
Machine Learning (CS 391L) : Spring 2013

Homework 2

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1. Files in submission

1. hw2.m : The main script
2. Visualization Utilities:
   a. hw2_vis.m : Signals plot
   b. hw2_plot.m : Real-time weights plot
   c. hw2_curvefit.m : Curve-fitting plot

2. Data

There are five sounds in the input, which we will refer to as follows (in order):

1. Speech
2. Drill
3. Applause
4. Laughter
5. Noise

3. Approach

Various combinations of signals were tried to see which ones work best. The signals are mixed using a matrix with random values with each row normalized, to maintain the same range of amplitude. There is an option to have more mixed signals than input signals, which affects the accuracy to some extent. After initializing the weights to random values, gradient descent runs until max iterations (*iters*) or if the changes for each value in W are less than *epsilon*, which is set to a very small number. W is updated during convergence as follows:

```
Y = W * X;
Z = 1 ./ (1 + exp(-Y));

dW = learnRate .* ((eye(n) + ((1 - 2.*Z) * Y')) * W);
if (abs(dW) < epsilon)
      break;
else
      W = W + dW;
end
```

We then normalize both the input and output signals to [-1,1] to compute a sum of squared errors. Due to the random ordering of the outputs, this is done for all permutations of the output signals and the permutation with the least error is selected. For more details see comments in the code.

4. Experiments and Observations

4.1 Gradient descent

Figure 5.2 shows the convergence over iterations for two signals (so that W is a 2x2 matrix). We can see that the values change rapidly initially and then smooth out. As the initial values of W are random, the no. of iterations required for convergence can be between 200 and 5000. It should be noted that different values of W converge at different rates, as can be seen in Figure 5.2. To ensure that all values converge, we terminate only when all changes in W become less than *epsilon*.

4.2 Signal recovery

As mentioned in section 3, different combinations of signals have different results. The best result was observed for the pair {*Speech*, *Drill*}, while any signal mixed with *Noise* performed poorly. A complete list of sum of squared errors for each pair is shown in Table 5.1. The performance for bigger sets of input signals roughly matches the pattern observed in the errors on pairs, with error increasing as no. of input signals increases. When all five signals are mixed, the error during recovery is 3399.1, which is more than that observed for any pair, as expected.

The original and recovered signals for the {*Speech, Drill*} pair can be seen in Figure 5.1. Though there are differences if we look at the signals at higher resolution, the overall amplitude variation and therefore the audible sounds themselves are recovered very well. If we play the recovered sounds, we can confirm the low error. *Speech* is almost completely recovered while *Drill* has only a low amount of *Speech* mixed in.

4.3 No. of mixed signals

If we generate more mixed signals (m) than the input signals (n), we get a larger weight matrix (mxm), and we can expect reconstruction to be more accurate due to the larger no. of parameters involved. Figure 5.3 shows a plot of mean squared error as no. of mixed signals increases. We notice that there is a sharp decrease in error initially (upto ~5x), after which the error stays at the same level.

5. Results

Pair	Sum of squared Errors	Pair	Sum of squared Errors
{*Speech, Drill*}	195.8	{*Drill, Laughter*}	963.7
{*Speech, Applause*}	991.1	{*Drill, Noise*}	1018.6
{*Speech, Laughter*}	851.9	{*Applause, Laughter*}	287.8
{*Speech, Noise*}	1237.8	{*Applause, Noise*}	1348.8
{*Drill, Applause*}	696.8	{*Laughter, Noise*}	1368.0

Table 5.1: Sum of squared errors for various pairs, averaged over 10 runs.

