Sistemas Nebulosos

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QUESTÃO 1: Modelagem de sistema estático monovariável

Aproximar a função y=x^2

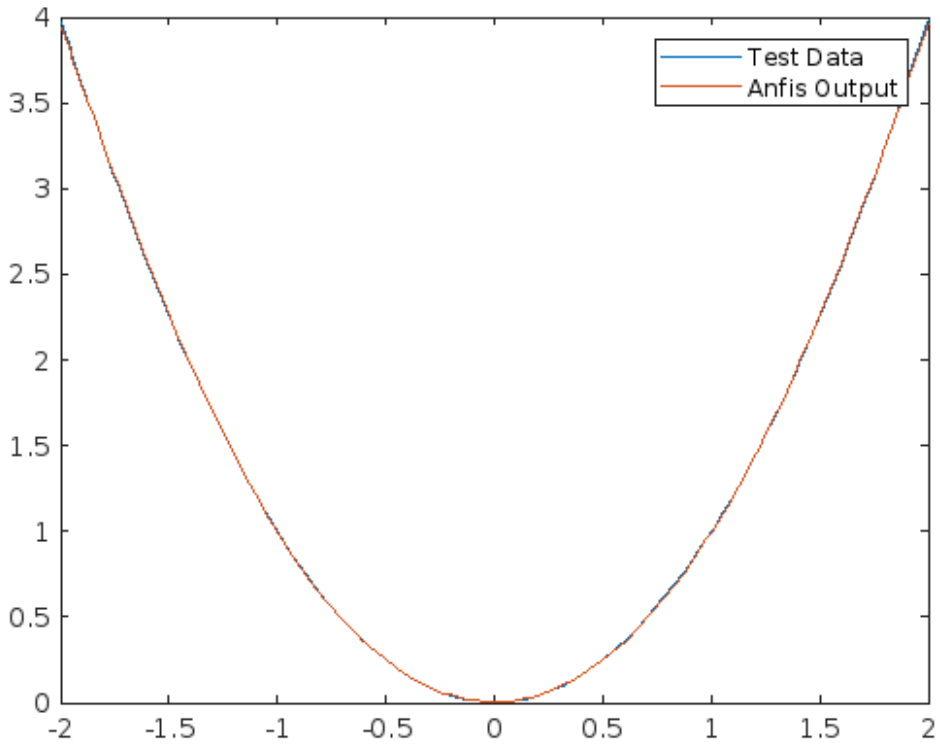
```
%_____________________________________________________________________
```

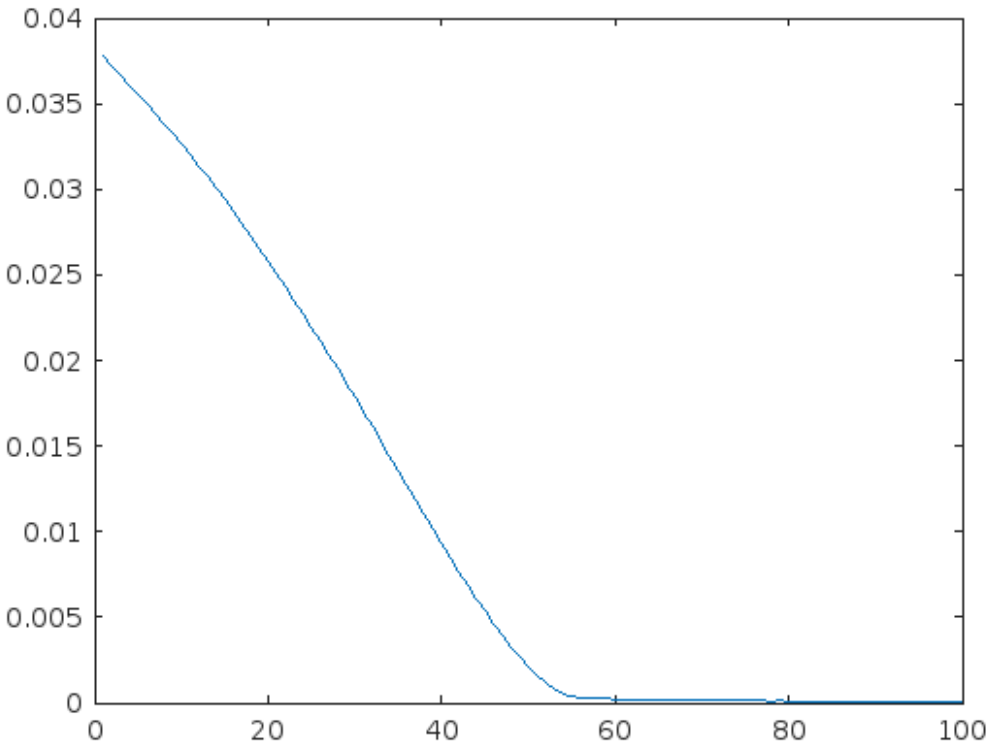
```
close all; clear; clc;
warning('off','all');

% 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

```
fig_number = 1;
[ys, ERROR] = run_anfis(X_train, y_train, X_test, 'GridPartition',2);
figure(fig_number)
plot(X_test, y_test, X_test, ys)
legend('Test Data','Anfis Output');
drawnow();
figure(fig_number+1)
plot(ERROR.^2)
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
fig_number = fig_number + 2;
```

