>>> Implementation Hand Written Digit Recognition with Neural Network
>>> in MATLAB

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>>> This presentation contains:

1. Intro
2. Creating Data
3. Neural Network
4. Learning
5. Results

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3. $[ax,\ ay]$: accelarations in x and y directions
4. nt: the time line

>>> getUserTraj.m interface

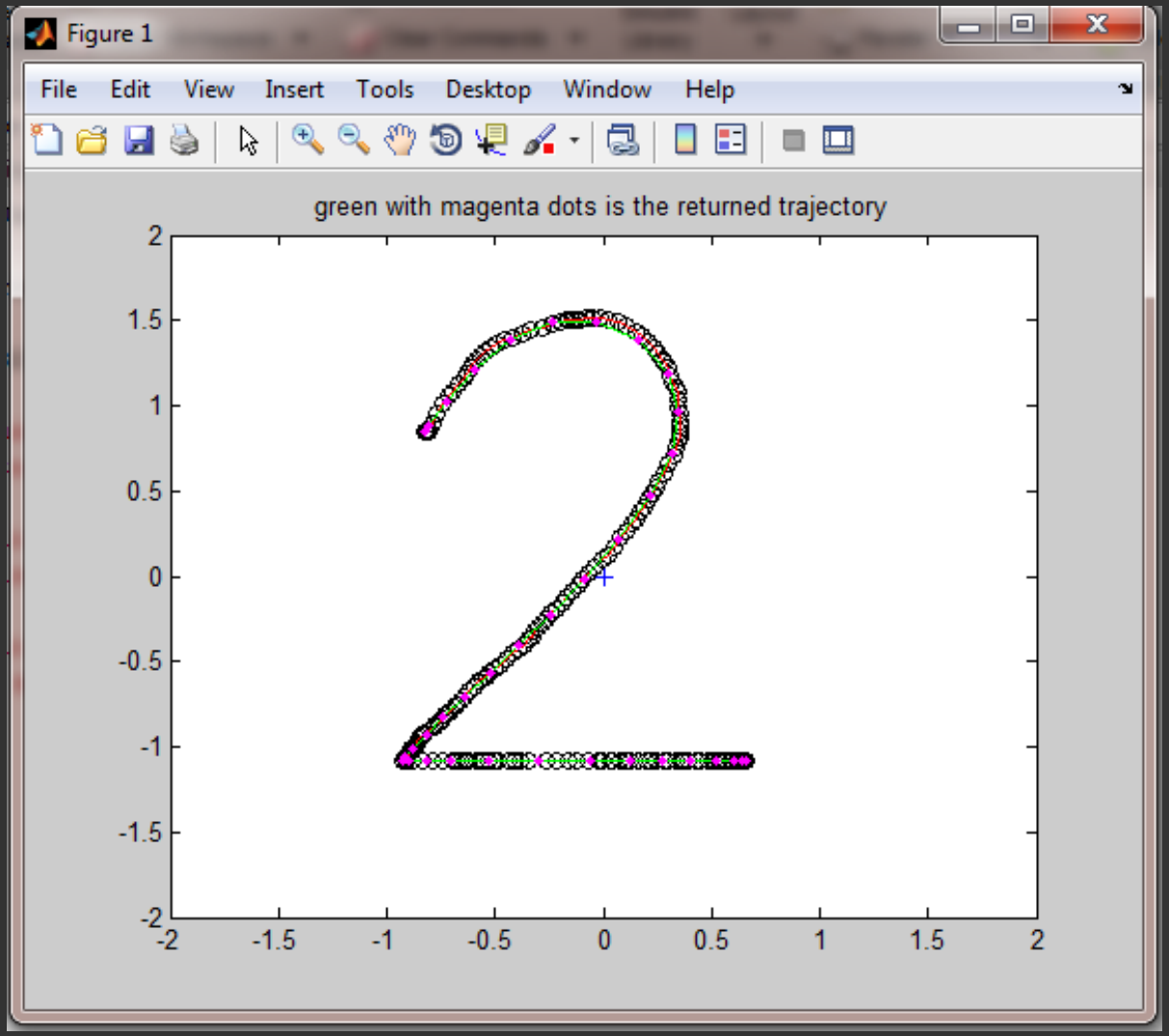


Figure: HR digit which is taken as an input to the data generator - number "2"

