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# TRABALHO PRÁTICO

## - Sistemas Nebulosos

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Vítor Gabriel Reis Caitité - 2016111849

## QUESTÃO 1: Modelagem de sistema estático monovariável

Aproximar a função  $y=x^2$

%

---

```
close all; clear; clc;

% Geração de dados
N = 1000;
X = (linspace(-2, 2, N)).';
y = (X.^2);

idx = randperm(length(y));
X_train = X(sort(idx(1:900)));
y_train = y(sort(idx(1:900)));
X_test = X(sort(idx(901:1000)));
y_test = y(sort(idx(901:1000)));
```

### Generate FIS Using Grid Partitioning

```
options = genfisOptions('GridPartition');
options.NumMembershipFunctions = 2;
in_fis = genfis(X_train,y_train,options);

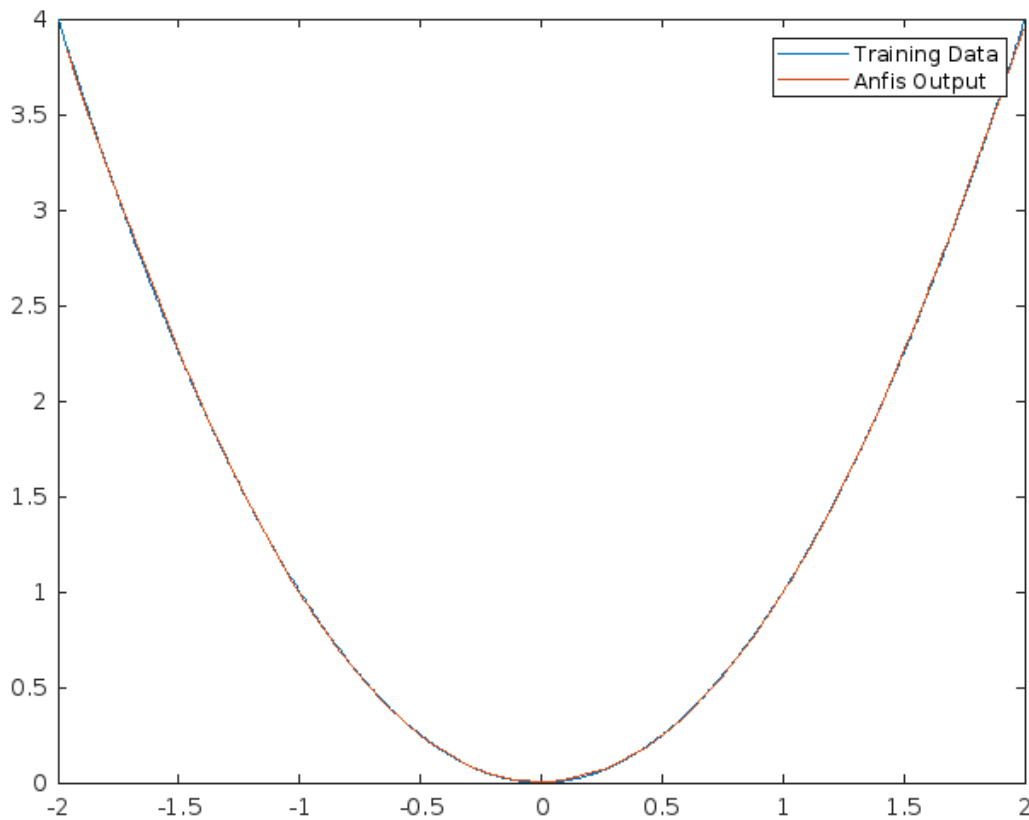
options = anfisOptions;
options.InitialFIS = in_fis;
options.EpochNumber = 100;
options.DisplayStepSize = 0;
options.DisplayErrorValues = 0;
```

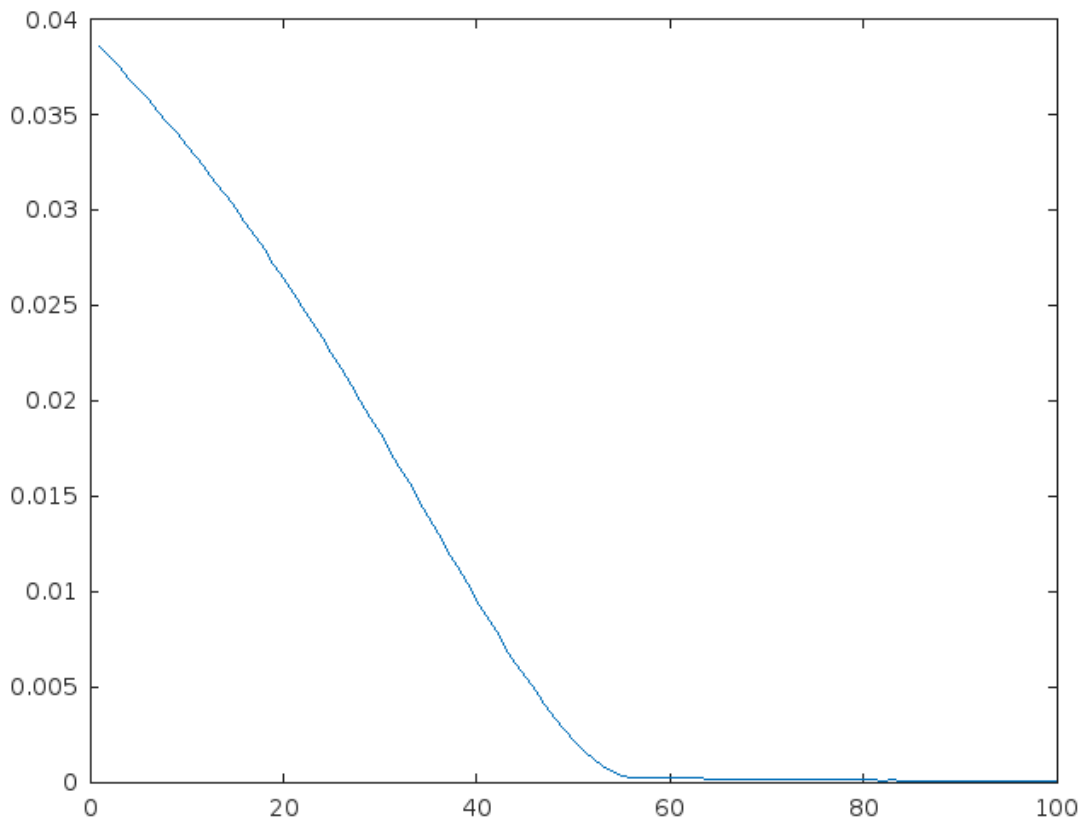
```
[out_fis,ERROR] = anfis([X_train y_train],options);  
ys=evalfis(out_fis, X_test);  
figure(1)  
plot(X_train, y_train, X_test, ys)  
legend('Training Data','Anfis Output');  
drawnow();  
figure(2)  
plot(ERROR.^2)  
fprintf('MSE: %.2E', immse(ys,y_test));  
drawnow();
```