```
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 = 0.0076546
MSE: 8.02E-05
```

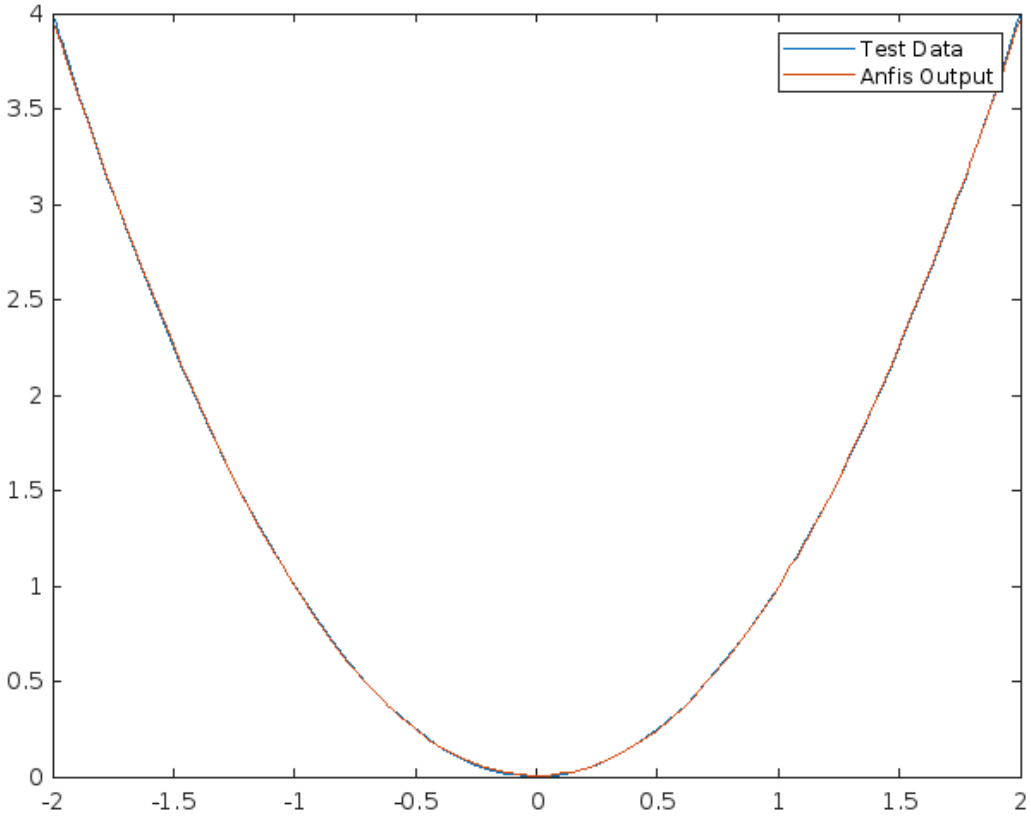


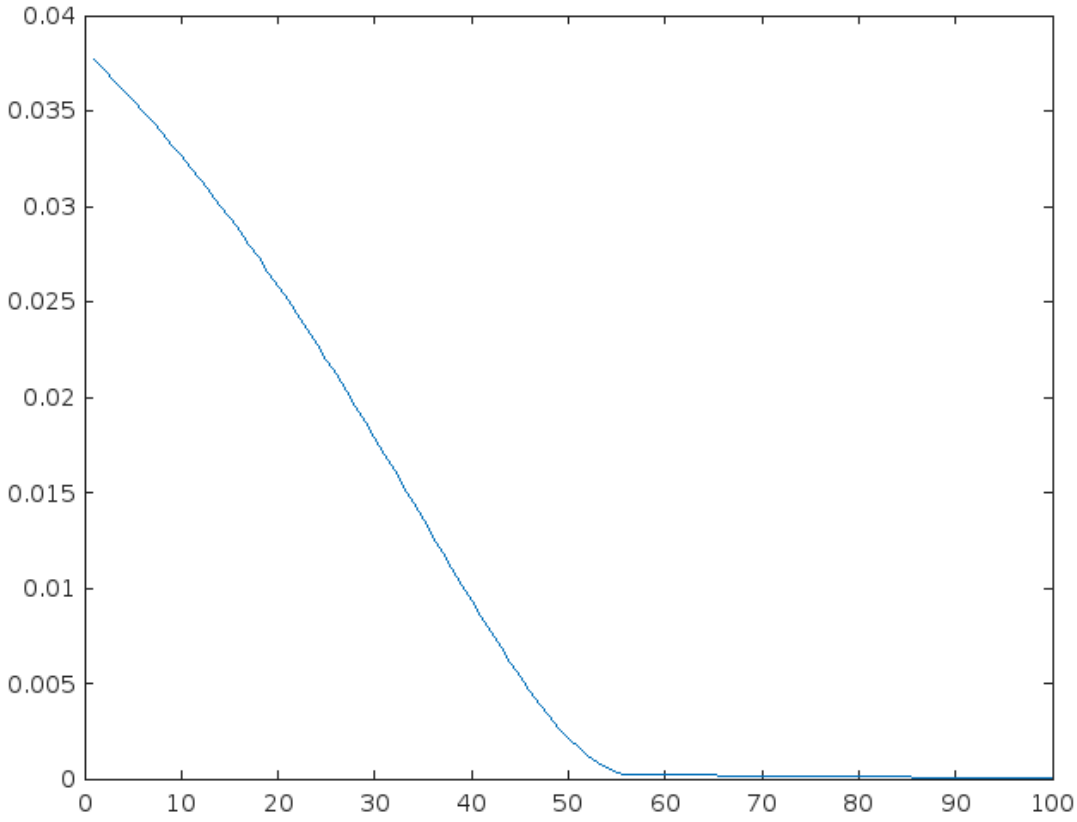


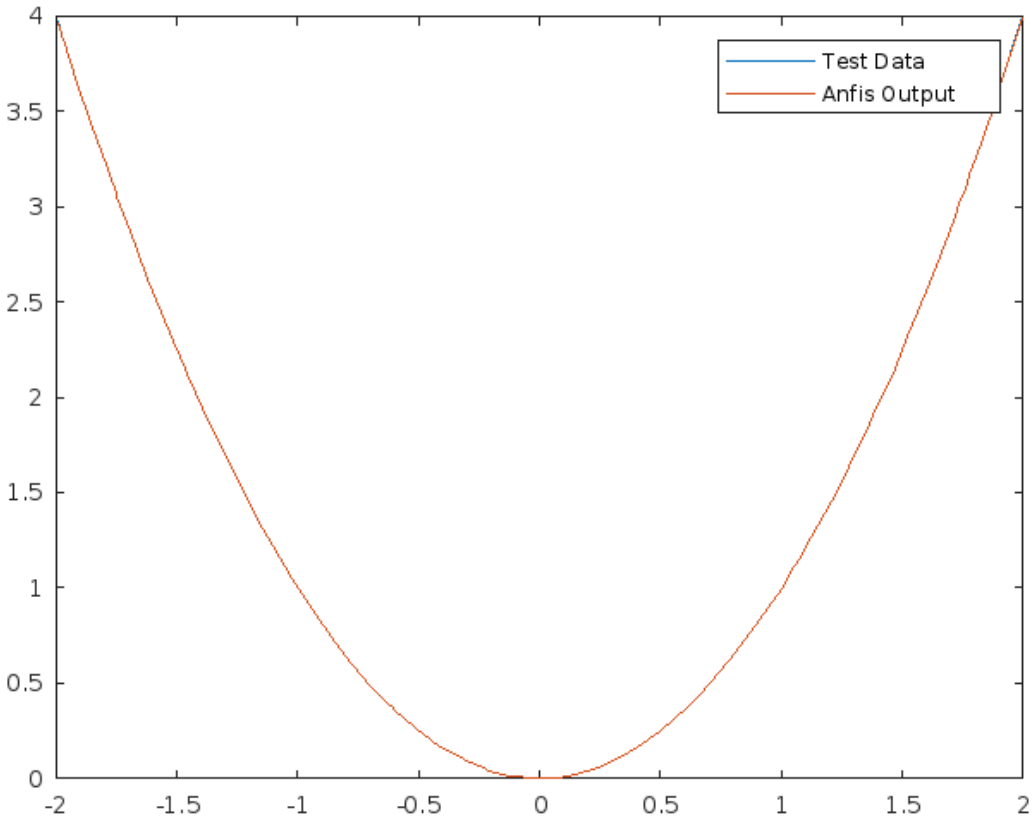
Generate FIS Using Subtractive Clustering

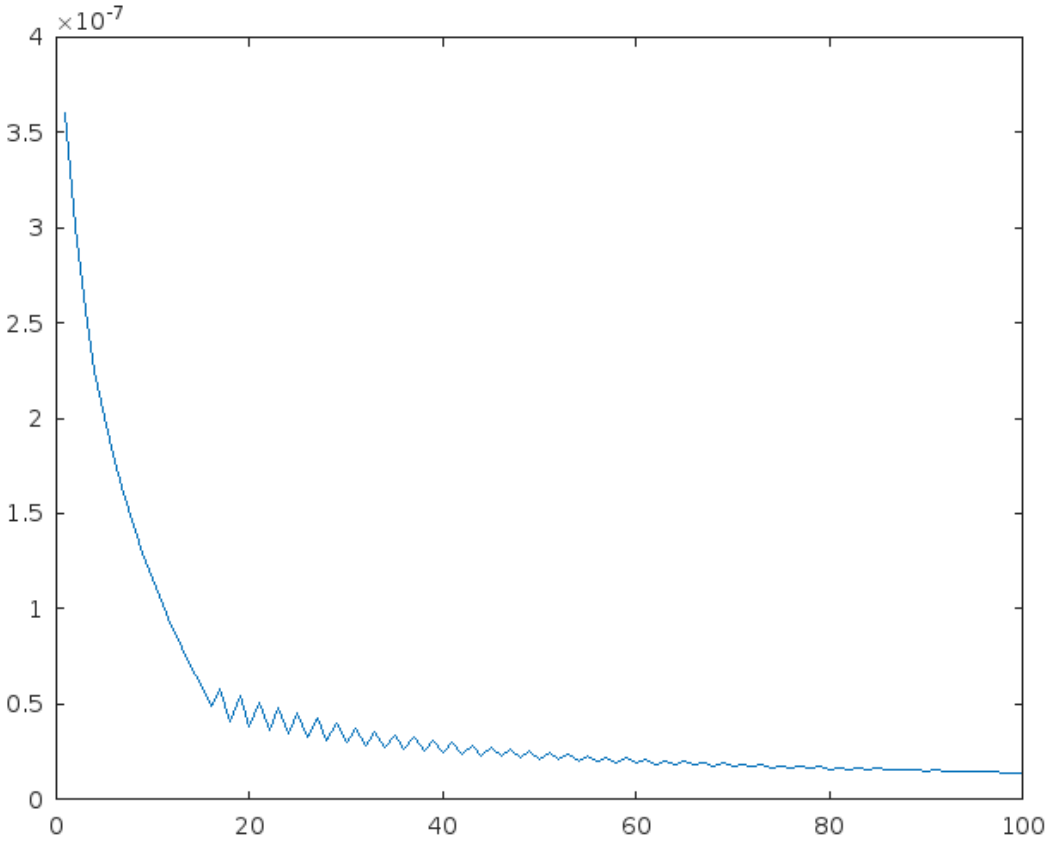
```
[ys, ERROR] = run_anfis(X_train, y_train, X_test, 'SubtractiveClustering');
figure(fig_number)
plot(X_test, y_test, X_test, ys)
legend('Test Data','Anfis Output');
drawnow();
figure(fig_number+1)
plot(ERROR.^2)
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
fig_number = fig_number + 2;
```