>>> Creating Data

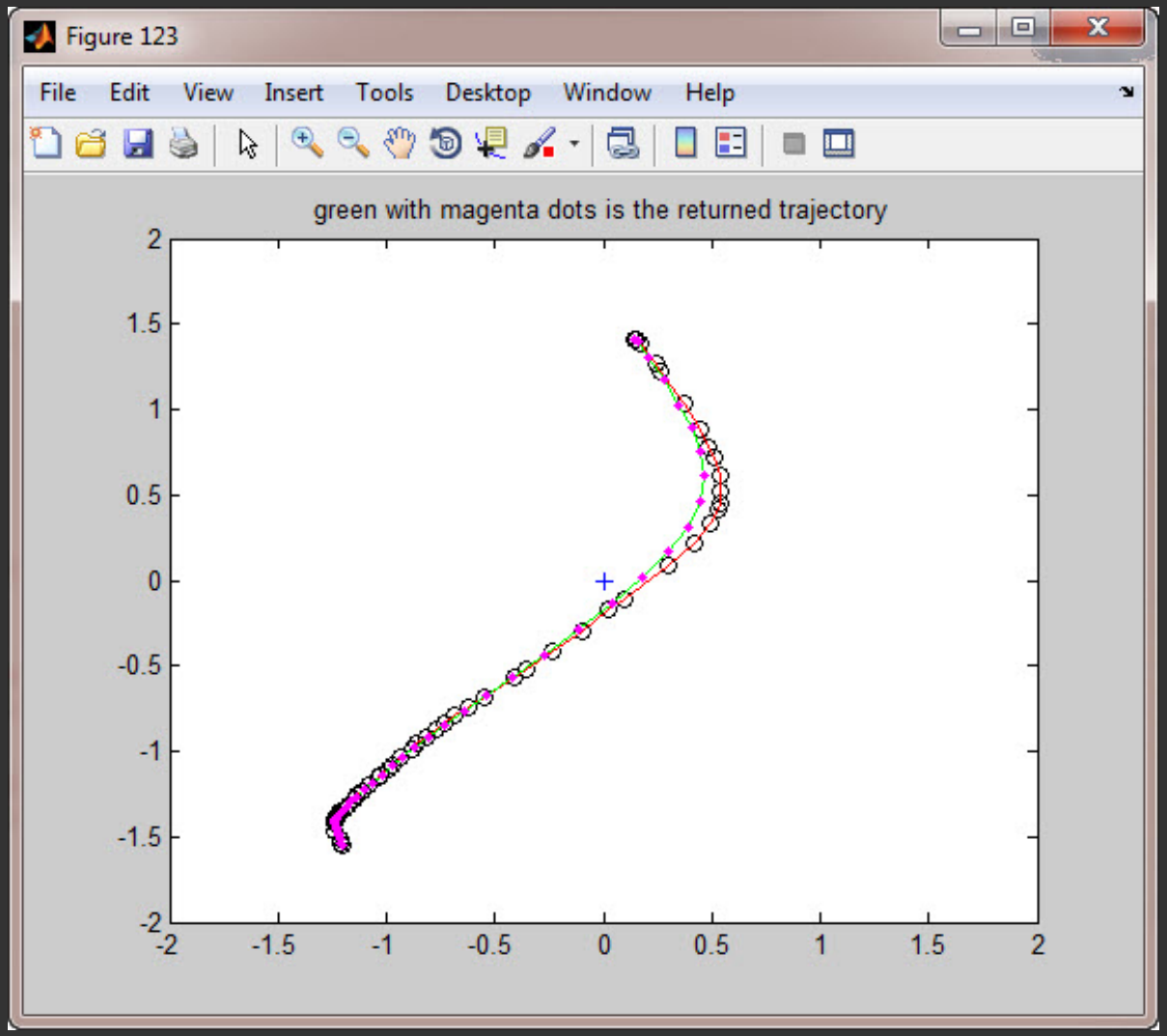