*ANFIS info:*

*Number of nodes: 12  
Number of linear parameters: 4  
Number of nonlinear parameters: 6  
Total number of parameters: 10  
Number of training data pairs: 900  
Number of checking data pairs: 0  
Number of fuzzy rules: 2*

*Minimal training RMSE = 0.00771647  
MSE: 6.70E-05*





## Generate FIS Using Subtractive Clustering

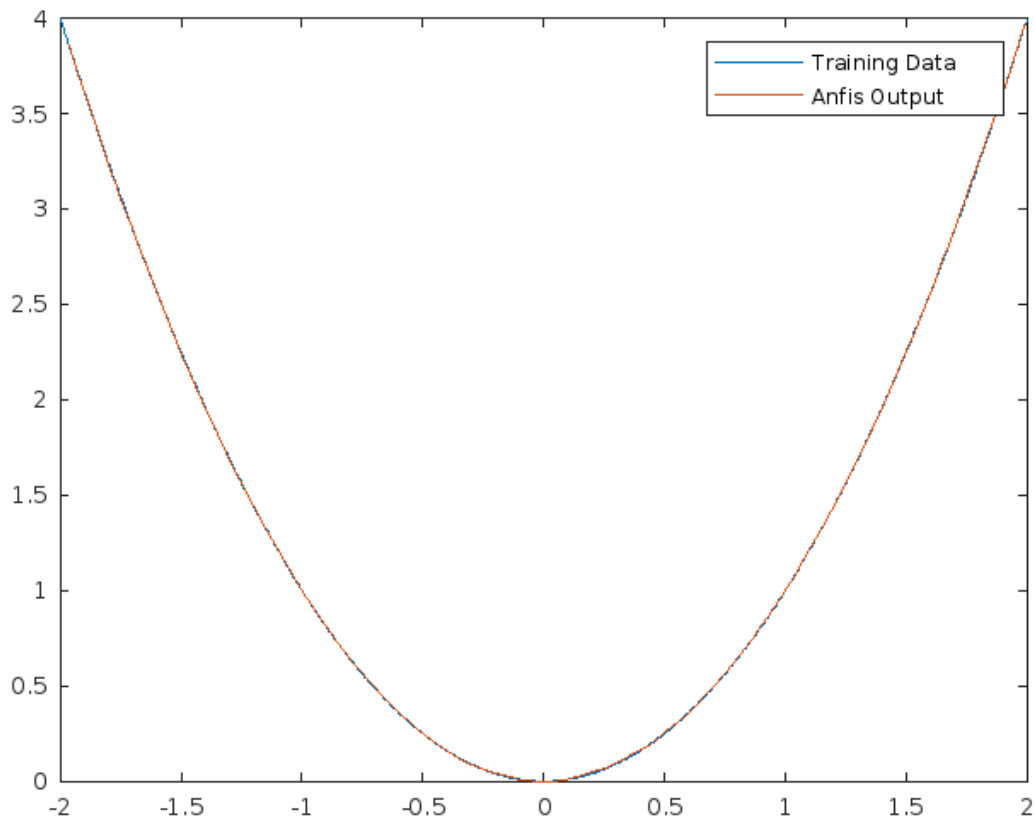
```
options = genfisOptions('SubtractiveClustering');
in_fis = genfis(X_train,y_train,options);

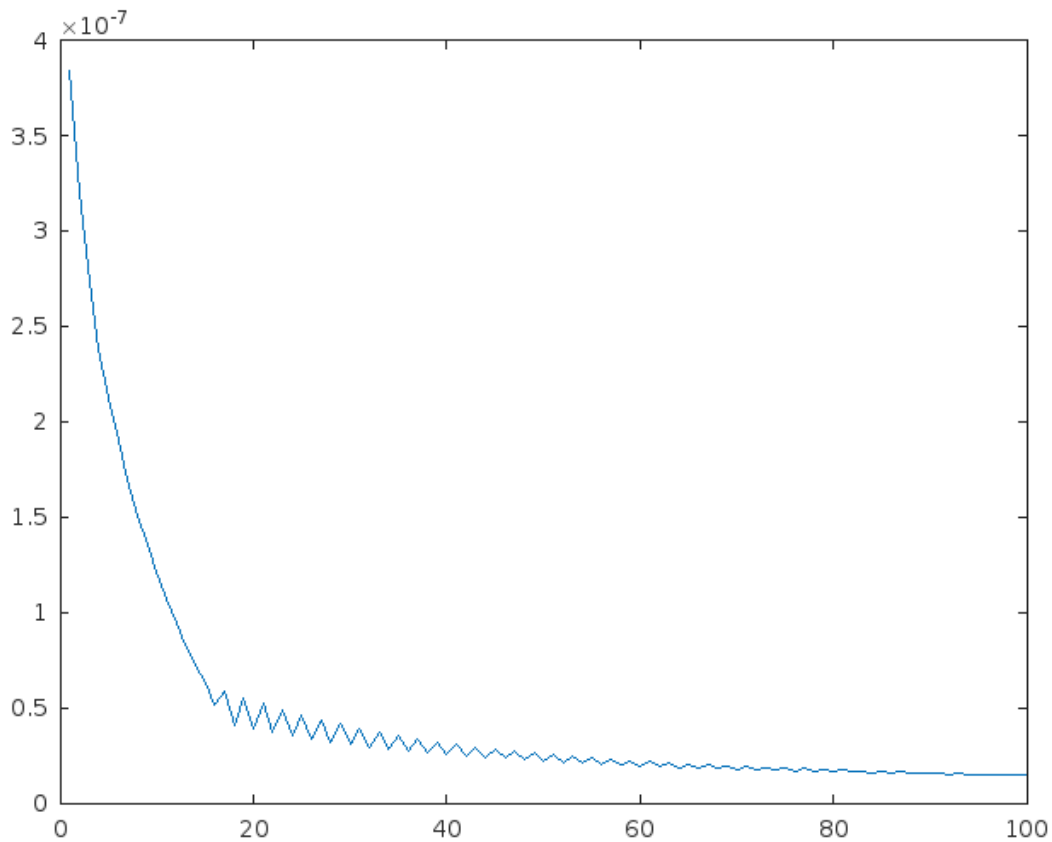
options = anfisOptions;
options.InitialFIS = in_fis;
options.EpochNumber = 100;
options.DisplayStepSize = 0;
options.DisplayErrorValues = 0;
[out_fis,ERROR] = anfis([X_train y_train],options);
ys=evalfis(out_fis, X_test);
figure(3)
plot(X_train, y_train, X_test, ys);
legend('Training Data','Anfis Output');
drawnow();
figure(4)
plot(ERROR.^2);
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
```

*ANFIS info:*

*Number of nodes: 24*  
*Number of linear parameters: 10*  
*Number of nonlinear parameters: 10*  
*Total number of parameters: 20*  
*Number of training data pairs: 900*  
*Number of checking data pairs: 0*  
*Number of fuzzy rules: 5*

