CS/ECE/ME532 Assignment 9

1. **Face Emotion Classification with a three layer neural network**. In this problem we return to the face emotion data studied previously. You may find it very helpful to use code from a past activity.

   a) Build a classifier using a full connected three layer neural network with logistic activation functions. Your network should

   - take a vector $\boldsymbol{x} \in \mathbb{R}^{10}$ as input (nine features plus a constant offset),
   - have a single, fully connected hidden layer with 32 neurons
   - output a scalar $\widehat{y}$.

   Note that since the logistic activation function is always positive, your decision should be as follows: $\widehat{y} > 0.5$ corresponds to a 'happy' face, while $\widehat{y} \leq 0.5$ is not happy.

   b) Train your classifier using stochastic gradient descent (start with a step size of $\alpha = 0.05$) and create a plot with the number of epochs on the horizontal axis, and training accuracy on the vertical axis. Does your classifier achieve 0% training error? If so, how many epoch does it take for your classifier to achieve perfect classification on the training set?

   c) Find a more realistic estimate of the accuracy of your classifier by using 8-fold cross validation. Can you achieve perfect test accuracy?

2. **Face Emotion Classification with Kernel Classifier.** In this problem you will apply a kernel classifier to the face emotion dataset. You may find it very helpful to use code from an activity.

   a) Build a kernel classifier using

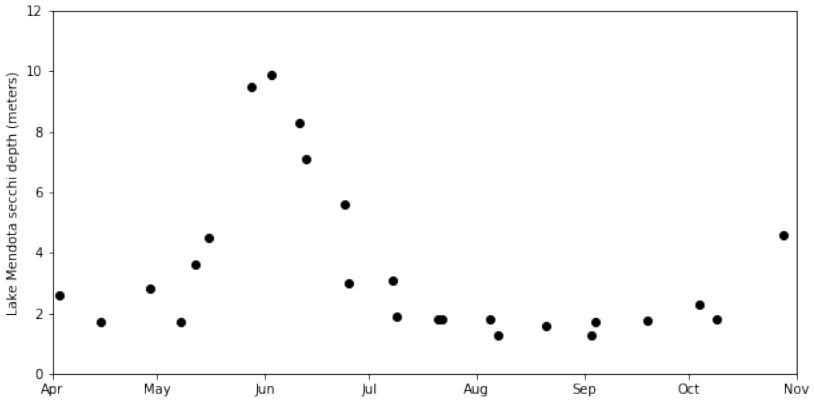
   - the squared error loss function
   - an ℓ_2 regularizer with $\lambda = 0.5$.
   - the Guassian Kernel $K(\boldsymbol{u}, \boldsymbol{v}) = \exp(-||\boldsymbol{u} - \boldsymbol{v}||^2/(2\sigma^2)$.

   b) Train your classifier choosing for different values of σ and create a plot with σ on the horizontal axis and accuracy on the vertical axis and comment on the plot. Does your classifier achieve 0% training error?

   c) Find a more realistic estimate of the accuracy of your classifier by using 8-fold cross validation. Can you achieve perfect test accuracy?

3. **Kernel Regression, Lake Mendota Clarity**. The *Secchi depth* is a measure of water clarity obtained by lowering a black and white disk off the shady side of a boat and recording the depth at which the disk is no longer visible.

   A dataset obtained from the University of Wisconsin's Limnology department contains Secchi disk readings (in meters) on Lake Mendota from 2019 and 2020. A Secchi depth of less than 2 meters is consider poor clarity, while a Secchi depth greater than 6 meters is consider very clear. Lake Mendota can have very clear water in late spring when native zooplankton *daphnia pulicaria* consume large amounts of algae and phytoplankton (for more details, see https://blog.limnology.wisc.edu/2019/06/12/whats-behind-this-extended-phase-of-crazy-clear-water-in-lake-mendota/).



   a) Use kernel ridge regression with a Gaussian kernel to fit the measurements. You may find it useful to use code from an activity. Use regularization parameter $\lambda = 0.01$ and scale parameter $\sigma = 10$. Plot the resulting fit, and comment on the results. Do these parameters overfit or underfit the data? Adjust the regularization parameter to find a visually better fit.

   b) Describe how you could use k-fold cross validation to systematically find a good value of σ and λ.