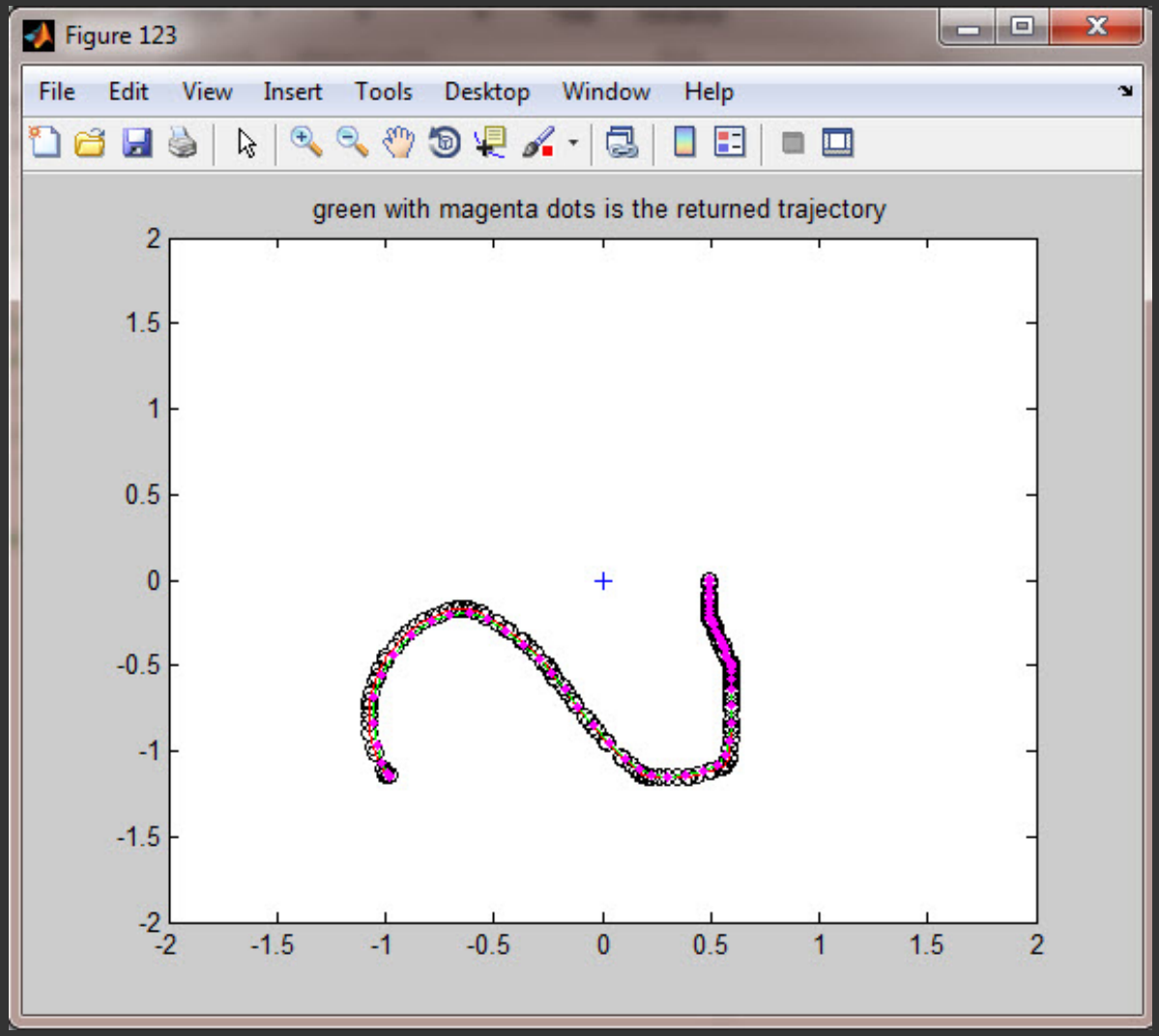