```
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 = 0.00011831
MSE: 1.97E-08
```


Test Data
Anfis Output
4
3.5
3
2.5
2
1.5
1
0.5
0
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2


0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
70
80
90
100


Test Data
Anfis Output
4
3.5
3
2.5
2
1.5
1
0.5
0
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2

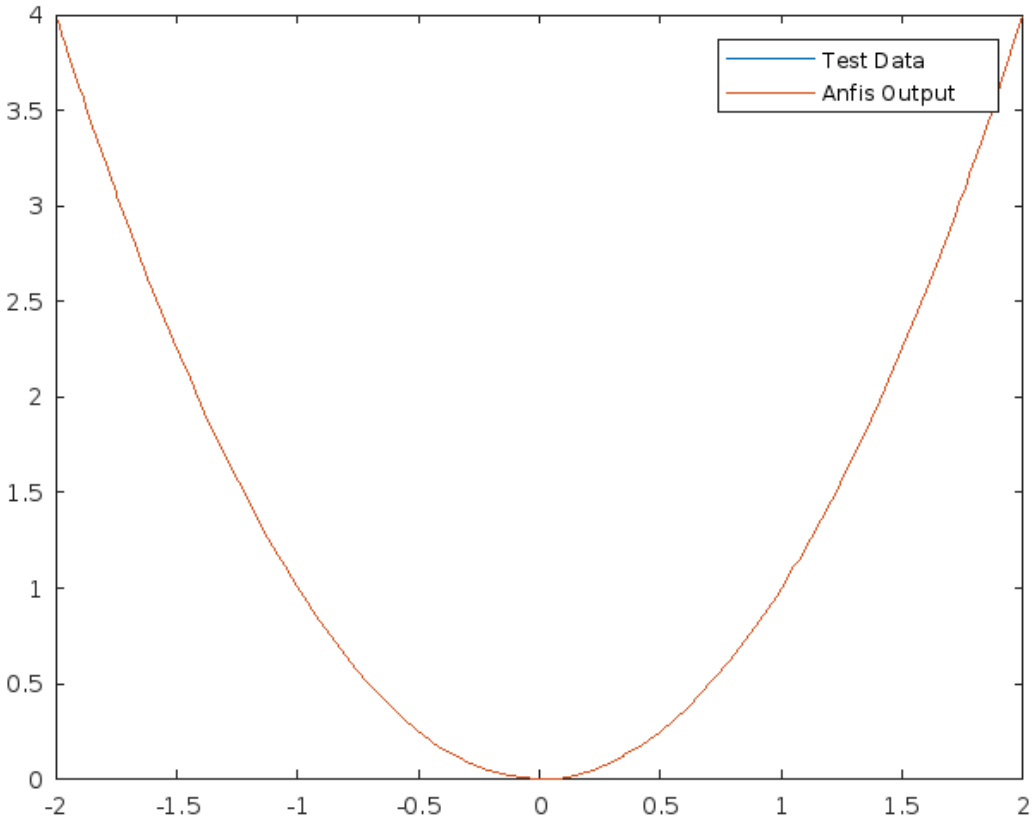


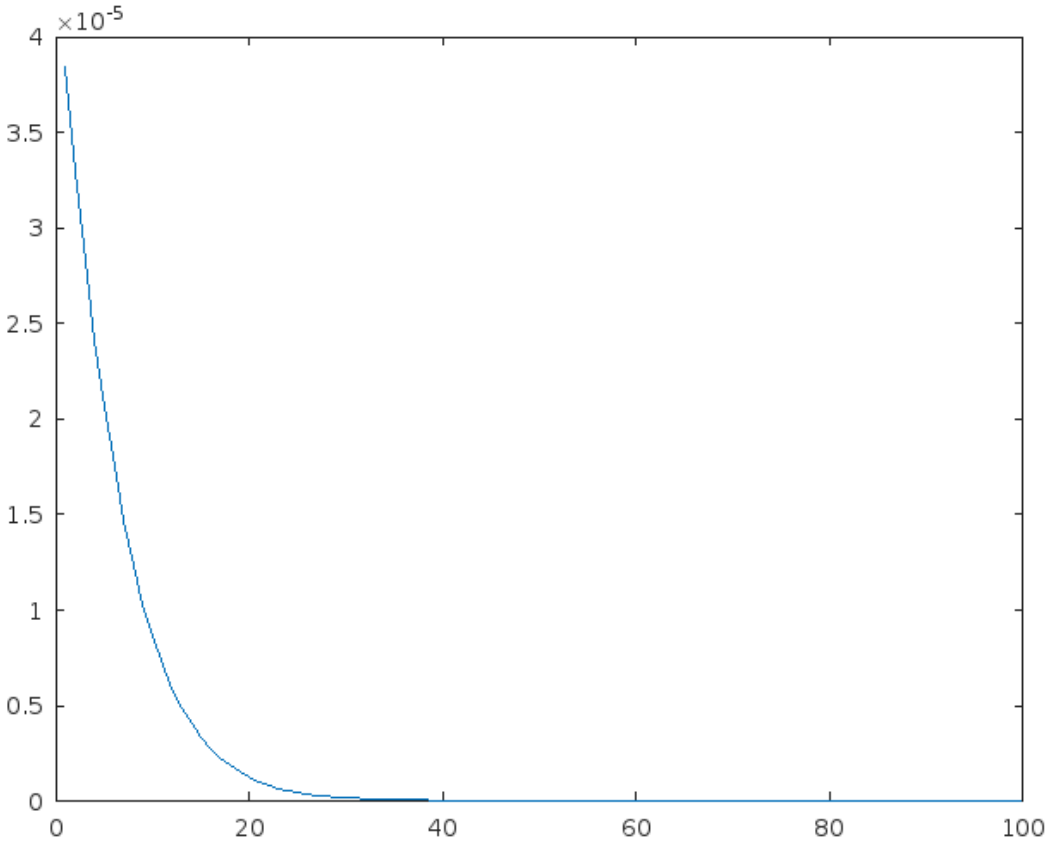
Generate FIS Using FCM Clustering

```
[ys, ERROR] = run_anfis(X_train, y_train, X_test, 'FCMClustering');
figure(fig_number)
plot(X_test, y_test, X_test, ys)
legend('Test Data','Anfis Output');
drawnow();
figure(fig_number+1)
plot(ERROR.^2)
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
fig_number = fig_number + 2;
```

```
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 = 8.23037e-05
MSE: 1.04E-08



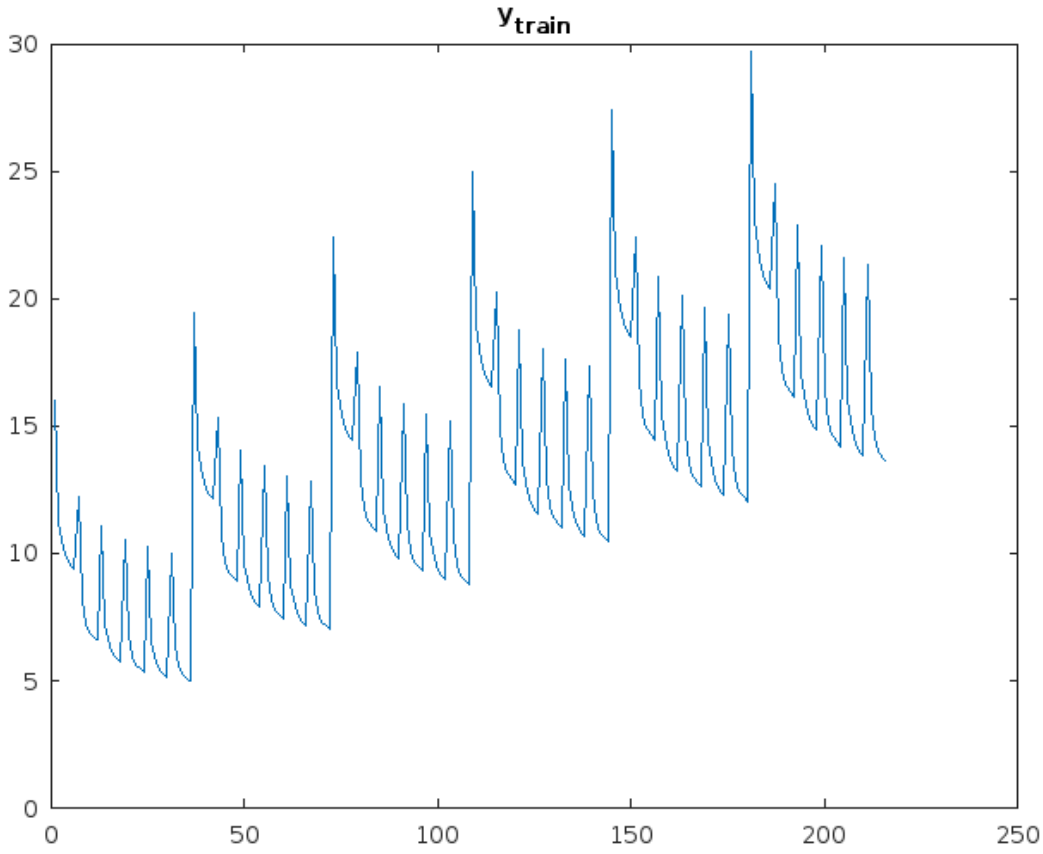


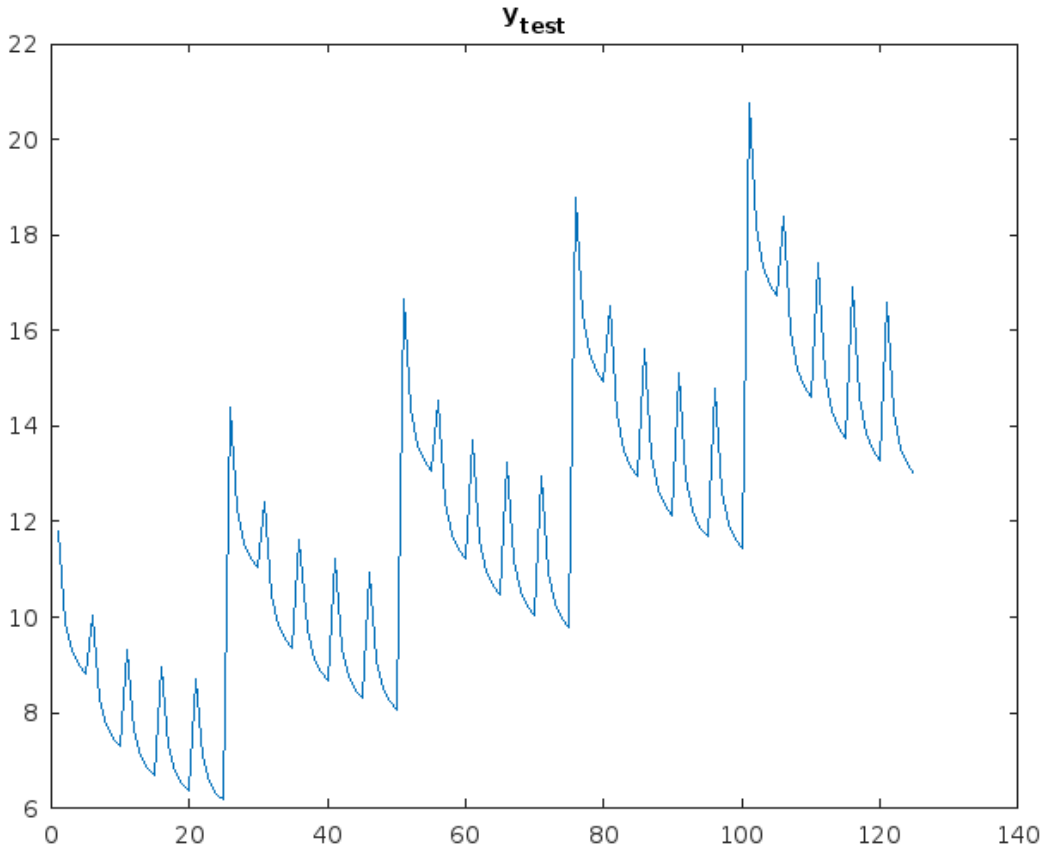
QUESTÃO 2: Modelagem de sistema estático multivariável