*Minimal training RMSE = 0.000120642*  
*MSE: 1.54E-08*





## Generate FIS Using FCM Clustering

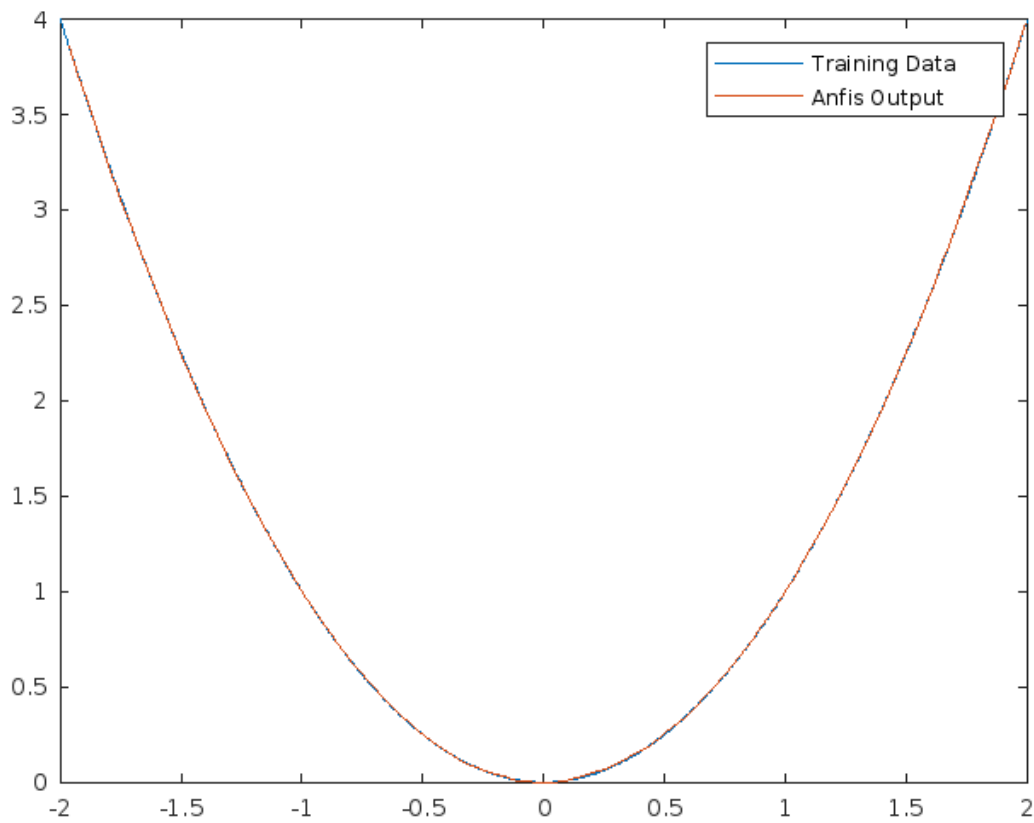
```
options = genfisOptions('FCMClustering');
options.Verbose = false;
in_fis = genfis(X_train,y_train,options);

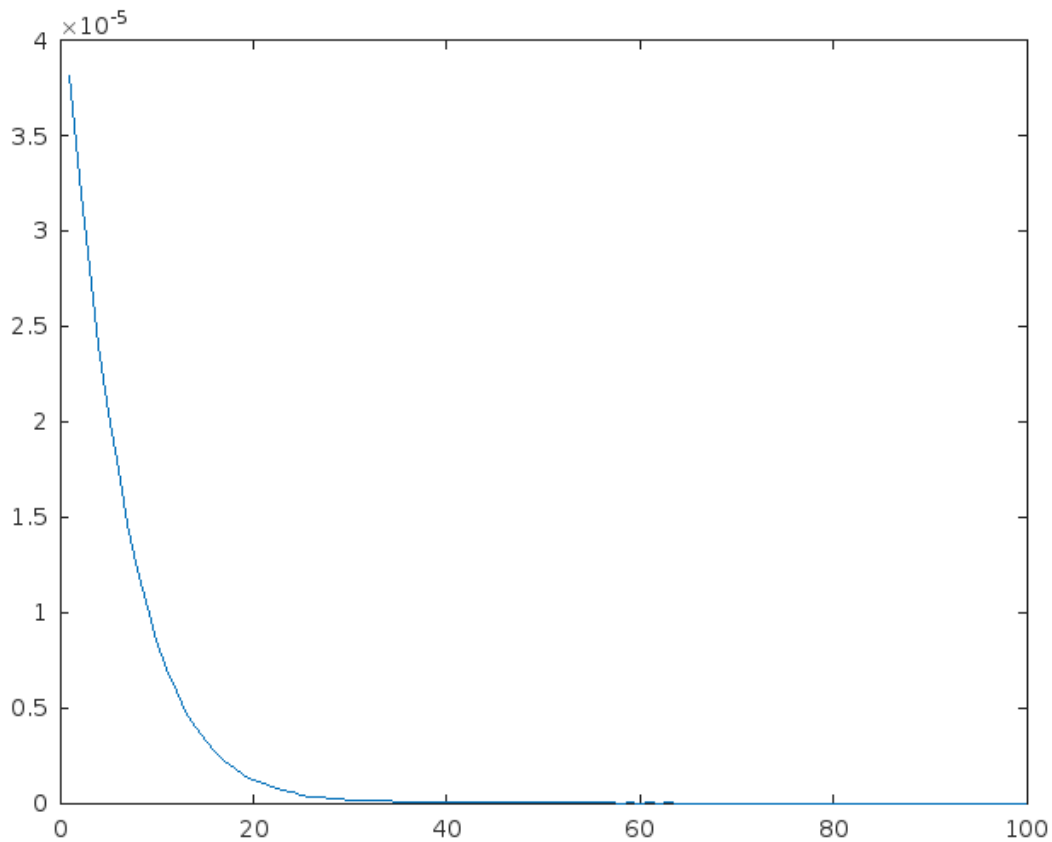
options = anfisOptions;
options.InitialFIS = in_fis;
options.EpochNumber = 100;
options.DisplayStepSize = 0;
options.DisplayErrorValues = 0;
[out_fis,ERROR] = anfis([X_train y_train],options);
ys=evalfis(out_fis, X_test);
figure(5)
plot(X_train, y_train, X_test, ys);
legend('Training Data','Anfis Output');
drawnow();
figure(6)
plot(ERROR.^2);
fprintf('MSE: %.2E', immse(ys,y_test));
drawnow();
```

*ANFIS info:*

*Number of nodes: 24*  
*Number of linear parameters: 10*  
*Number of nonlinear parameters: 10*  
*Total number of parameters: 20*  
*Number of training data pairs: 900*  
*Number of checking data pairs: 0*  
*Number of fuzzy rules: 5*

*Minimal training RMSE = 8.25389e-05*  
*MSE: 6.98E-09*



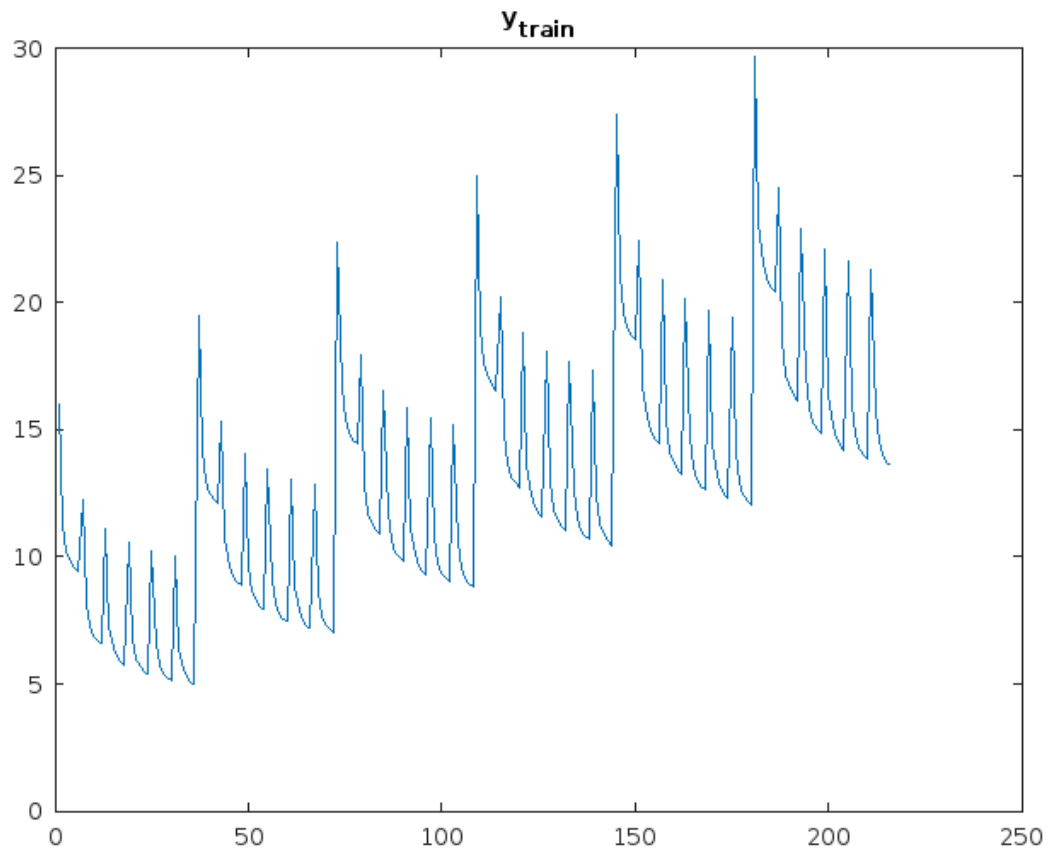


## QUESTÃO 2: Modelagem de sistema estático multivariável

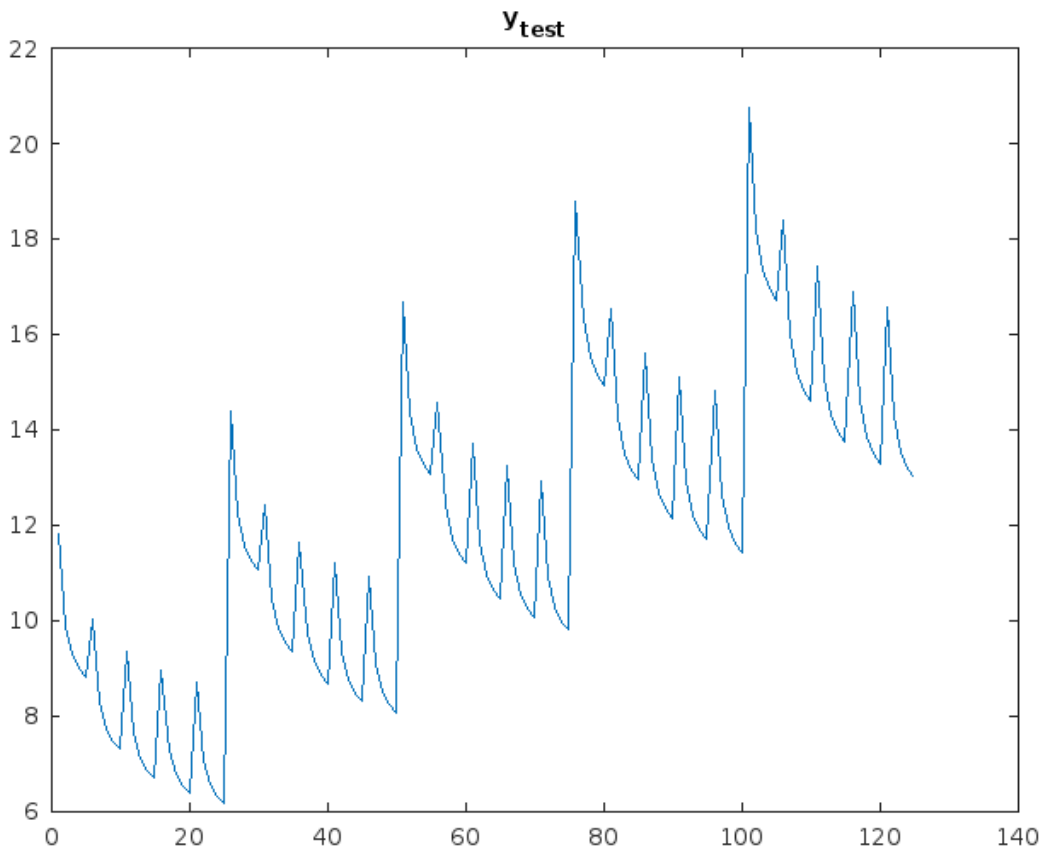
Modelar uma função não linear de 3 entradas:

$$\text{output} = (1 + x^{0.5} + y^{-1} + z^{-1.5})^2$$

```
%  
X_train = table2array(readtable('ex2_X_train.csv'));  
y_train = table2array(readtable('ex2_y_train.csv'));  
X_test = table2array(readtable('ex2_X_test.csv'));  
y_test = table2array(readtable('ex2_y_test.csv'));  
figure(7)  
plot(y_train);  
title("y_{train}");  
drawnow();  
figure(8)  
plot(y_test);  
title("y_{test}");  
drawnow();
```







## Generate FIS Using Grid Partitioning

```
options = genfisOptions('GridPartition');
options.NumMembershipFunctions = 3;
in_fis = genfis(X_train,y_train,options);

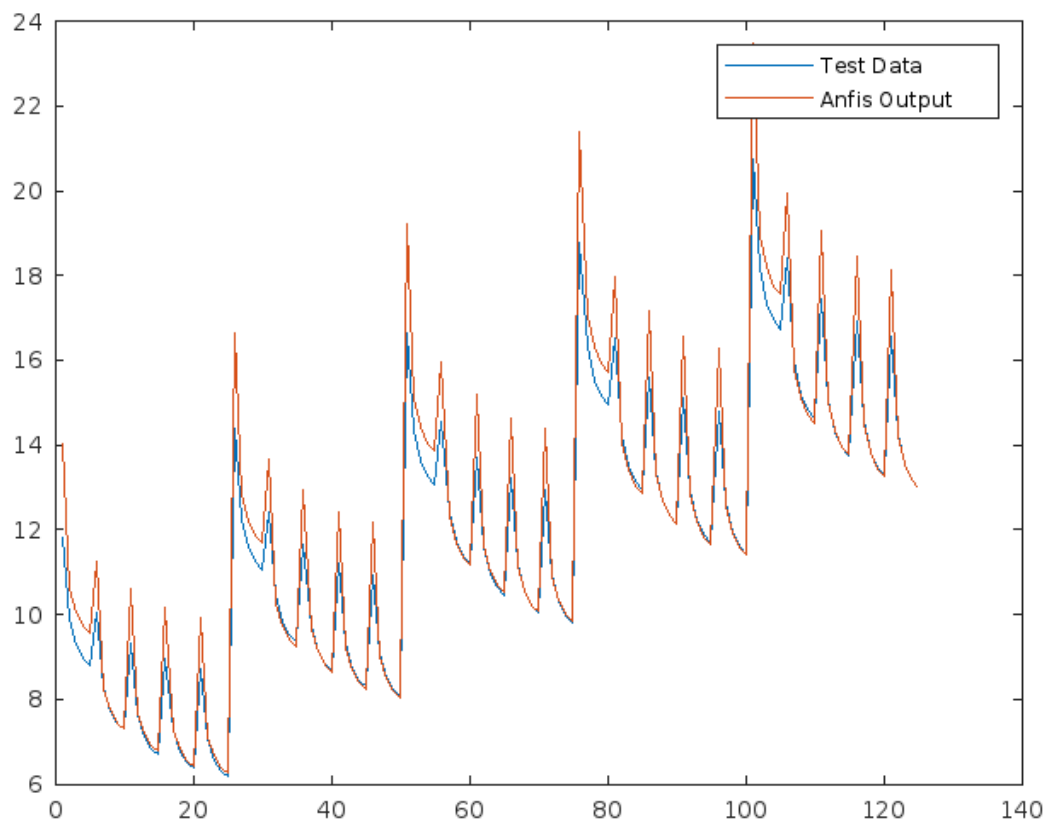
options = anfisOptions;
options.InitialFIS = in_fis;
options.EpochNumber = 100;
options.DisplayStepSize = 0;
options.DisplayErrorValues = 0;
[out_fis,ERROR] = anfis([X_train y_train],options);
ys=evalfis(out_fis, X_test);
figure(9)
plot(y_test);
hold on
plot(ys);
legend('Test Data','Anfis Output');

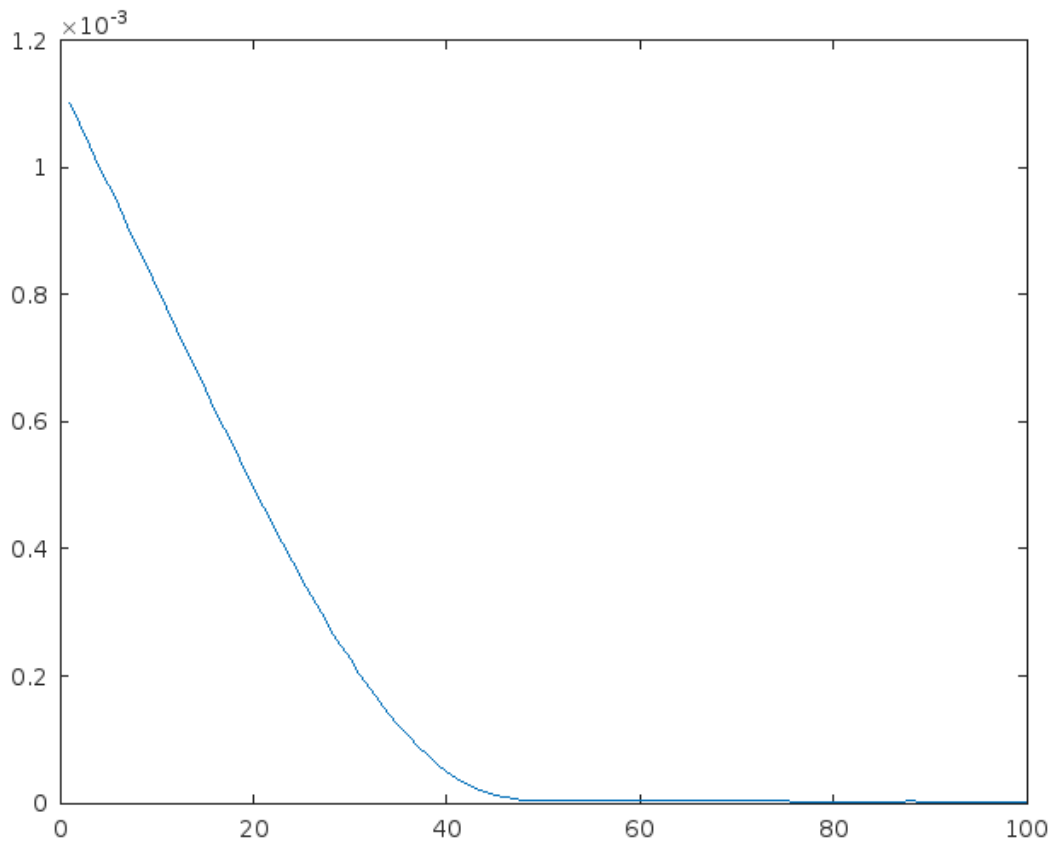
figure(10)
plot(ERROR.^2)
fprintf('MSE: %.2E', immse(ys,y_test));
```

*ANFIS info:*

*Number of nodes: 78*  
*Number of linear parameters: 108*  
*Number of nonlinear parameters: 27*  
*Total number of parameters: 135*  
*Number of training data pairs: 216*  
*Number of checking data pairs: 0*  
*Number of fuzzy rules: 27*

*Minimal training RMSE = 0.00101534*  
*MSE: 6.54E-01*





## Generate FIS Using Subtractive Clustering

```
options = genfisOptions('SubtractiveClustering');
in_fis = genfis(X_train,y_train,options);

options = anfisOptions;
options.InitialFIS = in_fis;
options.EpochNumber = 100;
options.DisplayStepSize = 0;
options.DisplayErrorValues = 0;
[out_fis,ERROR] = anfis([X_train y_train],options);
ys=evalfis(out_fis, X_test);
figure(11)
plot(y_test)
hold on
plot(ys)
legend('Test Data','Anfis Output');
figure(12)
plot(ERROR.^2)
fprintf('MSE: %.2E', immse(ys,y_test));
```

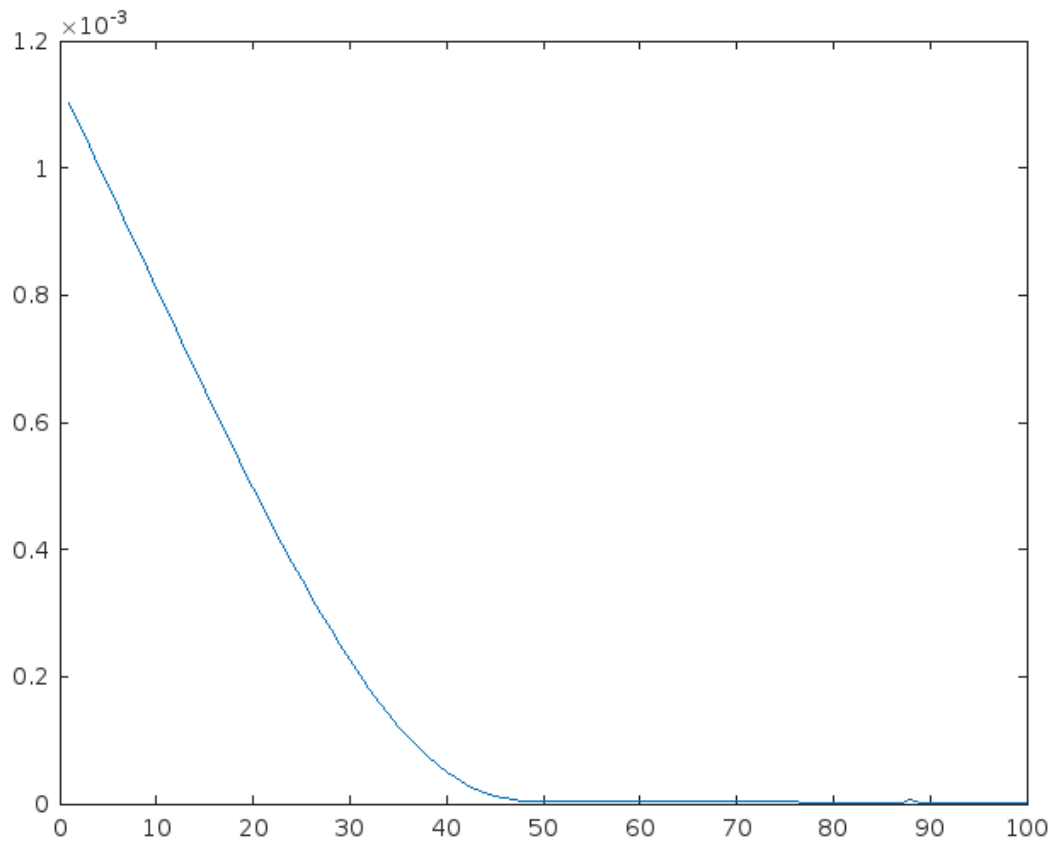
*ANFIS info:*

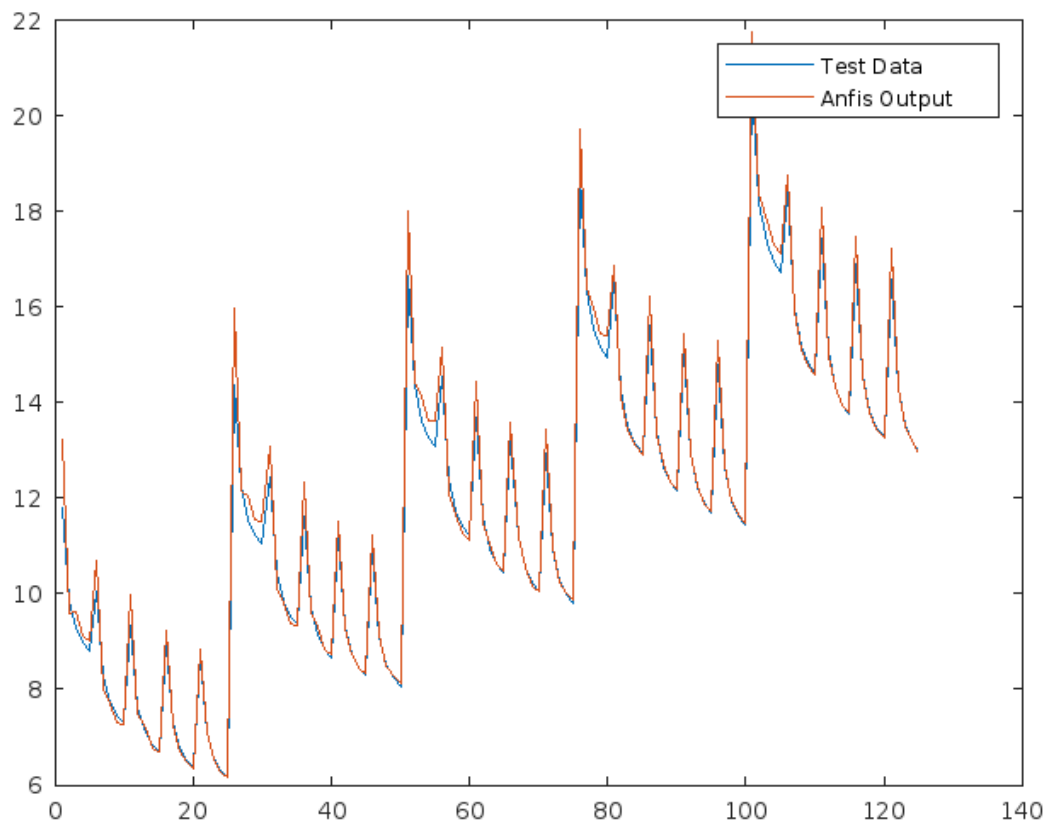
Number of nodes: 190  
Number of linear parameters: 92  
Number of nonlinear parameters: 138  
Total number of parameters: 230  
Number of training data pairs: 216  
Number of checking data pairs: 0  
Number of fuzzy rules: 23

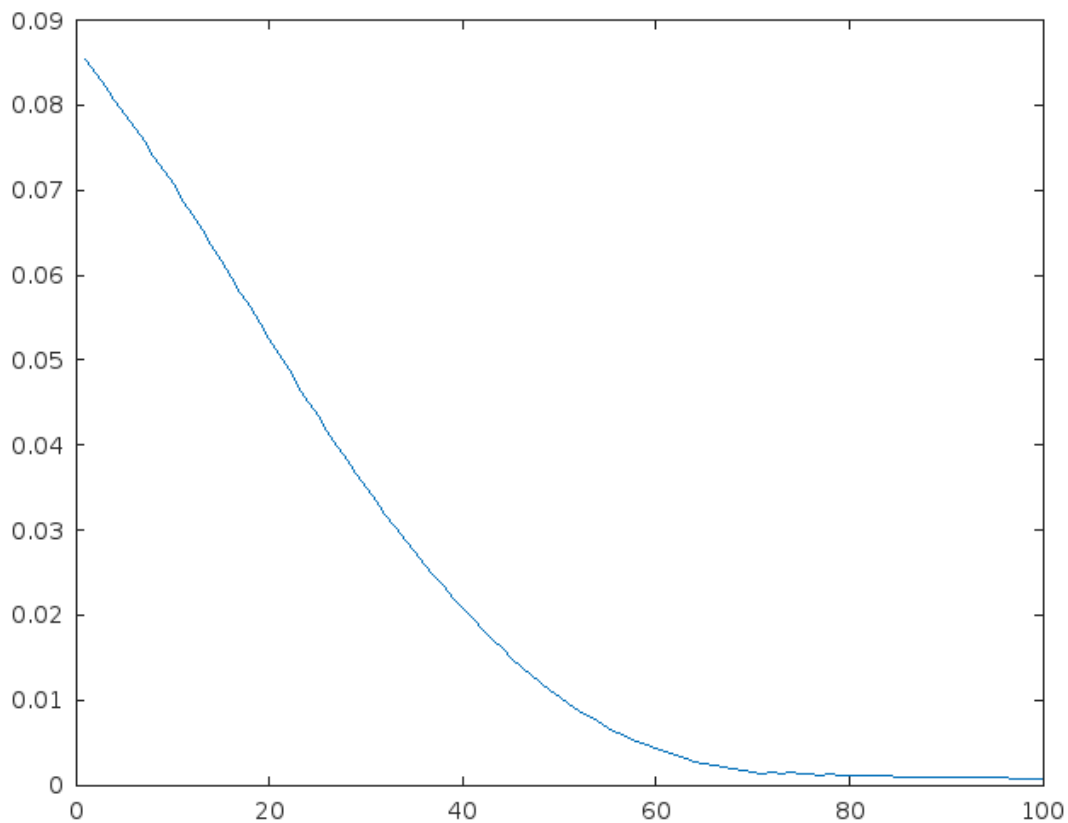
Warning: Number of training data is smaller than number of modifiable parameters.