Figure: HR digit which is taken as an input to the data generator - number "7"



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>>> Data Structure

* I stored data as $n \times 201$ matrix, where n is nymber of all data
* First 200 columns are $[x\ y]$ coordinates (output of the getUserTraj.m)
* column 201 is target

>>> Neural Network

* I used three layer Neural Network (provided in LMS)
* 50 hidden layers is used
* with one softmax layer in estimating final solution

$$z_i = \frac{\exp O_i}{\sum_i \exp O_i}$$

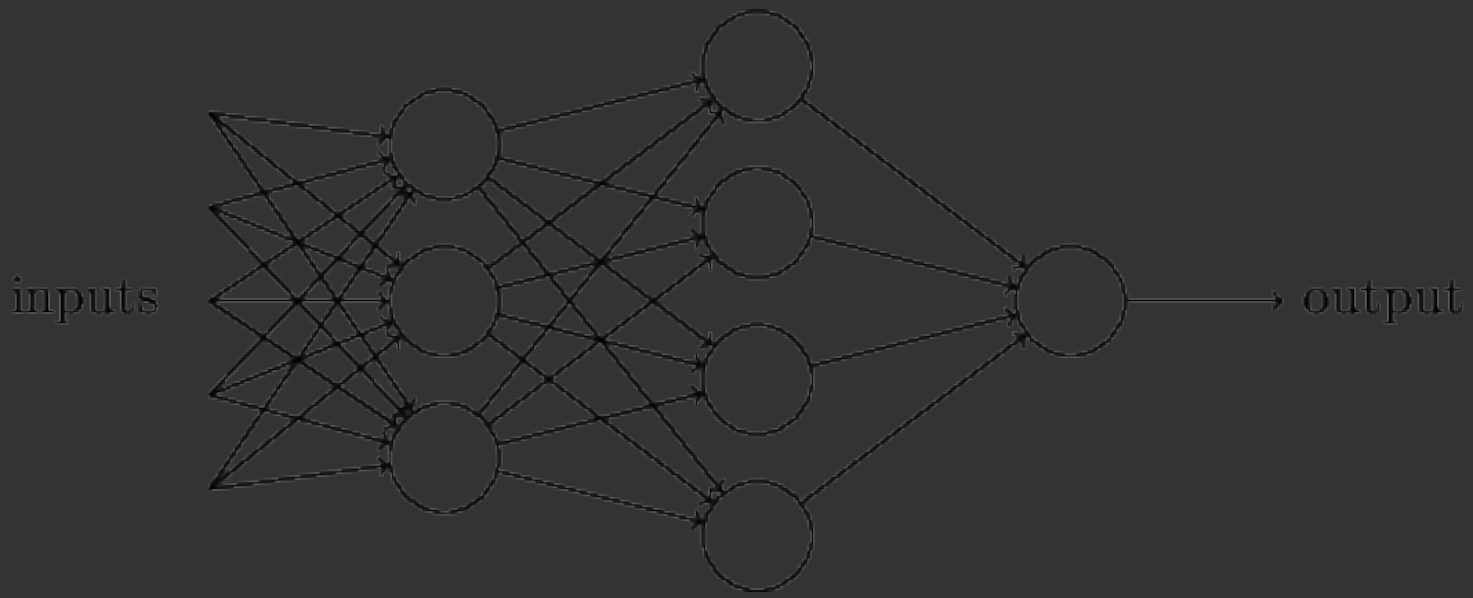

Figure: Structure of the Neural Network

Activation functions: Sigmoid, x-Sigmoid and Leaky RELU

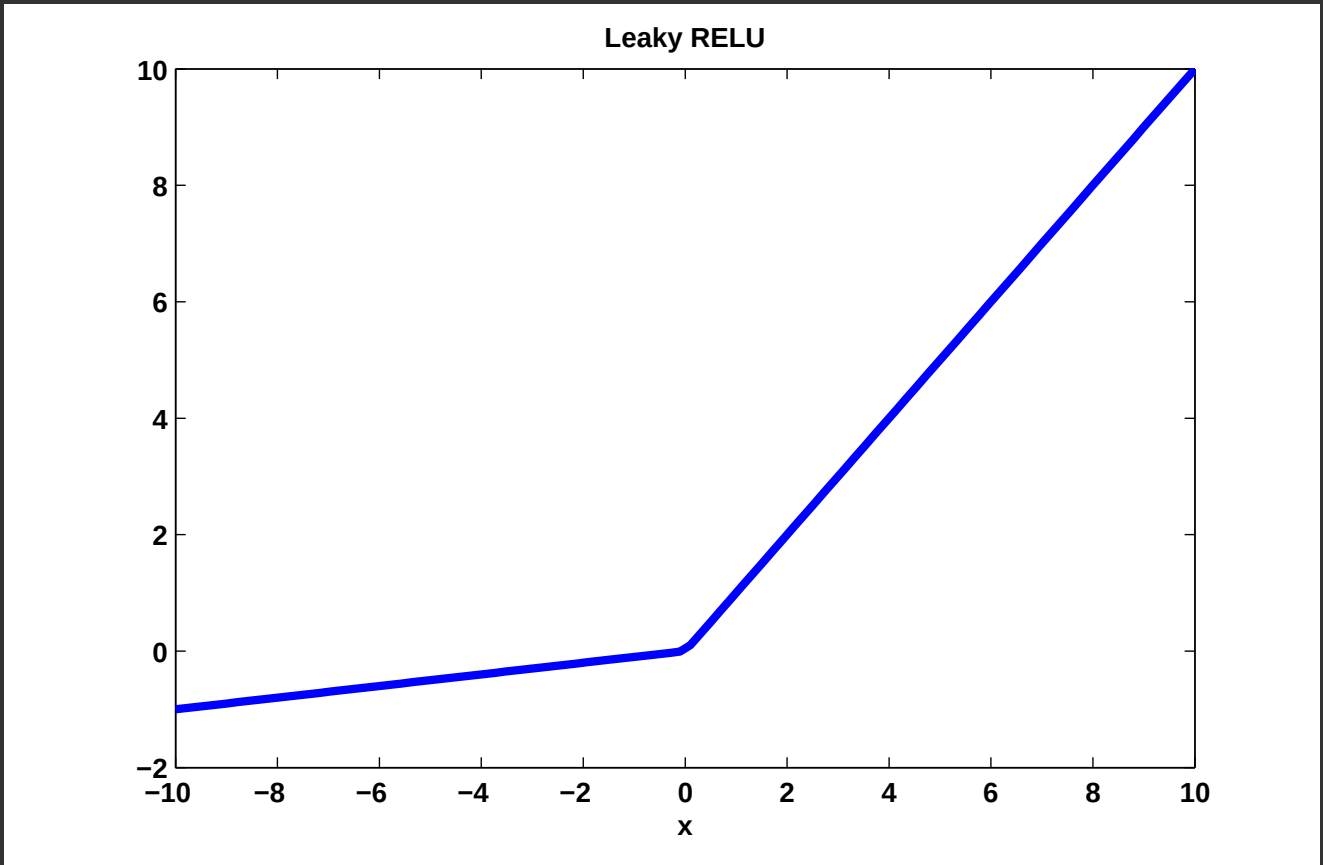

Figure: Structure of Leaky RELU

>>> Hyperparameters

* Size of data: 2000
* Maximum iteration: 1500000
* Learning rate: $\eta = 0.002$
* Noise coefficient: $\beta = 1e - 10$
* Guide vector (Accelerated Gradient) $\mu = 0.001$
* batch size: 20

>>> Preprocessing; Rotation and Scalling

* I prepared data carefully so there is no need to preprocessing to remove dummy data
* for rotation I provided rotated data and let the network to learn it
* for rotation I rotated data randomly using rotation function
* for scaling I normalized the data with mean 0.5 and Variance 0.5 (as best option)

```