Modelar uma função não linear de 3 entradas:

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(fig_number)
plot(y_train);
title("y_{train}");
drawnow();
fig_number = fig_number + 1;
figure(fig_number)
plot(y_test);
title("y_{test}");
drawnow();
fig_number = fig_number + 1;
```


y_{train}
30
25
20
15
10
5
0
0
50
100
150
200
250

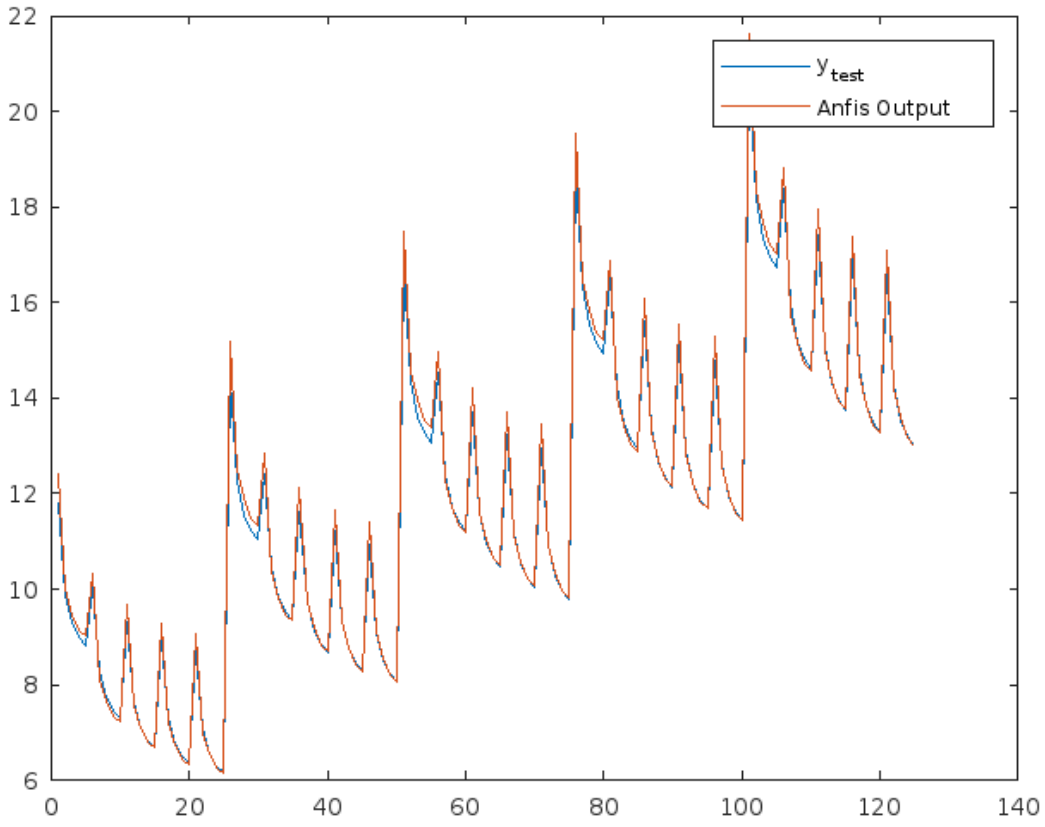


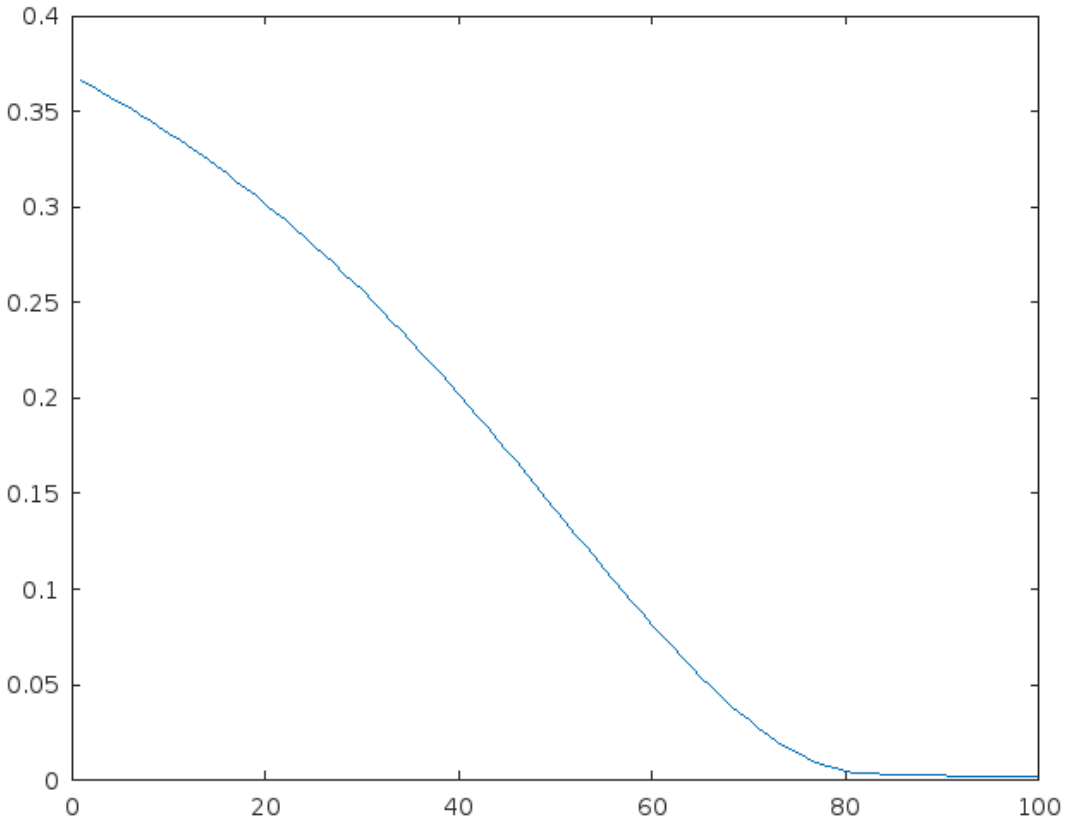
Generate FIS Using Grid Partitioning

