605e+01	2.04181e+02
15	19	1.00000e+00	2.80077e+01	2.96219e+02
16	20	1.00000e+00	2.75822e+01	4.34911e+02
17	21	1.00000e+00	2.71986e+01	4.55218e+02
18	23	4.87538e-01	2.69981e+01	3.97166e+02
19	24	1.00000e+00	2.67582e+01	1.93357e+02
20	25	1.00000e+00	2.66034e+01	2.57440e+02
21	26	1.00000e+00	2.64739e+01	3.13599e+02
22	27	1.00000e+00	2.59104e+01	4.34788e+02
23	28	1.00000e+00	2.54914e+01	5.91737e+02
24	29	1.00000e+00	2.42665e+01	3.39863e+02
25	30	1.00000e+00	2.35356e+01	2.27576e+02
26	31	1.00000e+00	2.32985e+01	3.64472e+02
27	32	1.00000e+00	2.30969e+01	2.50901e+02
28	33	1.00000e+00	2.28323e+01	2.36672e+02
29	34	1.00000e+00	2.23686e+01	3.43738e+02
30	35	1.00000e+00	2.16783e+01	3.52177e+02
31	37	3.22835e-01	2.13577e+01	4.50780e+02
32	38	1.00000e+00	2.09310e+01	3.55776e+02
33	39	1.00000e+00	2.06571e+01	2.64359e+02
34	40	1.00000e+00	2.03842e+01	2.33227e+02
35	41	1.00000e+00	2.01813e+01	2.52720e+02
36	42	1.00000e+00	1.99626e+01	2.79159e+02
37	43	1.00000e+00	1.96700e+01	2.90728e+02
38	44	1.00000e+00	1.93207e+01	2.92083e+02
39	45	1.00000e+00	1.88889e+01	2.75358e+02
40	46	1.00000e+00	1.85137e+01	2.94104e+02
41	47	1.00000e+00	1.81891e+01	1.99500e+02
42	48	1.00000e+00	1.79962e+01	1.63231e+02
43	49	1.00000e+00	1.78379e+01	1.66128e+02
44	50	1.00000e+00	1.77576e+01	1.78648e+02
45	51	1.00000e+00	1.76701e+01	1.56484e+02
46	52	1.00000e+00	1.74868e+01	1.45945e+02
47	53	1.00000e+00	1.72927e+01	1.46590e+02
48	54	1.00000e+00	1.69987e+01	1.95222e+02
49	55	1.00000e+00	1.67666e+01	1.54182e+02
50	56	1.00000e+00	1.66386e+01	1.19332e+02
51	57	1.00000e+00	1.65367e+01	1.23311e+02
52	58	1.00000e+00	1.64760e+01	1.16718e+02
53	59	1.00000e+00	1.63491e+01	1.15905e+02
54	60	1.00000e+00	1.62727e+01	1.36567e+02
55	61	1.00000e+00	1.61861e+01	1.28346e+02
56	62	1.00000e+00	1.58852e+01	1.48303e+02
57	63	1.00000e+00	1.58409e+01	2.11250e+02
58	64	1.00000e+00	1.56707e+01	1.19305e+02
59	65	1.00000e+00	1.55875e+01	8.81069e+01
60	66	1.00000e+00	1.55047e+01	1.05132e+02
61	67	1.00000e+00	1.54187e+01	1.33283e+02
62	68	1.00000e+00	1.53333e+01	9.97891e+01
63	69	1.00000e+00	1.52632e+01	8.57344e+01
64	70	1.00000e+00	1.51760e+01	1.10322e+02
65	71	1.00000e+00	1.50526e+01	1.30663e+02