function r_data = rotation(Data, rtheta)
```
$\text{Data}_x = Data(:, 1:100);$
$\text{Data}_y = Data(:, 101:200);$
```
sinus = sin(rtheta*pi/180);
cosinus = cos(rtheta*pi/180);
r_data
```
$= [\text{Data}_x * cosinus + Data_y * sinus - Data_x * sinus + Data_y * cosinus; ...$
$\text{Data}_x * cosinus + Data_y * sinus - Data_x * sinus + Data_y * cosinus];$

>>> Scalling

```
function [SData, mean_X, std_X] = standardize(varargin)switchnargin
case 1
mean_X = mean(varargin1);
std_X = std(varargin1);
SData = varargin1 - repmat(mean_X, [size(varargin1, 1)1]);
for i = 1:size(SData, 2)
SData(:, i) = SData(:, i) / std(SData(:, i));
end
case 3
mean_X = varargin2;
std_X = varargin3;
SData = varargin1 - repmat(mean_X, [size(varargin1, 1)1]);
for i = 1:size(SData, 2)
SData(:, i) = SData(:, i) / std_X(:, i);
end
end
```

* MSE cost function
* Accelerated gradient decent
* Stochastic gradient method is applied, each time the batch is trained which increased the accuracy
* Batch samples are secting randomly; MATLAB randi() function

if it==1
vect$_p$1 $= -eta * dW$;
end;
vect1 = mu*vect$_p$1 $- eta * dW$;
W = W - mu * vect$_p$1 $+ (1 + mu) * vect1$;
vect$_p$1 $= vect1$;

>>> Results On Provided Data

As number of data were too small, Network learns, but not good performance in recognizing HR digits

