In this homework, you will implement a multilayer perceptron (MLP) classifier. You should learn the weights of this classifier implementing the backpropagation algorithm. You will run the MLP classifier on the “Thyroid data set”, which you also used for the first homework. Please see the first homework description for the details of this data set. This homework has three parts:

**Part 1:**
Implement a multilayer perceptron with a single hidden layer. In this part,

(a) Write down the update rules that your implementation uses. Specify the loss function.

(b) List all the parameters (except the hidden unit number) that your implementation uses. Explain how you select the parameter values. Here you are not required to conduct cross-validation to select the values (of course, if you’d like, you can). Just explain why you select these values.

(c) Explain how you manage the situation of having unbalanced class distributions. Also explain if you use any normalization on the features.

(d) For different values of the hidden unit number (at least 5 different values), obtain training and test set accuracies. Report the overall accuracy as well as the class-based accuracies. You may report these accuracies in a “nice” table or you may draw them in a plot.

(e) Fix the hidden unit number to a value that gives good class-based test set accuracies. Now conduct the following experiments with your selected hidden unit number.

- Obtain the results with and without normalization. Compare the overall test set accuracy and the class-based test set accuracies. Discuss how the normalization affects the results.

- Obtain the results when you use the data as it is and when you handle the situation of having unbalanced class distributions (for example, by duplicating the samples from the minority classes). Compare the overall test set accuracy and the class-based test set accuracies. Discuss how the unbalanced class distributions affect the results.

- Use the stochastic, batch, and mini-batch approaches for the weight updates. Compare their results and discuss the difference in between the use of these approaches, if any.

**Part 2:**
Implement a multilayer perceptron with **TWO hidden layers**. In this part,

(a) Write down the update rules that your implementation uses. Specify the loss function.

(b) List all the parameters (except the hidden unit numbers) that your implementation uses. Just give your selected values of these parameters. In this part, you do not need to explain how or why you select these values.

(c) Select at least three different hidden unit numbers for the first hidden layer, and at least three different hidden unit numbers for the second hidden layer. Run your MLP classifier for each of these combinations (i.e., at least for nine different combinations). Obtain training and test set accuracies. Report the overall accuracy as well as the class-based accuracies.
Part 3:

Compare the results obtained using a MLP with a single hidden layer (Part 1) and a MLP with two hidden layers (Part 2). Discuss how an additional hidden layer affects the results. Are these results consistent with your expectations? Discuss it very briefly.

Please note that the runs of this homework may take a considerable amount of time, especially if you will use Matlab in your implementation. Therefore, do not leave this homework to the last minute; make sure to give yourselves enough time to finish your runs before the deadline.

Similar to the first homework, you are expected to write your report neatly and properly. The format, structure, and writing style of your report as well as the quality of the tables and figures will be a part of your grade. Additionally, you should follow the following instructions to prepare your report.

- **Part 1:** You SHOULD NOT give the screen shots or outputs of your program but you should summarize what you have found at the end of your runs. Do not forget to address the questions asked through the items (a)-(e). This part should be a maximum of 4 pages.
  
  You need to email the source code of your implementation for Part 1 and Part 2. The subject line of your email should CS 550: HW2. Do not submit the printout of your source code.

- **Part 2:** You SHOULD NOT give the screen shots or outputs of your program but you should summarize what you have found at the end of your runs. Do not forget to address the questions asked through the items (a)-(c). This part should be a maximum of 2 pages.

- **Part 3:** Your discussion should be brief, a maximum of 300 words.

- **All parts:** You should use reasonable font sizes, spacing, margin sizes, etc. You may submit either a one-column or a double-column document.

Please submit the hardcopy of your report before the deadline. DO NOT submit the printout of your source code.