66	72	1.00000e+00	1.49164e+01	1.37132e+02
67	73	1.00000e+00	1.48510e+01	1.21818e+02
68	74	1.00000e+00	1.47939e+01	7.95476e+01
69	75	1.00000e+00	1.47569e+01	8.16911e+01
70	76	1.00000e+00	1.47125e+01	9.83483e+01
71	77	1.00000e+00	1.46369e+01	1.11960e+02
72	78	1.00000e+00	1.45889e+01	1.31148e+02
73	79	1.00000e+00	1.44995e+01	8.05943e+01
74	80	1.00000e+00	1.44228e+01	7.13846e+01
75	81	1.00000e+00	1.43649e+01	8.76295e+01
76	82	1.00000e+00	1.42973e+01	1.10089e+02
77	83	1.00000e+00	1.42300e+01	9.35263e+01
78	84	1.00000e+00	1.41729e+01	7.27321e+01
79	85	1.00000e+00	1.41177e+01	7.28394e+01
80	86	1.00000e+00	1.40919e+01	8.05346e+01
81	87	1.00000e+00	1.40626e+01	6.70073e+01
82	88	1.00000e+00	1.40121e+01	6.74240e+01
83	89	1.00000e+00	1.39702e+01	7.83514e+01
84	90	1.00000e+00	1.38887e+01	8.33154e+01
85	91	1.00000e+00	1.38470e+01	1.31851e+02
86	92	1.00000e+00	1.37793e+01	6.41942e+01
87	93	1.00000e+00	1.37587e+01	4.97378e+01
88	94	1.00000e+00	1.37413e+01	5.06827e+01
89	95	1.00000e+00	1.37122e+01	6.29957e+01
90	96	1.00000e+00	1.36643e+01	7.51976e+01
91	97	1.00000e+00	1.36019e+01	7.70626e+01
92	98	1.00000e+00	1.35514e+01	8.13900e+01
93	99	1.00000e+00	1.35141e+01	5.67009e+01
94	100	1.00000e+00	1.34972e+01	4.89847e+01
95	101	1.00000e+00	1.34811e+01	4.81442e+01
96	102	1.00000e+00	1.34643e+01	4.88345e+01
97	103	1.00000e+00	1.34365e+01	5.82964e+01
98	104	1.00000e+00	1.33949e+01	7.42400e+01
99	105	1.00000e+00	1.33489e+01	7.88364e+01
100	106	1.00000e+00	1.33131e+01	5.78690e+01
101	107	1.00000e+00	1.32971e+01	4.35489e+01
102	108	1.00000e+00	1.32899e+01	4.26242e+01
103	109	1.00000e+00	1.32724e+01	5.79265e+01
104	110	1.00000e+00	1.32382e+01	7.37887e+01
105	111	1.00000e+00	1.31975e+01	8.47101e+01
106	112	1.00000e+00	1.31617e+01	6.76440e+01
107	113	1.00000e+00	1.31463e+01	3.71897e+01
108	114	1.00000e+00	1.31441e+01	4.52361e+01
109	115	1.00000e+00	1.31368e+01	4.06049e+01
110	116	1.00000e+00	1.31232e+01	3.86121e+01
111	117	1.00000e+00	1.30943e+01	4.36740e+01
112	118	1.00000e+00	1.30547e+01	7.25499e+01
113	119	1.00000e+00	1.30404e+01	7.24413e+01
114	120	1.00000e+00	1.30216e+01	3.47914e+01
115	121	1.00000e+00	1.30168e+01	3.01008e+01
116	122	1.00000e+00	1.30053e+01	4.71663e+01
117	123	1.00000e+00	1.29875e+01	6.02091e+01
118	124	1.00000e+00	1.29576e+01	7.39105e+01
119	125	1.00000e+00	1.29391e+01	7.86919e+01
120	126	1.00000e+00	1.29173e+01	3.78457e+01
121	127	1.00000e+00	1.29116e+01	3.14295e+01
122	128	1.00000e+00	1.29055e+01	3.25049e+01
123	129	1.00000e+00	1.28899e+01	4.67754e+01
124	130	1.00000e+00	1.28648e+01	6.22186e+01
125	131	1.00000e+00	1.28362e+01	7.54282e+01
126	132	1.00000e+00	1.28143e+01	5.69712e+01
127	133	1.00000e+00	1.28022e+01	3.48932e+01
128	134	1.00000e+00	1.27951e+01	3.17301e+01
129	135	1.00000e+00	1.27894e+01	3.96844e+01
130	136	1.00000e+00	1.27692e+01	5.94217e+01
131	137	1.00000e+00	1.27452e+01	7.15362e+01

