

- (d) Compute the updates for the remaining weights. Using the new weights, calculate the output of the network for the provided training example. Did the error decrease?

## Handwritten Digit Recognition

5. (35 points)

In this programming exercise, you will use the [Netlab](#) toolkit (provided with the assignment) in MATLAB to create a neural network for recognizing handwritten digits from the popular [MNIST](#) dataset.

To get started,

- Download the dataset (four files total) from <http://yann.lecun.com/exdb/mnist/>.
- Extract the files to the directory of your choice.
- Open and be ready to edit the file named “**mynetlabnn.m**”
- Run the following line of code in **mynetlabnn.m**:

```
[training, testing] = setupMNIST();
```

You should now see two structures in the MATLAB workspace called `training` and `testing`, containing 60,000 and 10,000 sample images of handwritten digits, respectively. The 28x28 grayscale images have been vectorized such that each column vector in the data arrays corresponds to the pixel intensities for a single example. Some example images are shown below.



To build the neural network, you will need the following three functions from Netlab:

- `mlp`: creates the neural network structure
- `netopt`: trains the network
- `mlpfwd`: tests the network

Use the help command to learn more about these function calls. Use ‘logistic’ for the activation function in `mlp` and ‘scg’ (scaled conjugate gradient) for the algorithm input in `netopt`. Before calling `netopt`, you should insert the following lines of code in your script and then use the *options* vector as an input in `netopt`: