Project 2.

Option 2: Training a Neural Network

COS 314
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Experiment 1:
In this experiment I create a neural network with one output neuron with the purpose of classifying an input pattern in two classes. Namely the class that the user inputs, or a second class which is everything else.

For this experiment I initialize the neural network architecture and control variables to the following values.

- Output neuron amount: 1
  - The neural network only has to classify the training set in 2 classes
- Hidden neuron amount: 30
  - The best amount of hidden neurons determined by trial and error and interpolation as shown in the graphs below. Few hidden neurons are needed as only one letter has its own class, and all the other letters share a class. This is a relative simple mapping and can be mapped relatively accurate using as few as 10 hidden neurons.
- Learning rate: 0.2
  - The optimal learning rate determined by trial and error and interpolation as shown in the graphs below. A medium learning rate delivered better accuracies.
- Momentum: 0.2
  - The optimal momentum determined by trial and error and interpolation as shown in the graphs below.

Other parameters

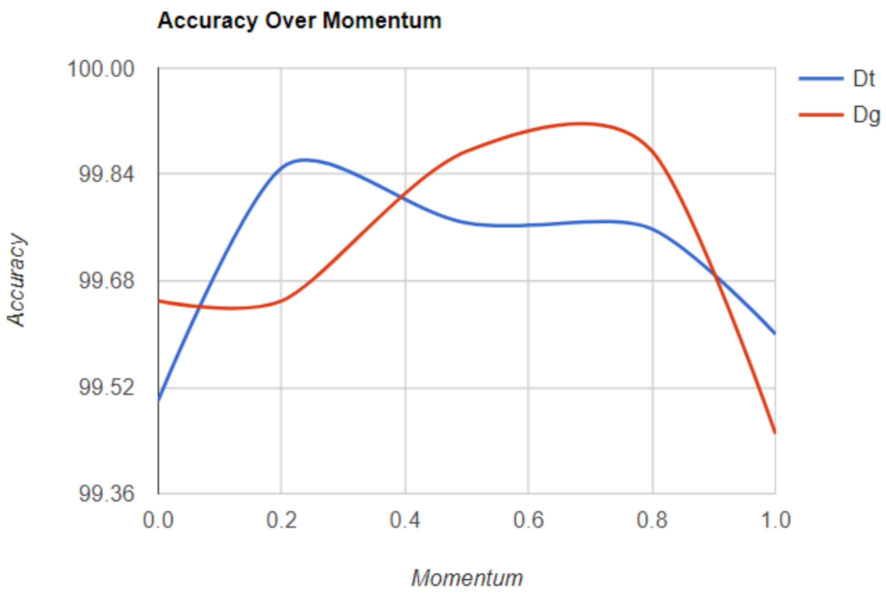
- Max epoch count: 1000
  - Extreme Overfitting occurs after 1000 epochs.
- Desired training accuracy: 99.5
  - A high accuracy with a high generalization ability.

Impact of the control variables on the training and generalization accuracy.

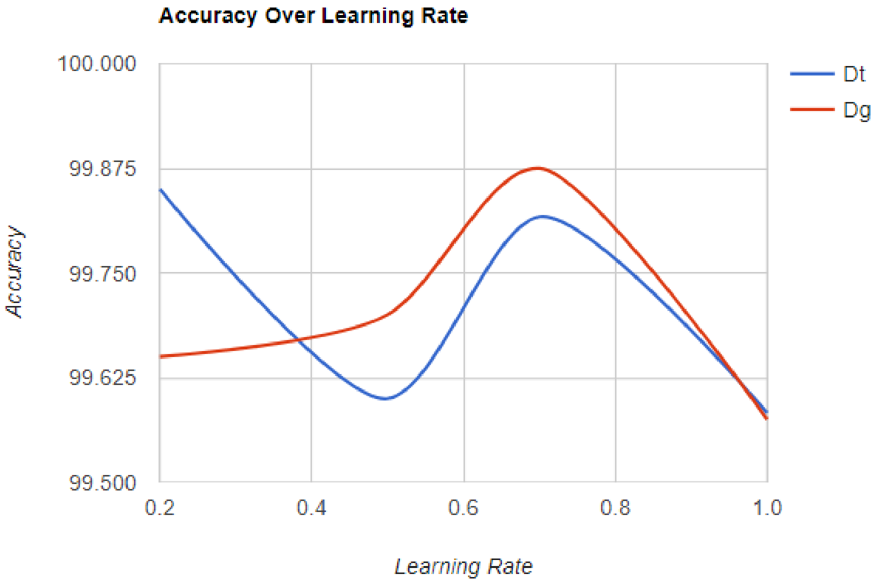
# Hidden Neurons	**Learning Rate**	**Momentum**	**Training Accuracy %**	**Generalization Accuracy %**
30	0.2	**1**	99.600	99.450
30	0.2	**0.8**	99.758	99.875
30	0.2	**0.5**	99.767	99.875
30	0.2	**0.2**	99.850	99.650
30	0.2	**0**	99.500	99.650
30	**0.5**	0.2	99.600	99.700
30	**0.7**	0.2	99.817	99.875
30	**1**	0.2	99.583	99.575
1	0.2	0.2	99.200	99.375
10	0.2	0.2	99.717	99.675
40	0.2	0.2	99.558	99.575
80	0.2	0.2	99.617	99.600
100	0.2	0.2	99.625	99.575

Accuracy vs the control variables as tested in the table:

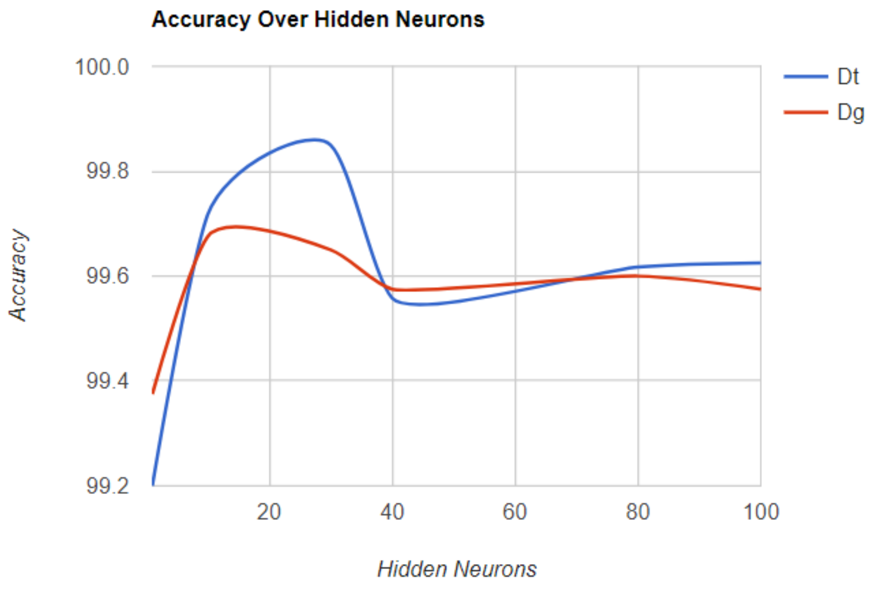
Momentum:



Learning Rate:

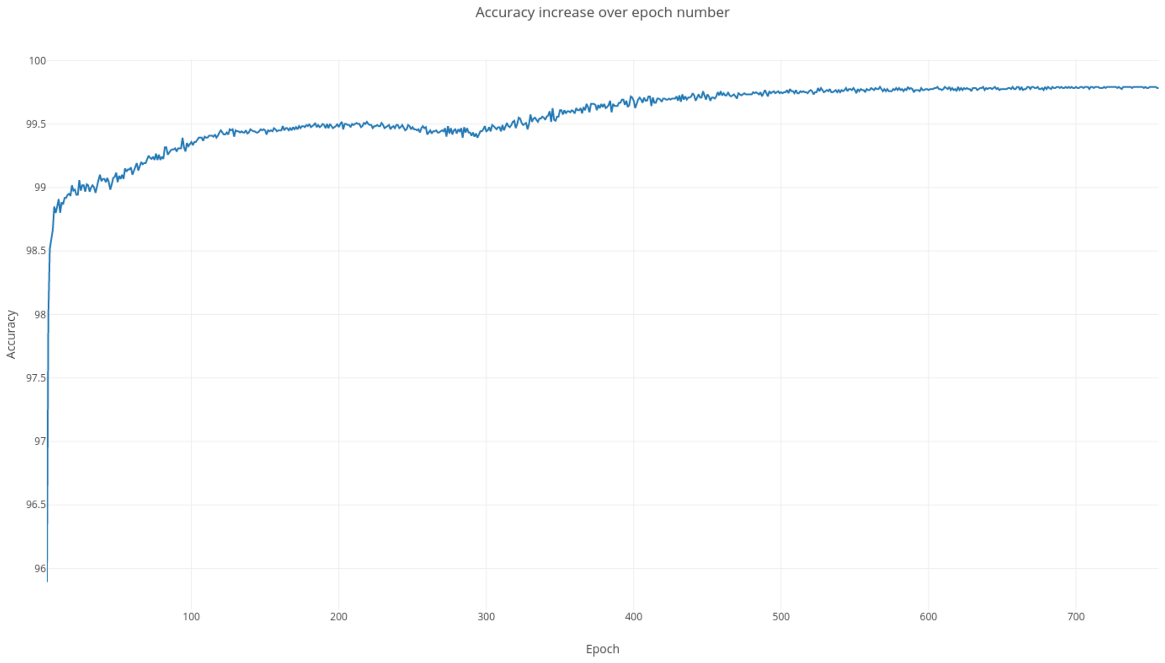


Hidden Neurons:



Learning Profile:

The learning profile of the neural network using the control variables as mentioned above:



Experiment 2
In this experiment I created a neural network again with one output neuron to classify the training set into two classes: vowels and non-vowels. A one as output means the class of the input pattern is a vowel, a zero classifies the pattern as non-vowel.

For this experiment I initialize the neural network architecture and control variables to the following values.

- Output neuron amount: 1
    - The neural network only has to classify the training set into 2 classes
- Hidden neuron amount: 50
    - The best amount of hidden neurons determined by trial and error and interpolation as shown in the graphs below. A higher amount of hidden neurons are needed to correctly map all vowels to one class. Lower hidden neuron counts can be used, but will result in lower generalization accuracies.
- Learning rate: 0.5
    - The optimal learning rate determined by trial and error and interpolation as shown in the graphs below. A high learning rate delivered higher final accuracies and faster training speeds with the increased amount of hidden neurons.
- Momentum: 0.2
    - The optimal momentum determined by trial and error and interpolation as shown in the graphs below. A medium momentum delivered the best accuracies on average.

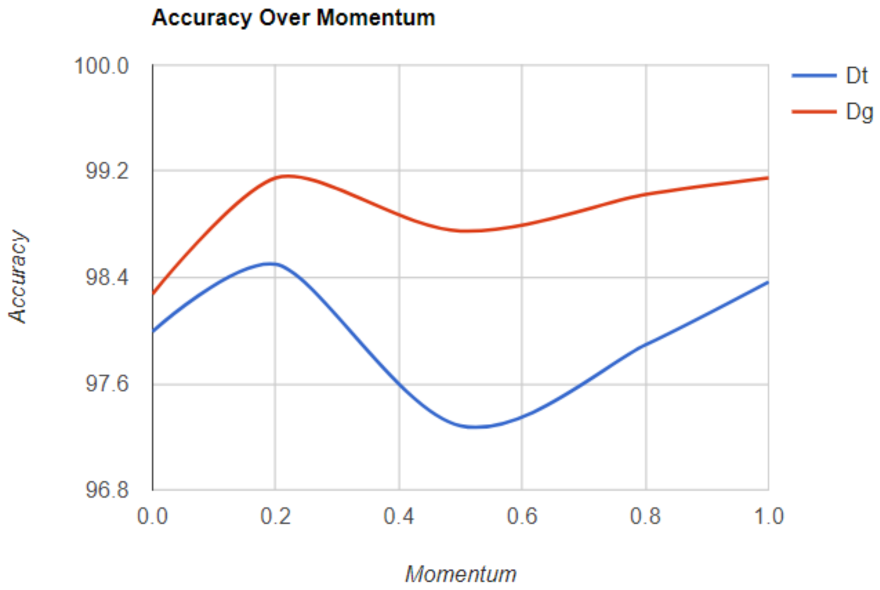
Other parameters

- Max epoch count: 1000
    - Overfitting occurs after 1000 epochs.
- Desired training accuracy: 98
    - A high accuracy with a high generalization ability.

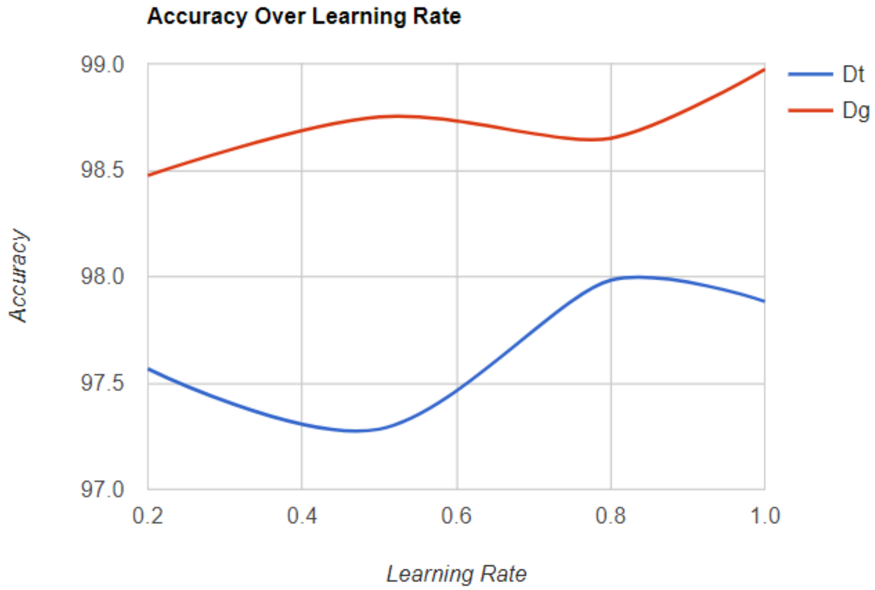
Impact of the control variables on the training and generalization accuracy.

# Hidden Neurons	Learning Rate	Momentum	Training Accuracy %	Generalization Accuracy %
50	0.5	**1**	98.367	99.150
50	0.5	**0.8**	97.892	99.025
50	0.5	**0.5**	97.283	98.750
50	0.5	**0.2**	98.500	99.150
50	0.5	**0**	97.992	98.275
50	**0.2**	0.2	97.567	98.475
50	**0.8**	0.2	97.983	98.650
50	**1**	0.2	97.883	98.975
100	0.5	0.2	97.733	99.075
70	0.5	0.2	97.925	98.700
30	0.5	0.2	96.967	98.875
10	0.5	0.2	94.850	96.400
1	0.5	0.2	64.550	63.750

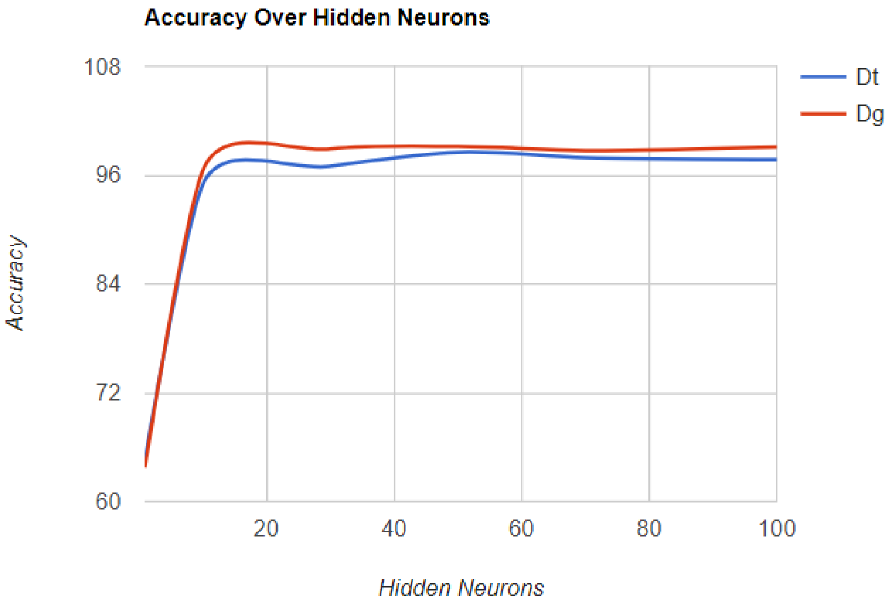
Accuracy vs the control variables as tested in the table:
Momentum:



Learning Rate:

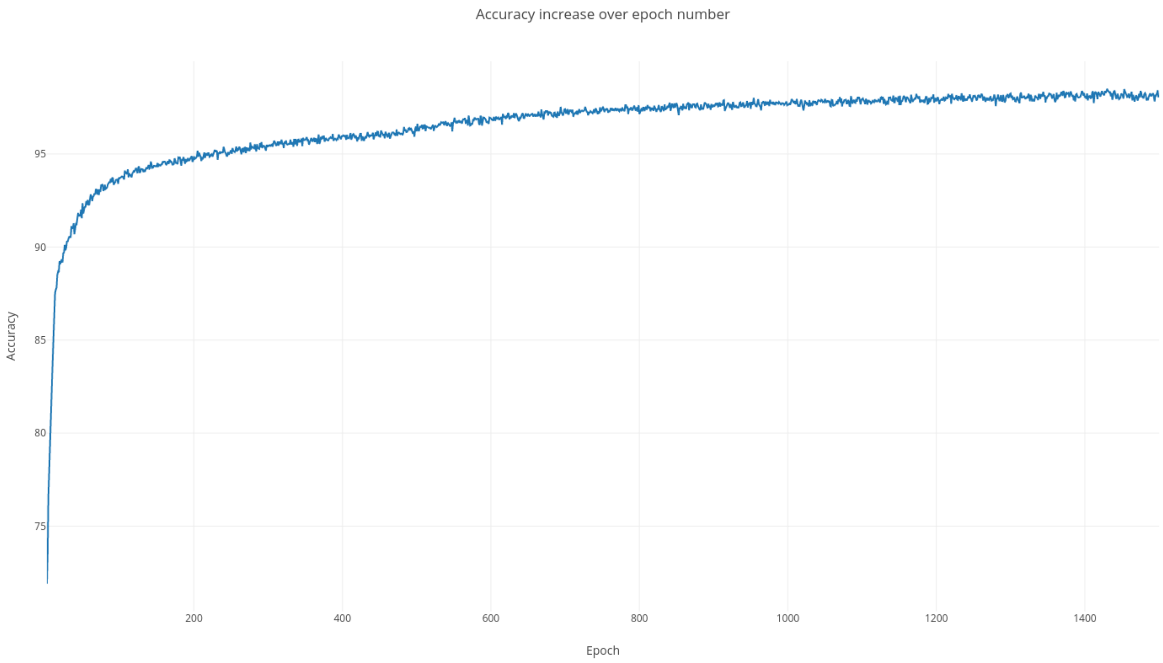


Hidden Neurons:



Learning Profile:

The learning profile of the neural network using the control variables as mentioned above:



Experiment 3
In this experiment I create a neural network with 26 output neurons. One output for each letter in the alphabet. The neural network is trained to recognize each letter of the alphabet and classify them in one of the 26 classes.

For this experiment I initialize the neural network architecture and control variables to the following values.

- Output neuron amount: 26
  - The neural network only has to classify the training set into 26 classes. One class for each letter in the English alphabet.
- Hidden neuron amount: 100
  - The best amount of hidden neurons determined by trial and error and interpolation as shown in the graphs below. A high amount of hidden neurons are needed to correctly map all letters of the alphabet to a separate class. Lower hidden neuron counts can be used, but will result in lower generalization accuracies.
- Learning rate: 0.5
  - The optimal learning rate determined by trial and error and interpolation as shown in the graphs below. A high learning rate delivered higher final accuracies and faster training speeds with the increased amount of hidden neurons.
- Momentum: 0.2
  - The optimal momentum determined by trial and error and interpolation as shown in the graphs below. A medium momentum delivered the best accuracies on average.

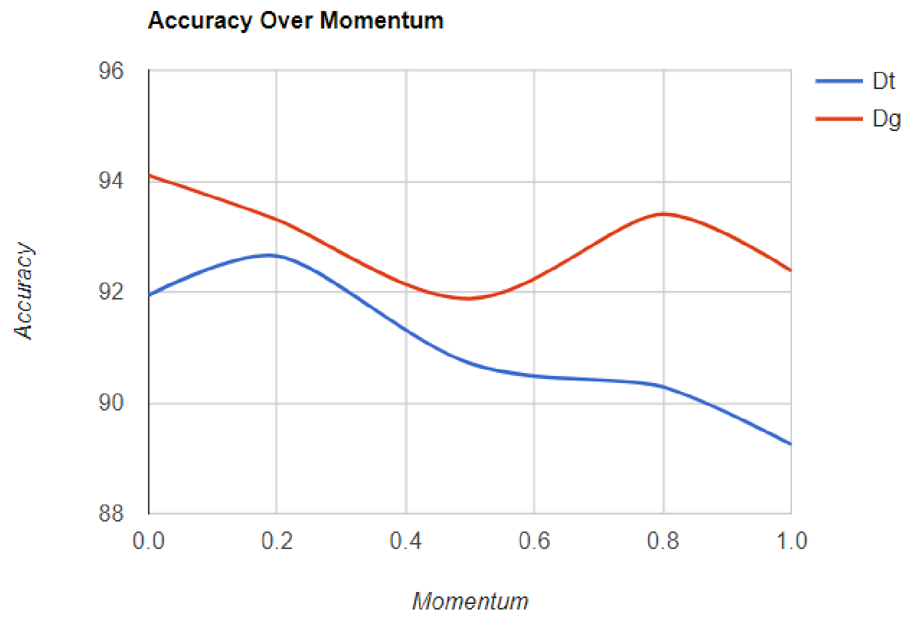
Other parameters

- Max epoch count: 400
  - Overfitting occurs after 400 epochs.
- Desired training accuracy: 90
  - A high accuracy with a high generalization ability.

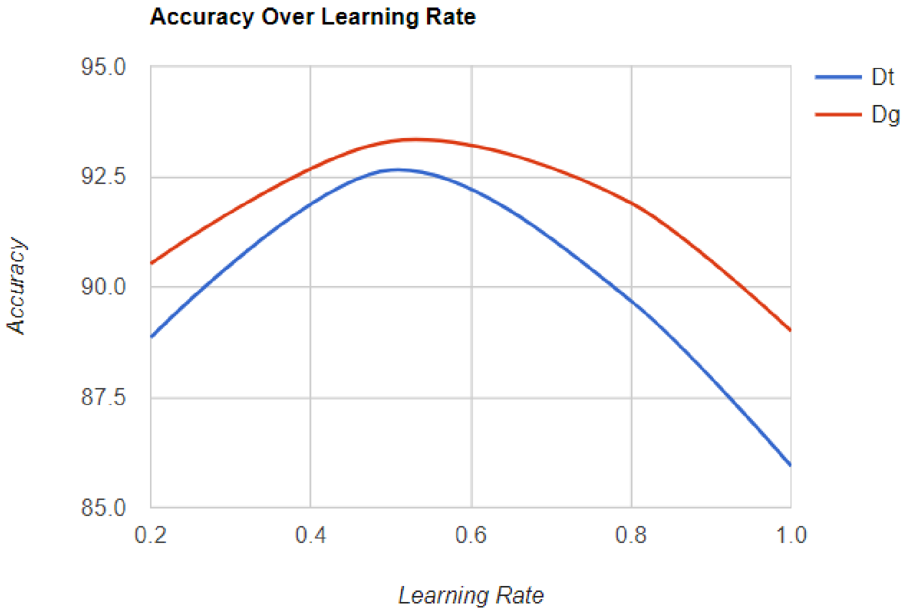
Impact of the control variables on the training and generalization accuracy.

# Hidden Neurons	**Learning Rate**	**Momentum**	**Training Accuracy %**	**Generalization Accuracy %**
100	0.5	**1**	89.242	92.375
100	0.5	**0.8**	90.283	93.400
100	0.5	**0.5**	90.708	91.875
100	0.5	**0.2**	92.650	93.300
100	0.5	**0**	91.933	94.100
100	**0.2**	0.2	88.850	90.525
100	**0.8**	0.2	89.683	91.900
100	**1**	0.2	85.942	89.000
200	0.5	0.2	92.483	97.225
50	0.5	0.2	84.392	90.225
10	0.5	0.2	62.333	65.550
1	0.5	0.2	0.875	0.475

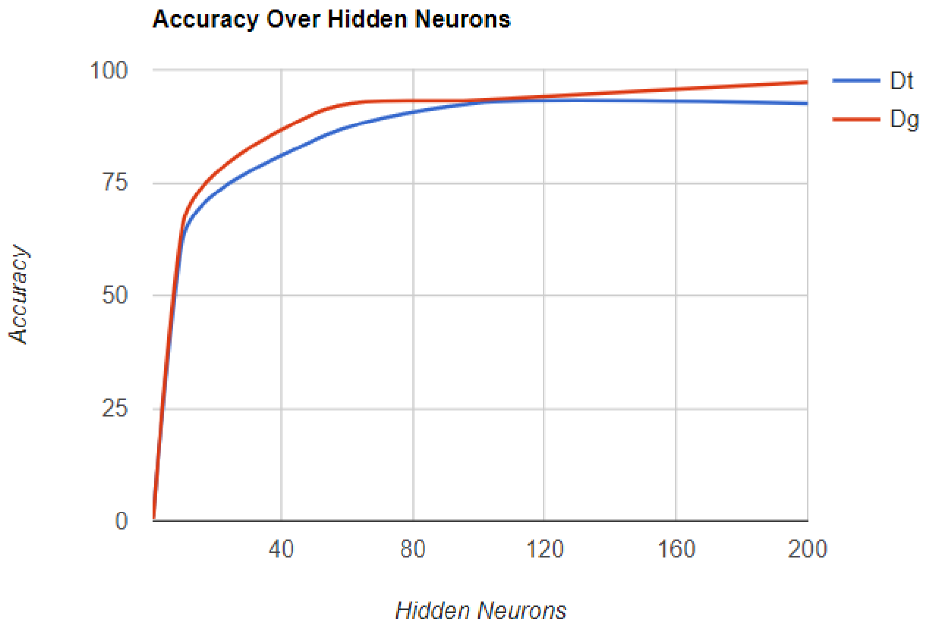
Accuracy vs the control variables as tested in the table:
Momentum:



Learning Rate:

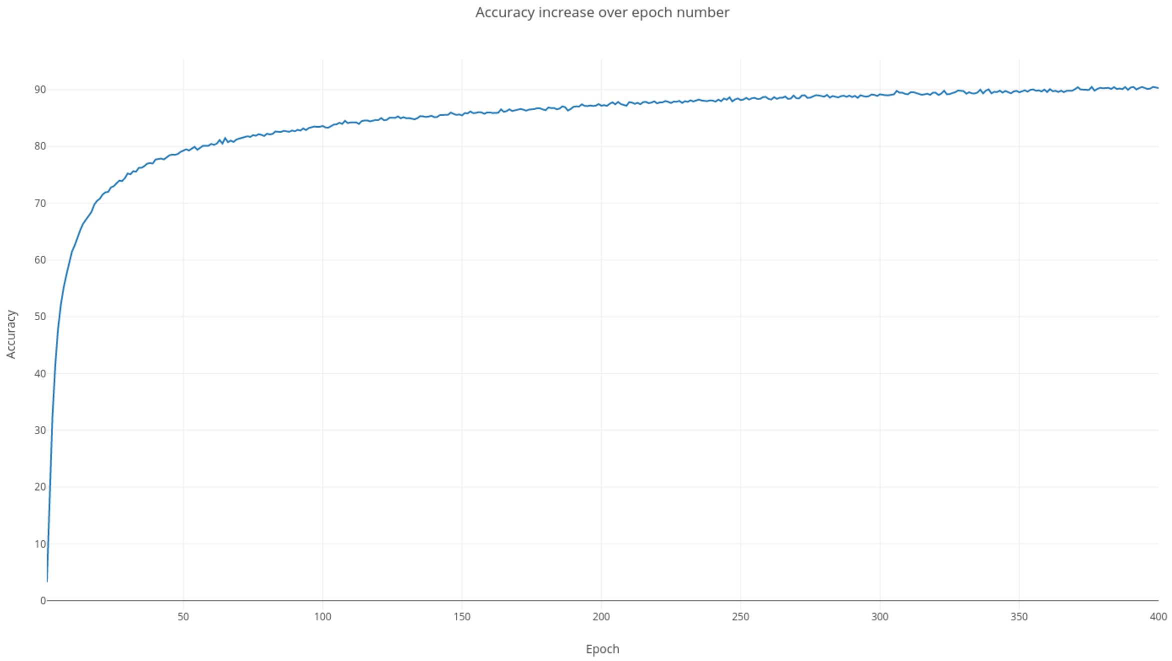


Hidden Neurons:



Learning Profile:

The learning profile of the neural network using the control variables as mentioned above:



Instructions:

To run the project.
Use the provided make file with the following commands:

make experiment1 to build and run Experiment 1
make experiment2 to build and run Experiment 2
make experiment3 to build and run Experiment 3

Each command will run an experiment with the default data file as dataset as given in the specs file.

The control parameters for the neural network are set in the Experiment concrete classes (Experiment1.java, Experiment2.java and Experiment3.java)

An explanation of each parameter is given in these files, so it can be updated.

Output for the experiments are stored in output.txt in the root directory.

The following source files are included:
Experiment.java: the abstract Experiment class that implements basic experiment functionality.
Experiment1.java: concrete Experiment class. Implements experiment 1's neural network and functionality.
Experiment2.java: concrete Experiment class. Implements experiment 2's neural network and functionality.
Experiment3.java: concrete Experiment class. Implements experiment 3's neural network and functionality.
Utils.java: Utility functions to read the data file and normalize the input training set vectors.
NeuralNetwork.java: The neural network class containing all the network matrices and matrix operations.
InputVector.java: The input vector class with the target array, input array and classification character.