Minimal training RMSE = 0.027412

MSE: 1.35E-01







## Generate FIS Using FCM Clustering

```
options = genfisOptions('FCMClustering');
options.Verbose = false;
in_fis = genfis(X_train,y_train, options);

options = anfisOptions;
options.InitialFIS = in_fis;
options.EpochNumber = 100;
options.DisplayStepSize = 0;
options.DisplayErrorValues = 0;
[out_fis,ERROR] = anfis([X_train y_train], options);
ys=evalfis(out_fis, X_test);
figure(13)
plot(y_test)
hold on
plot(ys)
legend('Test Data', 'Anfis Output');
figure(14)
plot(ERROR.^2)
fprintf('MSE: %.2E', immse(ys,y_test));
```

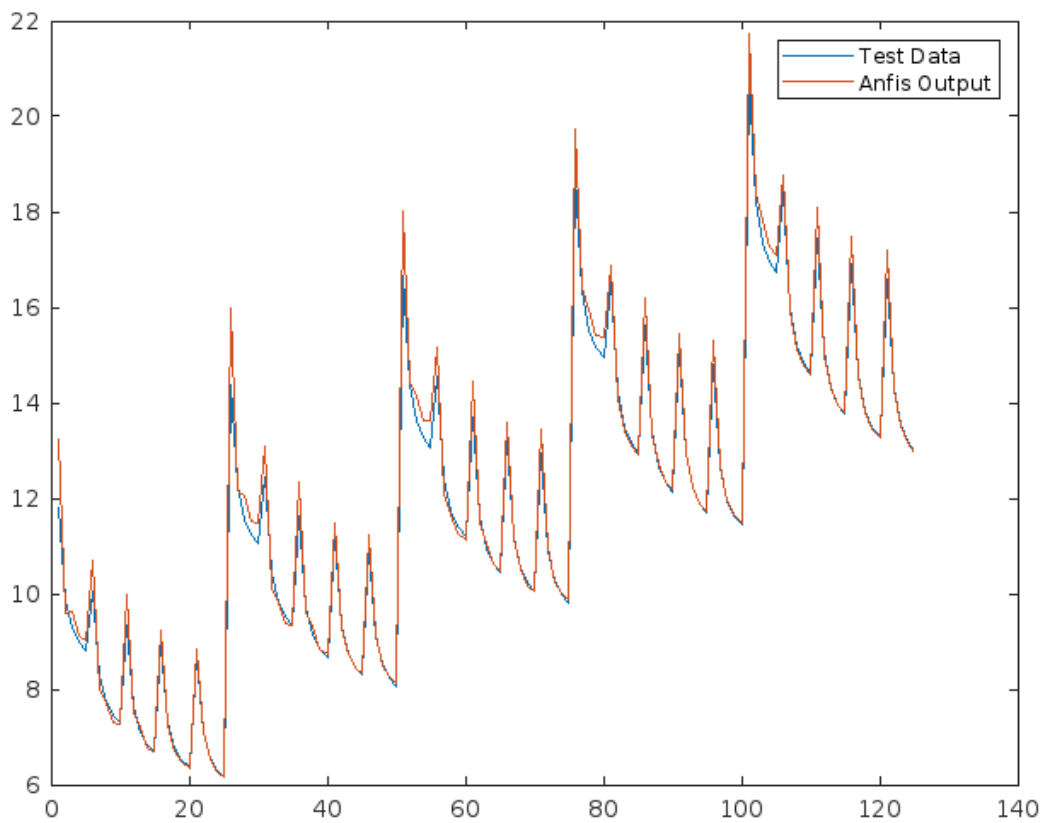
*ANFIS info:*

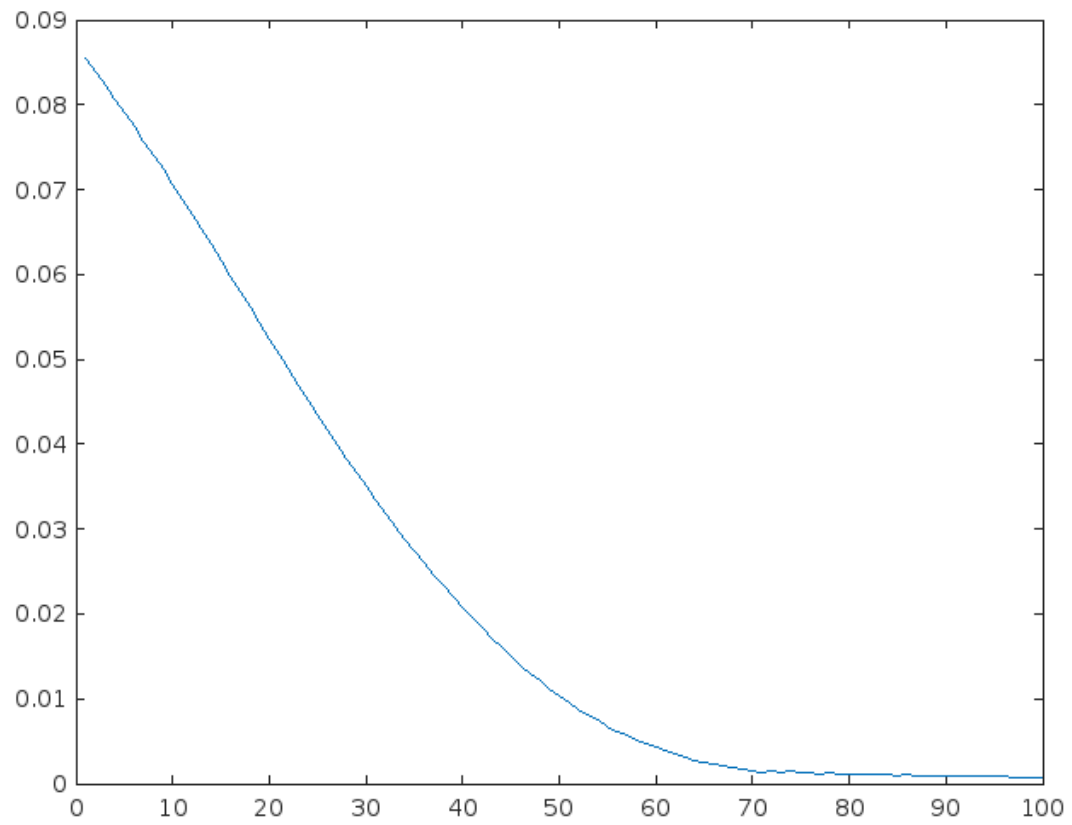
*Number of nodes: 190*  
*Number of linear parameters: 92*  
*Number of nonlinear parameters: 138*  
*Total number of parameters: 230*  
*Number of training data pairs: 216*  
*Number of checking data pairs: 0*  
*Number of fuzzy rules: 23*