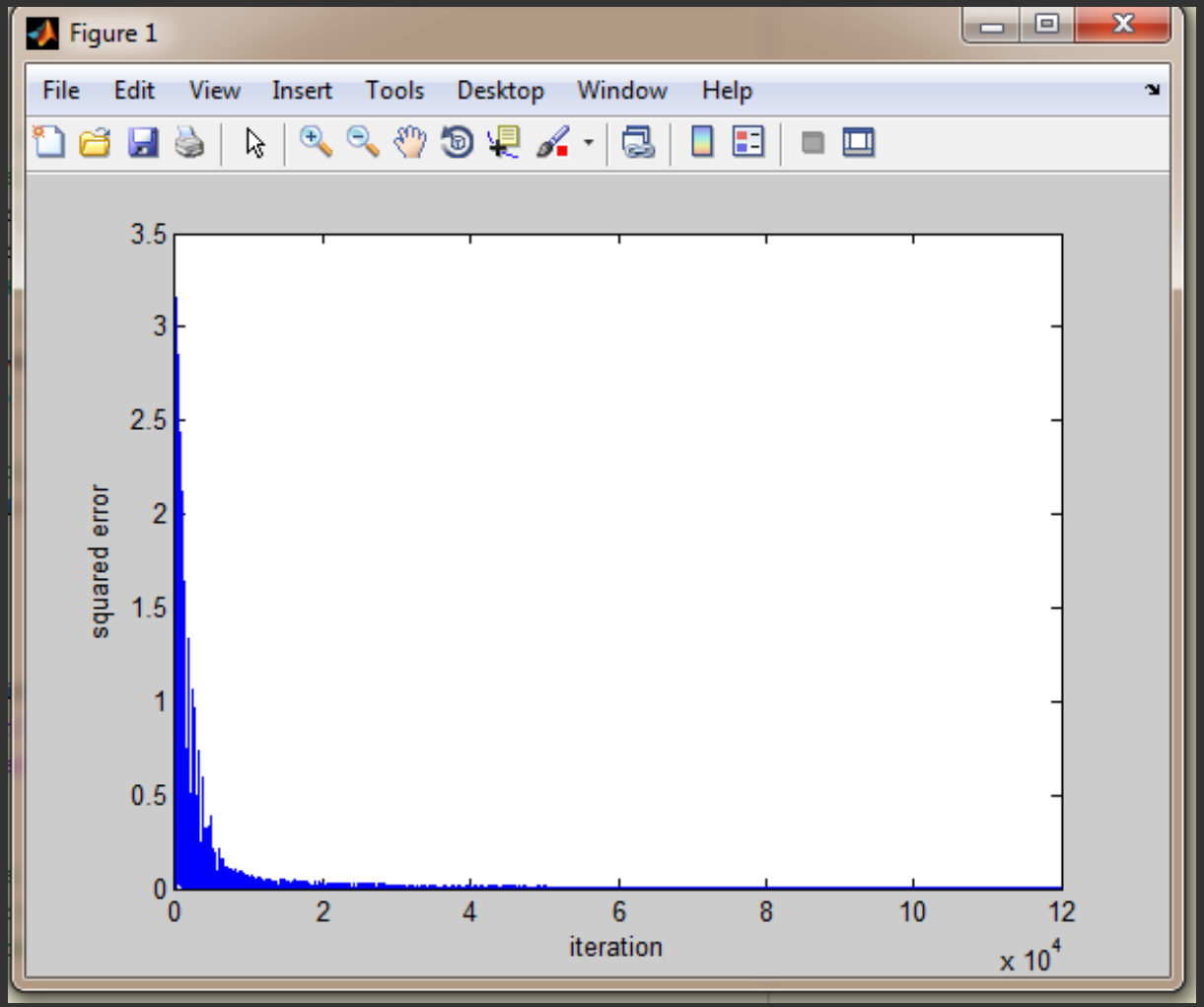

Figure: Results of this network over provided data

>>> Results On Large Data

Number of data large

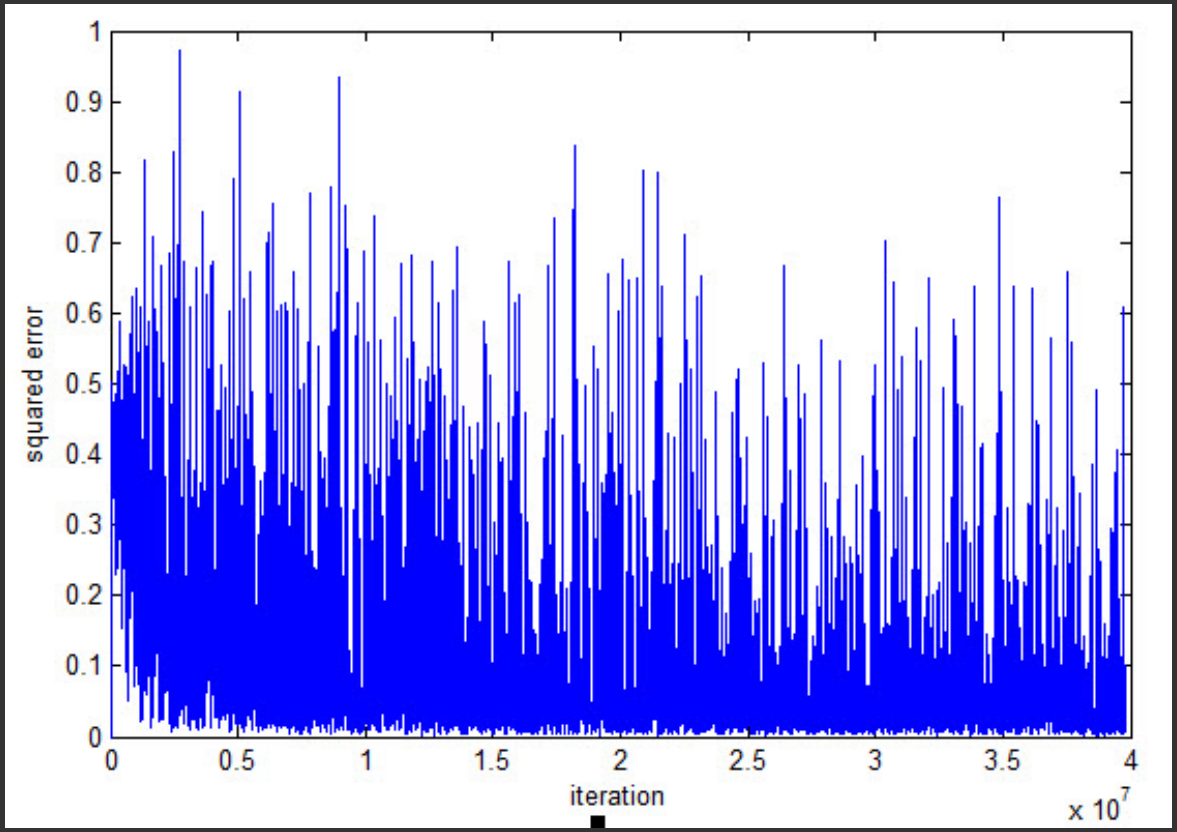

Figure: Results of this network over large data

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Testing results

Command Window