132	138	1.00000e+00	1.27237e+01	6.60430e+01
133	139	1.00000e+00	1.27078e+01	3.66903e+01
134	140	1.00000e+00	1.26982e+01	3.66899e+01
135	141	1.00000e+00	1.26920e+01	3.98244e+01
136	142	1.00000e+00	1.26764e+01	4.82656e+01
137	143	1.00000e+00	1.26601e+01	4.67052e+01
138	144	1.00000e+00	1.26448e+01	3.60643e+01
139	145	1.00000e+00	1.26309e+01	4.03199e+01
140	146	1.00000e+00	1.26206e+01	4.28611e+01
141	147	1.00000e+00	1.26073e+01	3.87067e+01
142	148	1.00000e+00	1.25953e+01	4.41942e+01
143	149	1.00000e+00	1.25830e+01	3.22737e+01
144	150	1.00000e+00	1.25735e+01	3.23726e+01
145	151	1.00000e+00	1.25547e+01	3.29569e+01
146	153	4.65618e-01	1.25482e+01	3.99788e+01
147	154	1.00000e+00	1.25402e+01	3.07800e+01
148	155	1.00000e+00	1.25257e+01	3.19838e+01
149	156	1.00000e+00	1.25160e+01	3.70503e+01
150	157	1.00000e+00	1.25022e+01	4.54284e+01
151	158	1.00000e+00	1.24886e+01	3.79468e+01
152	159	1.00000e+00	1.24772e+01	3.34333e+01
153	160	1.00000e+00	1.24656e+01	3.63886e+01
154	161	1.00000e+00	1.24582e+01	4.22217e+01
155	162	1.00000e+00	1.24470e+01	3.70921e+01
156	163	1.00000e+00	1.24311e+01	3.70221e+01
157	164	1.00000e+00	1.24240e+01	4.08735e+01
158	165	1.00000e+00	1.24173e+01	3.28163e+01
159	166	1.00000e+00	1.24059e+01	3.23959e+01
160	167	1.00000e+00	1.23968e+01	3.83387e+01
161	168	1.00000e+00	1.23792e+01	4.56283e+01
162	169	1.00000e+00	1.23690e+01	5.76724e+01
163	170	1.00000e+00	1.23574e+01	2.99048e+01
164	171	1.00000e+00	1.23522e+01	2.32979e+01
165	172	1.00000e+00	1.23474e+01	2.78993e+01
166	173	1.00000e+00	1.23368e+01	3.55870e+01
167	174	1.00000e+00	1.23259e+01	4.90922e+01
168	175	1.00000e+00	1.23121e+01	3.46394e+01
169	176	1.00000e+00	1.23018e+01	2.95227e+01
170	177	1.00000e+00	1.22950e+01	3.20335e+01
171	178	1.00000e+00	1.22877e+01	4.16695e+01
172	179	1.00000e+00	1.22792e+01	3.01005e+01
173	180	1.00000e+00	1.22709e+01	2.65034e+01
174	181	1.00000e+00	1.22653e+01	3.47687e+01
175	182	1.00000e+00	1.22578e+01	3.84263e+01
176	183	1.00000e+00	1.22449e+01	5.23783e+01
177	184	1.00000e+00	1.22321e+01	3.57073e+01
178	185	1.00000e+00	1.22250e+01	2.21090e+01
179	186	1.00000e+00	1.22192e+01	2.72438e+01
180	187	1.00000e+00	1.22141e+01	3.24657e+01
181	188	1.00000e+00	1.22043e+01	3.52460e+01
182	189	1.00000e+00	1.21979e+01	3.71010e+01
183	190	1.00000e+00	1.21914e+01	2.56240e+01
184	191	1.00000e+00	1.21835e+01	2.95552e+01
185	192	1.00000e+00	1.21776e+01	3.51685e+01
186	193	1.00000e+00	1.21681e+01	3.61205e+01
187	194	1.00000e+00	1.21609e+01	3.08349e+01
188	195	1.00000e+00	1.21560e+01	2.30935e+01
189	196	1.00000e+00	1.21523e+01	2.66832e+01
190	197	1.00000e+00	1.21447e+01	3.23463e+01
191	198	1.00000e+00	1.21399e+01	4.22990e+01
192	199	1.00000e+00	1.21327e+01	2.73734e+01
193	200	1.00000e+00	1.21274e+01	2.24299e+01
194	201	1.00000e+00	1.21228e+01	2.68224e+01
195	202	1.00000e+00	1.21149e+01	3.49428e+01
196	203	1.00000e+00	1.21097e+01	4.59669e+01
197	204	1.00000e+00	1.21004e+01	2.75131e+01

198	205	1.00000e+00	1.20952e+01	2.08180e+01
199	206	1.00000e+00	1.20911e+01	2.34886e+01
200	207	1.00000e+00	1.20858e+01	2.74159e+01
201	208	1.00000e+00	1.20796e+01	3.77819e+01
202	209	1.00000e+00	1.20715e+01	2.54450e+01
203	210	1.00000e+00	1.20636e+01	2.23636e+01
204	211	1.00000e+00	1.20575e+01	2.58904e+01
205	212	1.00000e+00	1.20533e+01	3.81681e+01
206	213	1.00000e+00	1.20473e+01	2.51278e+01
207	214	1.00000e+00	1.20408e+01	2.26245e+01
208	215	1.00000e+00	1.20354e+01	2.67980e+01
209	216	1.00000e+00	1.20305e+01	3.10988e+01
210	217	1.00000e+00	1.20247e+01	3.20597e+01
211	218	1.00000e+00	1.20189e+01	2.61333e+01
212	219	1.00000e+00	1.20122e+01	2.46619e+01
213	220	1.00000e+00	1.20089e+01	2.69905e+01
214	221	1.00000e+00	1.20051e+01	2.73438e+01
215	222	1.00000e+00	1.19969e+01	2.94974e+01
216	223	1.00000e+00	1.19931e+01	3.22959e+01
217	224	1.00000e+00	1.19884e+01	1.94418e+01
218	225	1.00000e+00	1.19851e+01	1.72650e+01
219	226	1.00000e+00	1.19828e+01	2.32816e+01
220	227	1.00000e+00	1.19782e+01	2.81806e+01
221	228	1.00000e+00	1.19727e+01	3.13178e+01
222	229	1.00000e+00	1.19665e+01	2.31490e+01
223	230	1.00000e+00	1.19620e+01	1.86534e+01
224	231	1.00000e+00	1.19584e+01	2.26570e+01
225	232	1.00000e+00	1.19545e+01	2.41783e+01
226	233	1.00000e+00	1.19486e+01	2.31072e+01
227	234	1.00000e+00	1.19429e+01	1.97132e+01
228	235	1.00000e+00	1.19394e+01	1.96226e+01
229	236	1.00000e+00	1.19361e+01	1.82581e+01
230	237	1.00000e+00	1.19318e+01	1.75178e+01
231	238	1.00000e+00	1.19284e+01	2.39893e+01
232	239	1.00000e+00	1.19240e+01	1.77991e+01
233	240	1.00000e+00	1.19187e+01	1.65068e+01
234	241	1.00000e+00	1.19160e+01	1.66442e+01
235	242	1.00000e+00	1.19100e+01	1.93051e+01
236	243	1.00000e+00	1.19042e+01	2.71138e+01
237	244	1.00000e+00	1.18991e+01	2.34489e+01
238	245	1.00000e+00	1.18956e+01	1.66204e+01
239	246	1.00000e+00	1.18935e+01	1.60456e+01
240	247	1.00000e+00	1.18907e+01	1.88599e+01
241	248	1.00000e+00	1.18859e+01	2.51555e+01
242	249	1.00000e+00	1.18807e+01	2.33193e+01
243	250	1.00000e+00	1.18765e+01	1.67833e+01
244	251	1.00000e+00	1.18737e+01	1.59808e+01
245	252	1.00000e+00	1.18719e+01	1.76739e+01
246	253	1.00000e+00	1.18680e+01	1.90760e+01
247	254	1.00000e+00	1.18659e+01	3.93455e+01
248	255	1.00000e+00	1.18587e+01	1.75974e+01
249	256	1.00000e+00	1.18565e+01	1.32404e+01
250	257	1.00000e+00	1.18544e+01	1.45881e+01
251	258	1.00000e+00	1.18521e+01	2.19732e+01
252	259	1.00000e+00	1.18483e+01	1.98702e+01
253	260	1.00000e+00	1.18406e+01	2.06874e+01
254	262	4.07391e-01	1.18384e+01	1.79742e+01
255	263	1.00000e+00	1.18366e+01	1.33554e+01
256	264	1.00000e+00	1.18350e+01	1.33533e+01
257	265	1.00000e+00	1.18329e+01	1.81237e+01
258	266	1.00000e+00	1.18291e+01	1.98390e+01
259	267	1.00000e+00	1.18236e+01	2.79398e+01
260	268	1.00000e+00	1.18208e+01	2.52599e+01
261	269	1.00000e+00	1.18179e+01	1.39617e+01
262	270	1.00000e+00	1.18168e+01	1.31072e+01
263	271	1.00000e+00	1.18152e+01	1.47913e+01