```
[ys, ERROR] = run_anfis(X_train, y_train, X_test, 'GridPartition',2);
figure(fig_number)
plot(y_test)
hold on
plot(ys)
legend('y_{test}','Anfis Output');
drawnow();
figure(fig_number+1)
plot(ERROR.^2)
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
fig_number = fig_number + 2;
```

```
ANFIS info:
 Number of nodes: 34
 Number of linear parameters: 32
 Number of nonlinear parameters: 18
 Total number of parameters: 50
 Number of training data pairs: 216
 Number of checking data pairs: 0
```

```
 Number of fuzzy rules: 8

Minimal training RMSE = 0.0412386
MSE: 6.95E-02
```



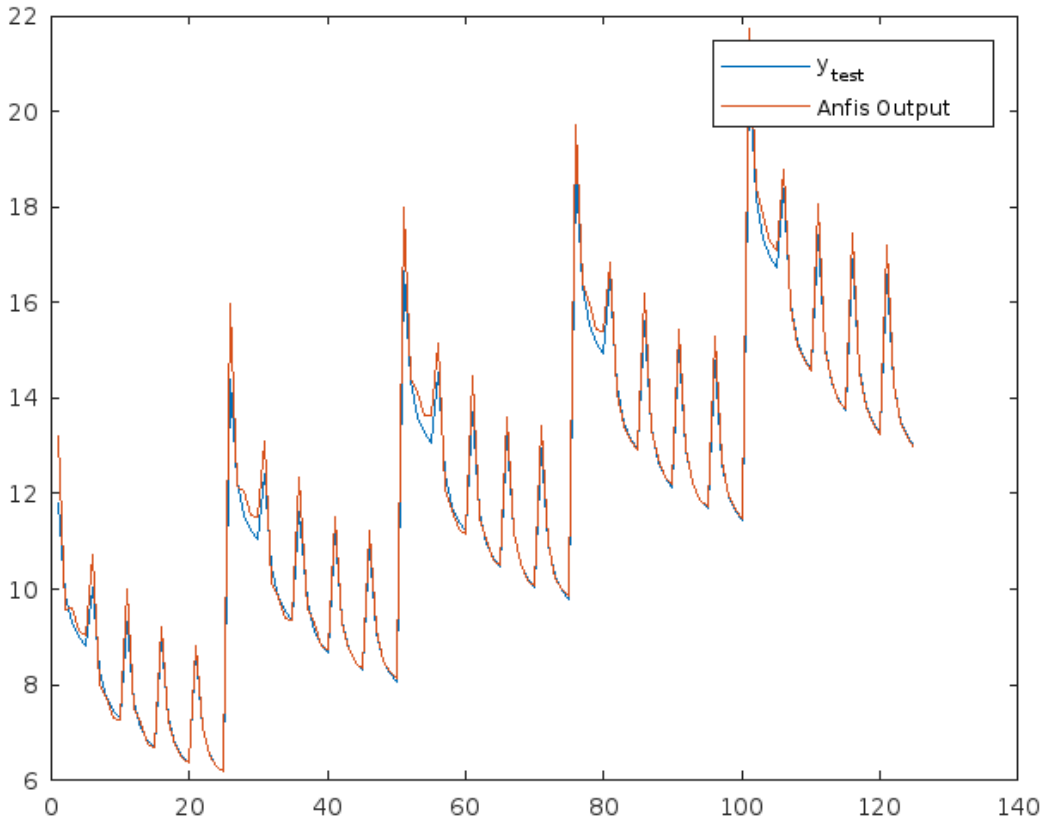


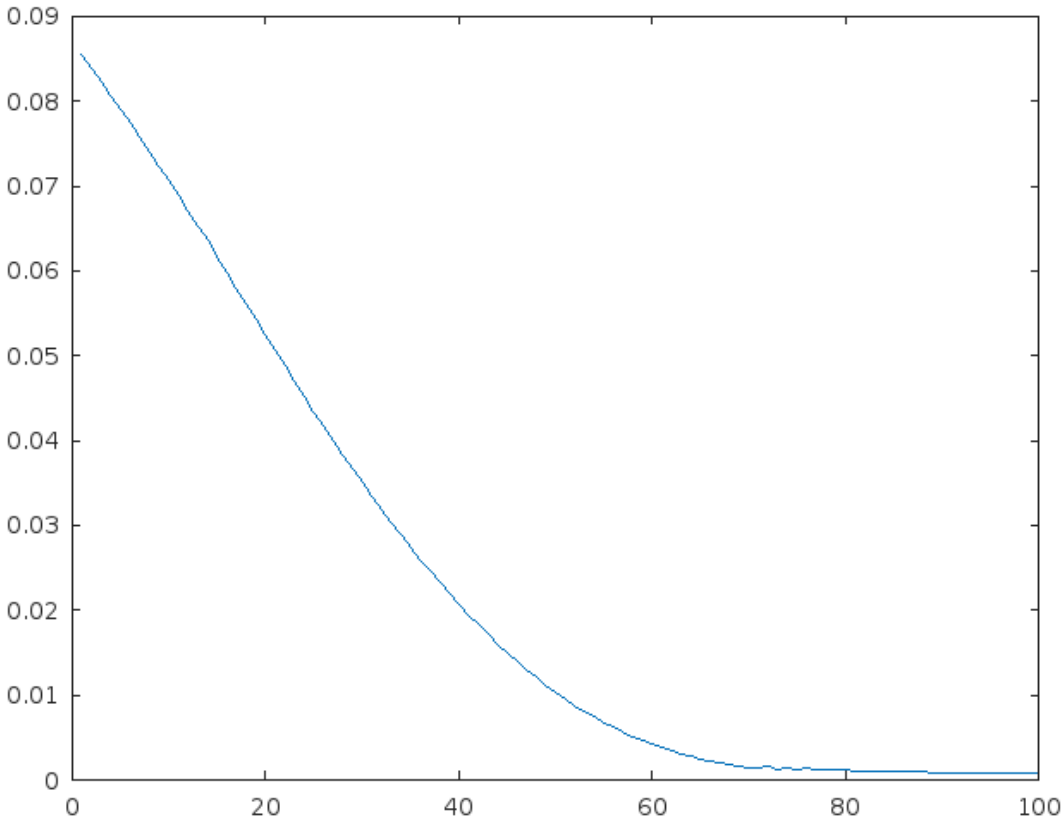
Generate FIS Using Subtractive Clustering