```
trajduration =

    2.8019

Network digit estimation is 0
:Enter true y: 6

y_true =

     6


trajduration =

    1.9334

Network digit estimation is 6
:Enter true y: 3

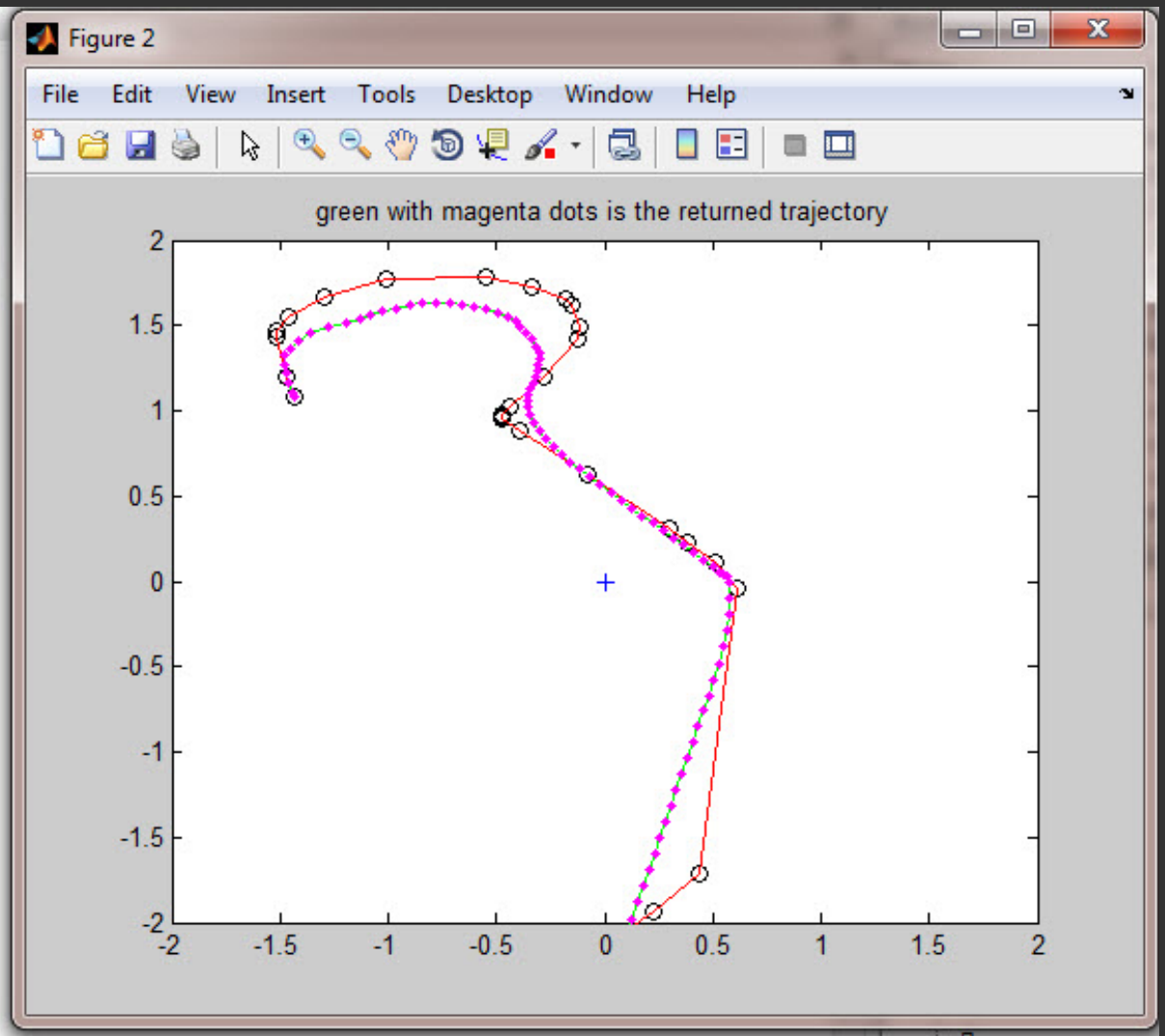
y_true =

     3


trajduration =

    1.8483

Network digit estimation is 3
:Enter true y:
```