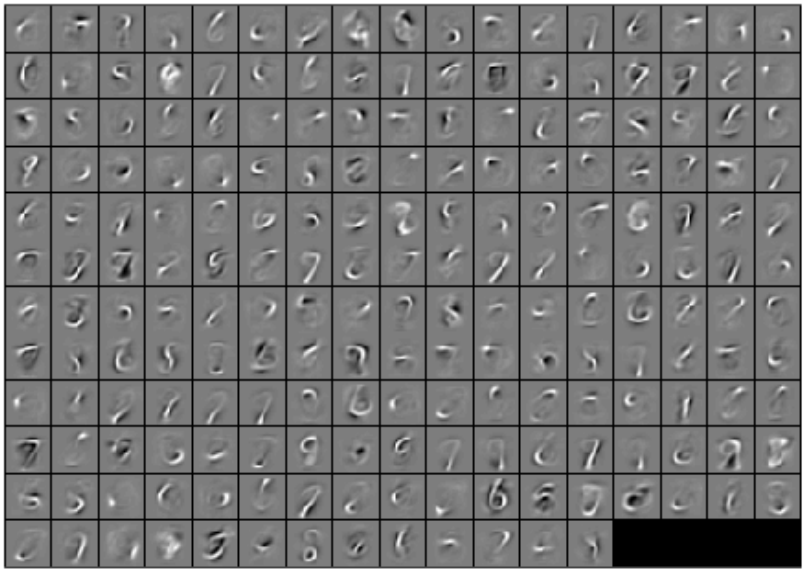
264	272	1.00000e+00	1.18123e+01	1.63075e+01
265	273	1.00000e+00	1.18098e+01	3.07939e+01
266	274	1.00000e+00	1.18055e+01	1.51054e+01
267	275	1.00000e+00	1.18037e+01	1.39711e+01
268	276	1.00000e+00	1.18016e+01	1.56333e+01
269	277	1.00000e+00	1.17990e+01	2.24376e+01
270	278	1.00000e+00	1.17958e+01	1.61188e+01
271	279	1.00000e+00	1.17931e+01	1.35645e+01
272	280	1.00000e+00	1.17914e+01	1.67677e+01
273	281	1.00000e+00	1.17900e+01	1.64113e+01
274	282	1.00000e+00	1.17885e+01	1.52363e+01
275	283	1.00000e+00	1.17853e+01	1.76110e+01
276	284	1.00000e+00	1.17832e+01	1.98259e+01
277	285	1.00000e+00	1.17810e+01	1.75260e+01
278	286	1.00000e+00	1.17775e+01	1.44083e+01
279	287	1.00000e+00	1.17766e+01	1.68403e+01
280	288	1.00000e+00	1.17756e+01	1.28973e+01
281	289	1.00000e+00	1.17734e+01	1.33253e+01
282	290	1.00000e+00	1.17715e+01	1.74659e+01
283	291	1.00000e+00	1.17690e+01	1.89100e+01
284	292	1.00000e+00	1.17675e+01	2.18503e+01
285	293	1.00000e+00	1.17660e+01	1.39770e+01
286	294	1.00000e+00	1.17648e+01	1.17909e+01
287	295	1.00000e+00	1.17635e+01	1.47060e+01
288	296	1.00000e+00	1.17614e+01	1.86143e+01
289	297	1.00000e+00	1.17594e+01	1.88382e+01
290	298	1.00000e+00	1.17580e+01	2.21734e+01
291	299	1.00000e+00	1.17561e+01	1.50492e+01
292	300	1.00000e+00	1.17543e+01	1.33365e+01
293	301	1.00000e+00	1.17529e+01	1.51172e+01
294	302	1.00000e+00	1.17512e+01	1.66748e+01
295	303	1.00000e+00	1.17493e+01	1.80284e+01
296	304	1.00000e+00	1.17475e+01	1.59713e+01
297	305	1.00000e+00	1.17459e+01	1.22070e+01
298	306	1.00000e+00	1.17446e+01	1.27255e+01
299	307	1.00000e+00	1.17438e+01	1.25096e+01
300	308	1.00000e+00	1.17425e+01	1.36868e+01
301	309	1.00000e+00	1.17397e+01	1.50072e+01
302	311	4.66303e-01	1.17386e+01	1.69181e+01
303	312	1.00000e+00	1.17371e+01	1.16738e+01
304	313	1.00000e+00	1.17358e+01	9.55563e+00
305	314	1.00000e+00	1.17348e+01	1.21128e+01
306	315	1.00000e+00	1.17330e+01	1.50568e+01
307	316	1.00000e+00	1.17320e+01	2.01100e+01
308	317	1.00000e+00	1.17300e+01	1.12229e+01
309	318	1.00000e+00	1.17292e+01	8.17644e+00
310	319	1.00000e+00	1.17284e+01	1.02582e+01
311	320	1.00000e+00	1.17272e+01	1.31153e+01
312	321	1.00000e+00	1.17254e+01	1.50403e+01
313	322	1.00000e+00	1.17248e+01	1.96780e+01
314	323	1.00000e+00	1.17228e+01	1.02881e+01
315	324	1.00000e+00	1.17220e+01	8.46336e+00
316	325	1.00000e+00	1.17212e+01	1.09020e+01
317	326	1.00000e+00	1.17198e+01	1.39181e+01
318	327	1.00000e+00	1.17181e+01	1.51406e+01
319	328	1.00000e+00	1.17171e+01	1.69516e+01
320	329	1.00000e+00	1.17159e+01	9.29539e+00
321	330	1.00000e+00	1.17153e+01	8.57954e+00
322	331	1.00000e+00	1.17146e+01	1.03618e+01
323	332	1.00000e+00	1.17128e+01	1.34186e+01
324	334	5.19029e-01	1.17117e+01	1.54914e+01
325	335	1.00000e+00	1.17100e+01	1.07612e+01
326	336	1.00000e+00	1.17089e+01	8.26823e+00
327	337	1.00000e+00	1.17084e+01	1.02882e+01
328	338	1.00000e+00	1.17078e+01	1.15064e+01
329	339	1.00000e+00	1.17060e+01	1.27160e+01