*Warning: Number of training data is smaller than number of modifiable parameters.*

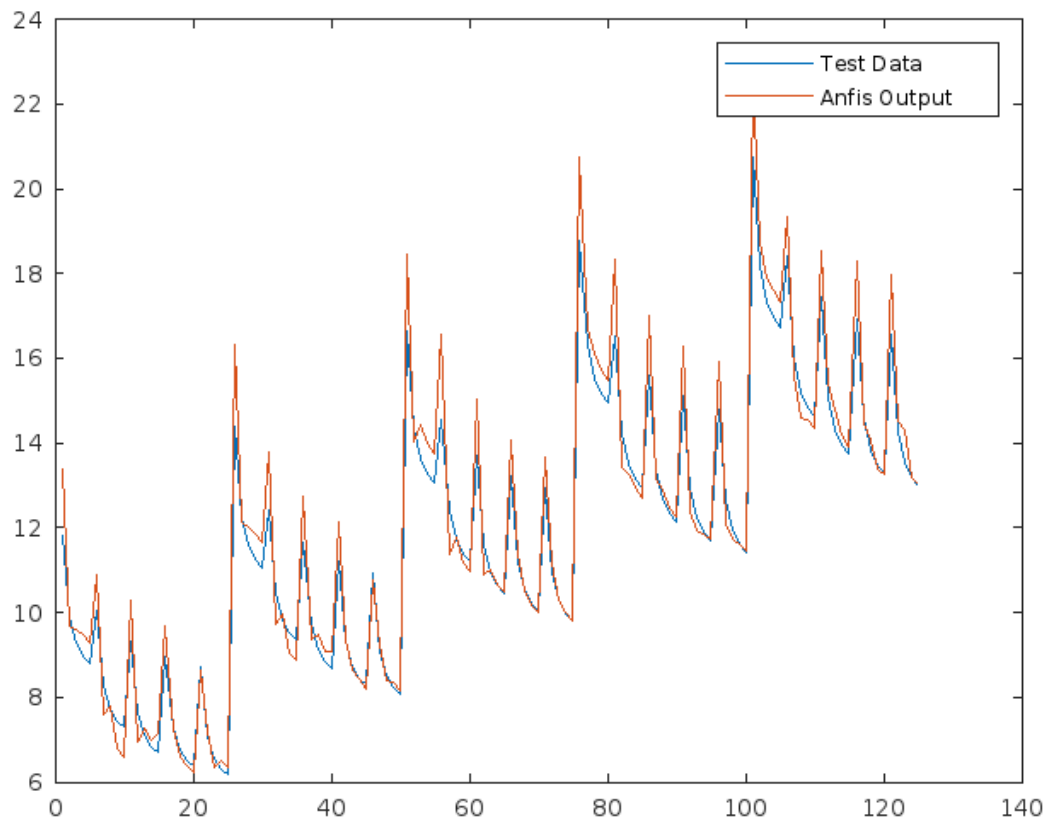
*Minimal training RMSE = 0.0663042*

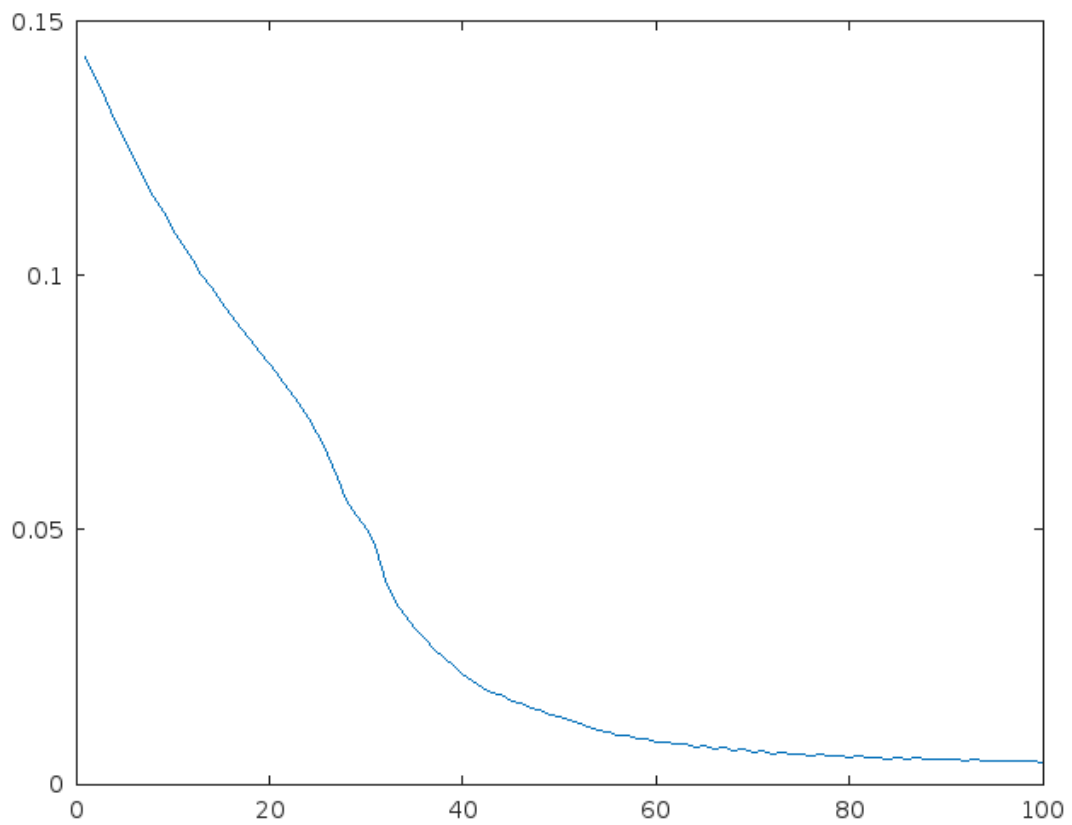
*MSE: 4.70E-01*











*Published with MATLAB® R2022a*