>>> Results On Large Data

Testing results- digit 6 with rotation

Command Window

```
trajduration =

    2.4804

Network digit estimation is 3
:Enter true y: 6

y_true =

     6


trajduration =

    2.8019

Network digit estimation is 0
:Enter true y: 6

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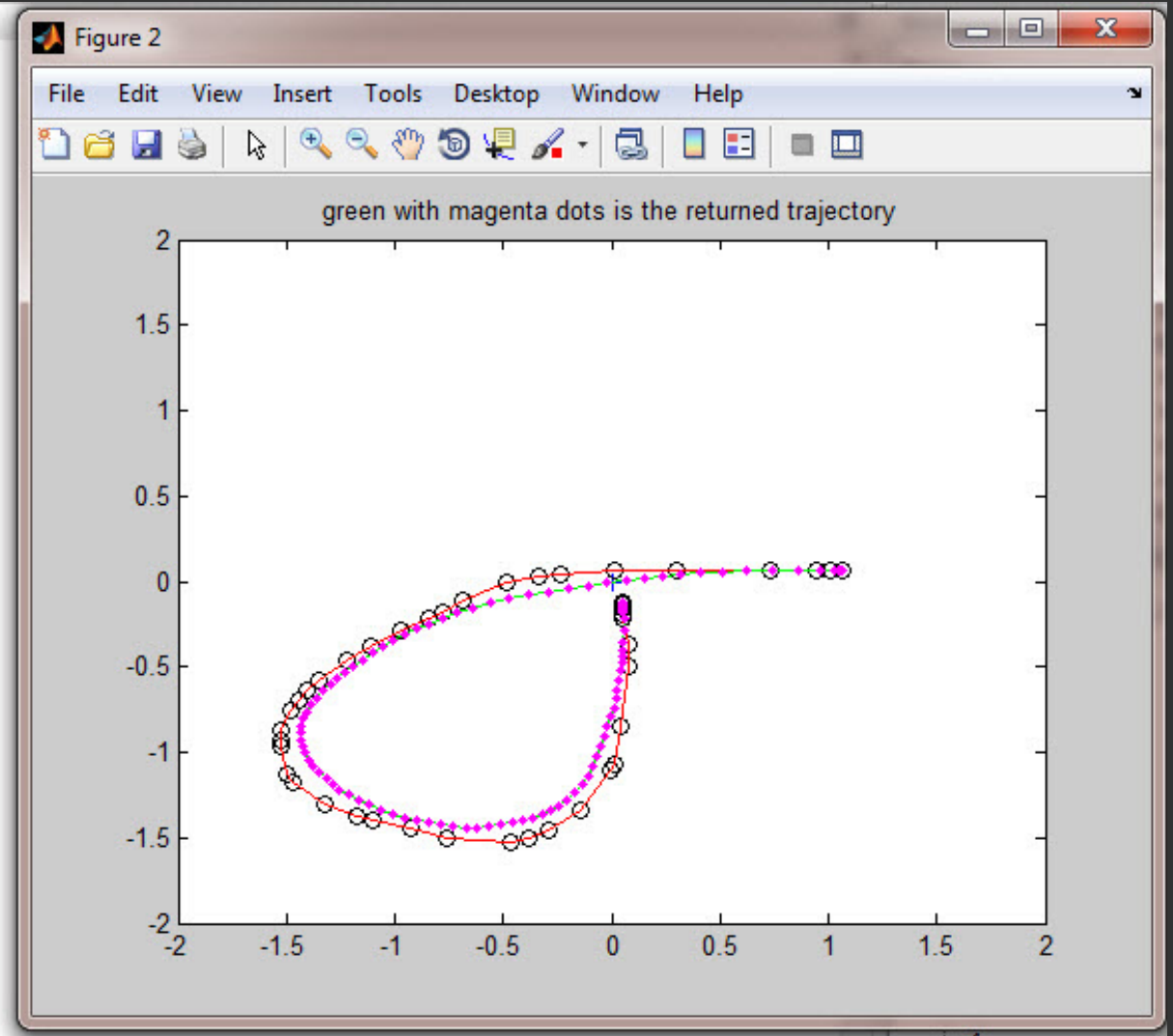

>>> Future Improvements

* Accuracy percentage is depend on the provided data, but in uniform random case it returns accuracy close to 90%
* Increasing data
* improving convergence
* setting proper hyperparameters
* Applying SVM
* Cross Validation technique

>>> Questions?

Thank you