330	341	4.64458e-01	1.17049e+01	1.39783e+01
331	342	1.00000e+00	1.17034e+01	8.80598e+00
332	343	1.00000e+00	1.17025e+01	9.36689e+00
333	344	1.00000e+00	1.17020e+01	1.07726e+01
334	345	1.00000e+00	1.17012e+01	1.14295e+01
335	346	1.00000e+00	1.17003e+01	1.92297e+01
336	347	1.00000e+00	1.16984e+01	8.65726e+00
337	348	1.00000e+00	1.16978e+01	7.45961e+00
338	349	1.00000e+00	1.16971e+01	9.49652e+00
339	350	1.00000e+00	1.16962e+01	1.22532e+01
340	351	1.00000e+00	1.16947e+01	1.22609e+01
341	352	1.00000e+00	1.16935e+01	1.72076e+01
342	353	1.00000e+00	1.16921e+01	8.14696e+00
343	354	1.00000e+00	1.16918e+01	6.58717e+00
344	355	1.00000e+00	1.16913e+01	7.49983e+00
345	356	1.00000e+00	1.16902e+01	9.51129e+00
346	357	1.00000e+00	1.16887e+01	1.03555e+01
347	358	1.00000e+00	1.16872e+01	1.22464e+01
348	359	1.00000e+00	1.16864e+01	9.78641e+00
349	360	1.00000e+00	1.16859e+01	7.76198e+00
350	361	1.00000e+00	1.16854e+01	7.19596e+00
351	362	1.00000e+00	1.16845e+01	8.47549e+00
352	363	1.00000e+00	1.16836e+01	1.47472e+01
353	364	1.00000e+00	1.16824e+01	9.42498e+00
354	365	1.00000e+00	1.16819e+01	7.67048e+00
355	366	1.00000e+00	1.16812e+01	9.06251e+00
356	367	1.00000e+00	1.16802e+01	1.10583e+01
357	368	1.00000e+00	1.16791e+01	1.07263e+01
358	369	1.00000e+00	1.16782e+01	9.00455e+00
359	370	1.00000e+00	1.16777e+01	8.58734e+00
360	371	1.00000e+00	1.16773e+01	8.52974e+00
361	372	1.00000e+00	1.16761e+01	9.10942e+00
362	373	1.00000e+00	1.16749e+01	1.30825e+01
363	374	1.00000e+00	1.16738e+01	1.00007e+01
364	375	1.00000e+00	1.16732e+01	7.92157e+00
365	376	1.00000e+00	1.16727e+01	8.40321e+00
366	377	1.00000e+00	1.16721e+01	8.62115e+00
367	378	1.00000e+00	1.16712e+01	9.02457e+00
368	379	1.00000e+00	1.16707e+01	1.17025e+01
369	380	1.00000e+00	1.16700e+01	7.10423e+00
370	381	1.00000e+00	1.16694e+01	7.43769e+00
371	382	1.00000e+00	1.16686e+01	9.29128e+00
372	383	1.00000e+00	1.16675e+01	1.02631e+01
373	385	3.25124e-01	1.16670e+01	1.04935e+01
374	386	1.00000e+00	1.16663e+01	6.96057e+00
375	387	1.00000e+00	1.16659e+01	6.60863e+00
376	388	1.00000e+00	1.16654e+01	8.79623e+00
377	389	1.00000e+00	1.16645e+01	1.09499e+01
378	390	1.00000e+00	1.16637e+01	1.30232e+01
379	391	1.00000e+00	1.16629e+01	8.67711e+00
380	392	1.00000e+00	1.16625e+01	6.07895e+00
381	393	1.00000e+00	1.16622e+01	6.80563e+00
382	394	1.00000e+00	1.16618e+01	8.53876e+00
383	395	1.00000e+00	1.16608e+01	1.11979e+01
384	396	1.00000e+00	1.16600e+01	1.39845e+01
385	397	1.00000e+00	1.16590e+01	9.06288e+00
386	398	1.00000e+00	1.16585e+01	5.94476e+00
387	399	1.00000e+00	1.16582e+01	6.57274e+00
388	400	1.00000e+00	1.16578e+01	8.37614e+00
389	401	1.00000e+00	1.16569e+01	1.09609e+01
390	402	1.00000e+00	1.16565e+01	1.51337e+01
391	403	1.00000e+00	1.16554e+01	8.41069e+00
392	404	1.00000e+00	1.16551e+01	5.42269e+00
393	405	1.00000e+00	1.16549e+01	5.69162e+00
394	406	1.00000e+00	1.16545e+01	7.77896e+00
395	407	1.00000e+00	1.16538e+01	1.09776e+01

```
        396         408     1.00000e+00     1.16528e+01     1.21141e+01
        397         409     1.00000e+00     1.16523e+01     1.40211e+01
        398         410     1.00000e+00     1.16515e+01     6.77725e+00
        399         411     1.00000e+00     1.16512e+01     4.79278e+00
        400         412     1.00000e+00     1.16510e+01     6.06121e+00
Exceeded Maximum Number of Iterations
```

```
% Visualize weights
W1 = reshape(opttheta(1:hiddenSize * inputSize), hiddenSize, inputSize);
display_network(W1');

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



STEP 3: Extract Features from the Supervised Dataset

You need to complete the code in feedForwardAutoencoder.m so that the
following command will extract features from the data.