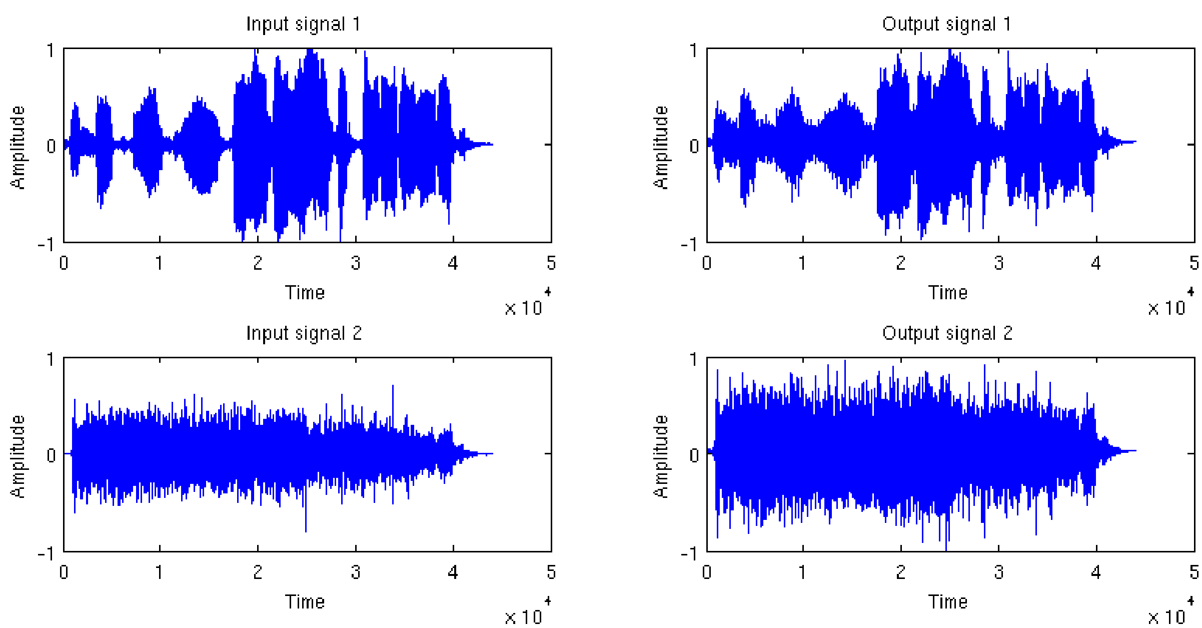

Figure 5.1 : Original and recovered signals for {*Speech, Drill*} pair.

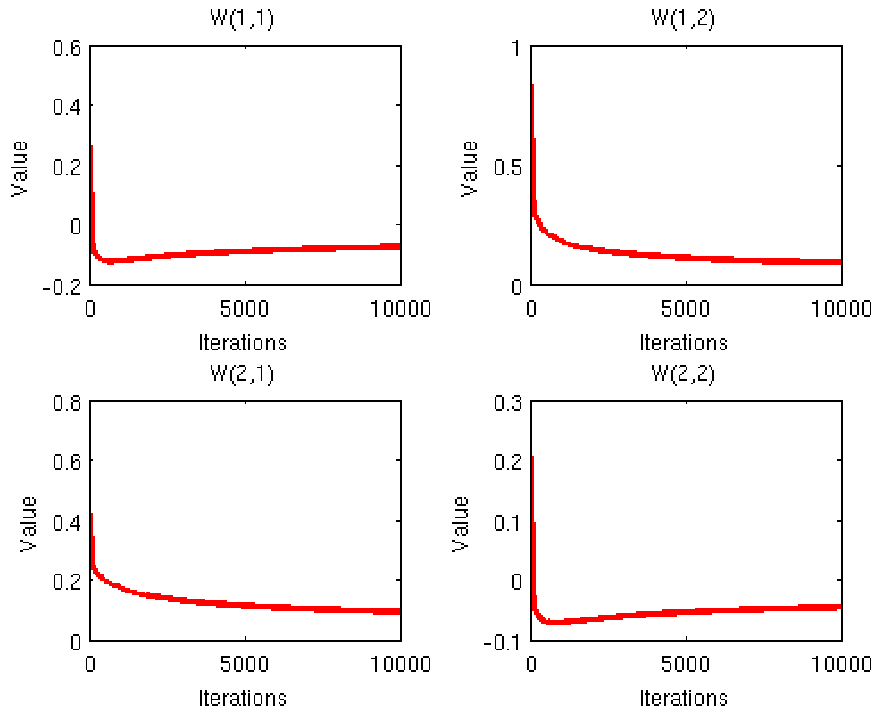

Figure 5.2 : Convergence on weights (W transposed) for 2 input and output signals.

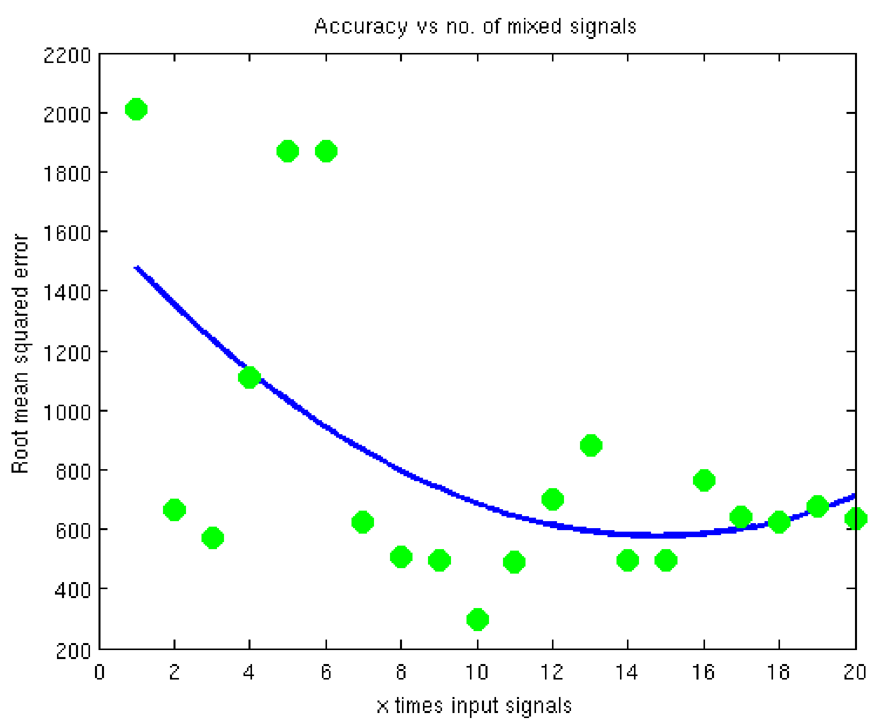

Figure 5.3 : Change in accuracy as no. of mixed signals increases as a multiple of input signals.

(Note: The incorrectly labeled error on the Y axis is actually the sum of squared errors)