```
trainFeatures = feedForwardAutoencoder(opttheta, hiddenSize, inputSize, ...
                                       trainData);

testFeatures = feedForwardAutoencoder(opttheta, hiddenSize, inputSize, ...
                                       testData);

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

STEP 4: Train the softmax classifier

```
softmaxModel = struct;
```

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

Use softmaxTrain.m from the previous exercise to train a multi-class
classifier.

```
%  Use lambda = 1e-4 for the weight regularization for softmax

% You need to compute softmaxModel using softmaxTrain on trainFeatures and
% trainLabels


%TODO: numclasses (second parameter)?
numClasses = numLabels;
softmaxModel = softmaxTrain(size(trainFeatures,1), numClasses, lambda, trainFeatures, trainLabels, options);
```

```
 Iteration    FunEvals     Step Length    Function Val        Opt Cond
         1           3     6.36196e-01     1.33497e+00     1.32257e+01
         2           4     1.00000e+00     4.74263e-01     4.61980e+00
         3           5     1.00000e+00     3.36611e-01     3.25911e+00
         4           6     1.00000e+00     2.56673e-01     1.51167e+00
         5           7     1.00000e+00     2.02376e-01     8.41515e-01
         6           8     1.00000e+00     1.64045e-01     8.52121e-01
         7           9     1.00000e+00     1.35332e-01     7.70914e-01
         8          10     1.00000e+00     1.21191e-01     4.26088e-01
         9          11     1.00000e+00     1.08163e-01     2.63100e-01
        10          12     1.00000e+00     9.84830e-02     2.48788e-01
        11          13     1.00000e+00     8.56455e-02     2.12026e-01
        12          14     1.00000e+00     7.10349e-02     2.32977e-01
        13          15     1.00000e+00     6.10744e-02     1.36751e-01
        14          16     1.00000e+00     5.73789e-02     1.01526e-01
        15          17     1.00000e+00     5.25205e-02     9.39663e-02
        16          18     1.00000e+00     4.78129e-02     1.20996e-01
        17          19     1.00000e+00     4.41772e-02     9.78569e-02
        18          20     1.00000e+00     3.97134e-02     8.33212e-02
        19          21     1.00000e+00     3.69123e-02     8.29278e-02
        20          22     1.00000e+00     3.50902e-02     5.13764e-02
        21          23     1.00000e+00     3.30047e-02     4.75294e-02
        22          24     1.00000e+00     3.08803e-02     5.19886e-02
        23          25     1.00000e+00     2.78050e-02     4.60122e-02
        24          27     3.93888e-01     2.65762e-02     6.44841e-02
        25          28     1.00000e+00     2.48205e-02     3.66557e-02
        26          29     1.00000e+00     2.37104e-02     2.65275e-02
        27          30     1.00000e+00     2.24124e-02     2.93779e-02
        28          31     1.00000e+00     2.12620e-02     2.98684e-02
        29          32     1.00000e+00     1.99678e-02     2.51606e-02
        30          33     1.00000e+00     1.86769e-02     2.71834e-02
        31          34     1.00000e+00     1.75297e-02     3.03202e-02
        32          35     1.00000e+00     1.67584e-02     2.43802e-02
        33          36     1.00000e+00     1.55925e-02     1.97607e-02
        34          37     1.00000e+00     1.48072e-02     2.25549e-02
        35          38     1.00000e+00     1.41815e-02     1.67298e-02
        36          39     1.00000e+00     1.32595e-02     1.67678e-02
        37          40     1.00000e+00     1.25670e-02     1.92289e-02
        38          41     1.00000e+00     1.18497e-02     2.32757e-02
        39          42     1.00000e+00     1.12050e-02     2.02210e-02
        40          43     1.00000e+00     1.07260e-02     2.02083e-02
        41          44     1.00000e+00     9.99713e-03     1.40883e-02
        42          45     1.00000e+00     9.49947e-03     1.28538e-02
        43          46     1.00000e+00     9.03008e-03     1.22851e-02
        44          47     1.00000e+00     8.40422e-03     1.09966e-02
        45          48     1.00000e+00     7.74442e-03     1.31562e-02
        46          49     1.00000e+00     7.29999e-03     8.69803e-03
        47          50     1.00000e+00     7.00117e-03     8.90130e-03
        48          51     1.00000e+00     6.62966e-03     9.49878e-03
        49          52     1.00000e+00     6.15874e-03     1.02286e-02
        50          53     1.00000e+00     5.74425e-03     1.05769e-02
```

```
         51          54     1.00000e+00     5.44024e-03     9.06070e-03
         52          55     1.00000e+00     5.26351e-03     1.06360e-02
         53          56     1.00000e+00     5.01555e-03     8.36821e-03
         54          57     1.00000e+00     4.74889e-03     5.53041e-03
         55          58     1.00000e+00     4.49073e-03     4.62436e-03
         56          59     1.00000e+00     4.26168e-03     5.21395e-03
         57          60     1.00000e+00     3.94117e-03     5.81362e-03
         58          61     1.00000e+00     3.66187e-03     7.63935e-03
         59          62     1.00000e+00     3.44681e-03     5.20709e-03
         60          63     1.00000e+00     3.29185e-03     4.80135e-03
         61          64     1.00000e+00     3.07250e-03     4.75724e-03
         62          65     1.00000e+00     2.81752e-03     4.80489e-03
         63          66     1.00000e+00     2.51722e-03     5.94375e-03
         64          70     1.25000e-01     2.46296e-03     5.46013e-03
         65          78     7.81250e-03     2.45761e-03     5.42162e-03
         66          89     9.76562e-04     2.45666e-03     5.41601e-03
         67         102     2.44141e-04     2.45637e-03     5.41449e-03
         68         119     1.52588e-05     2.45636e-03     5.41439e-03
         69         140     9.53674e-07     2.45636e-03     5.41439e-03
         70         162     4.76837e-07     2.45635e-03     5.41439e-03
Function Value changing by less than TolX
```

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

STEP 5: Testing

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

Compute Predictions on the test set (testFeatures) using softmaxPredict and softmaxModel

```
pred = softmaxPredict(softmaxModel, testFeatures);
```

```
% Classification Score
fprintf('Test Accuracy: %f%%\n', 100*mean(pred(:) == testLabels(:)));

% (note that we shift the labels by 1, so that digit 0 now corresponds to
%  label 1)
%
% Accuracy is the proportion of correctly classified images
% The results for our implementation was:
%
% Accuracy: 98.3%
%
%
```

```
Test Accuracy: 98.091254%
```

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