```
[ys, ERROR] = run_anfis(X_train, y_train, X_test, 'SubtractiveClustering');
figure(fig_number)
plot(y_test)
hold on
plot(ys)
legend('y_{test}','Anfis Output');
drawnow();
figure(fig_number+1)
plot(ERROR.^2)
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
fig_number = fig_number + 2;
```

```
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

Minimal training RMSE = 0.027412
MSE: 1.35E-01
```



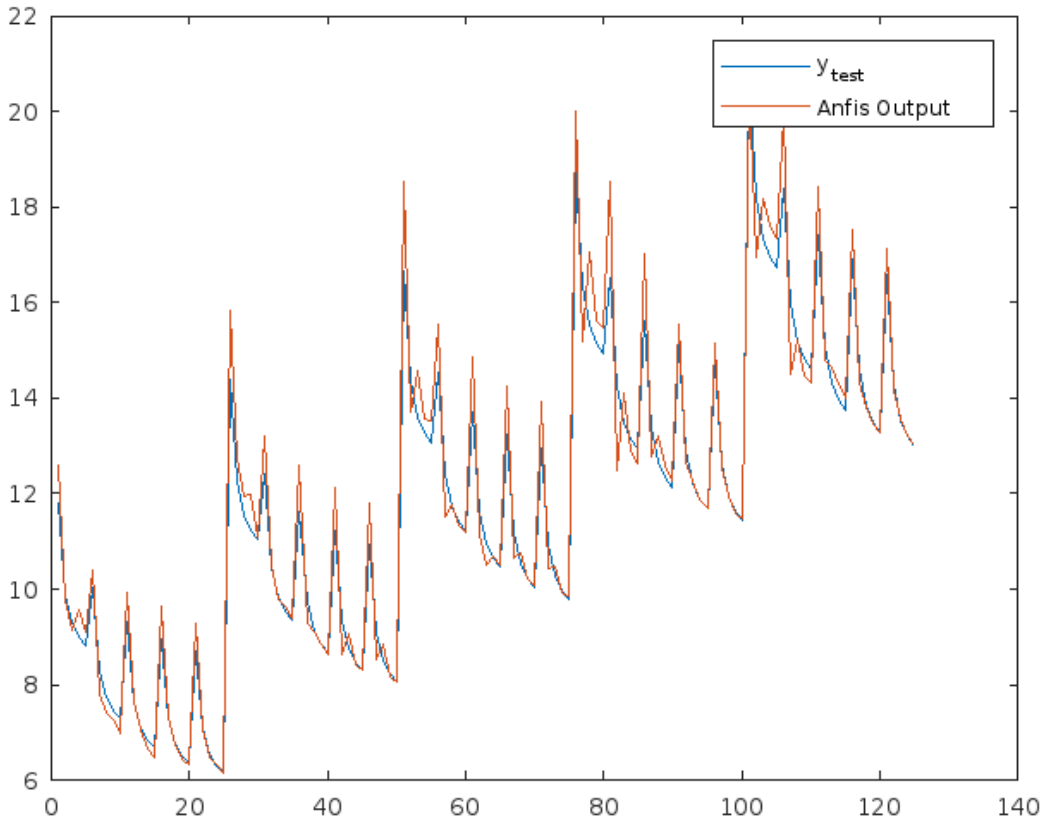


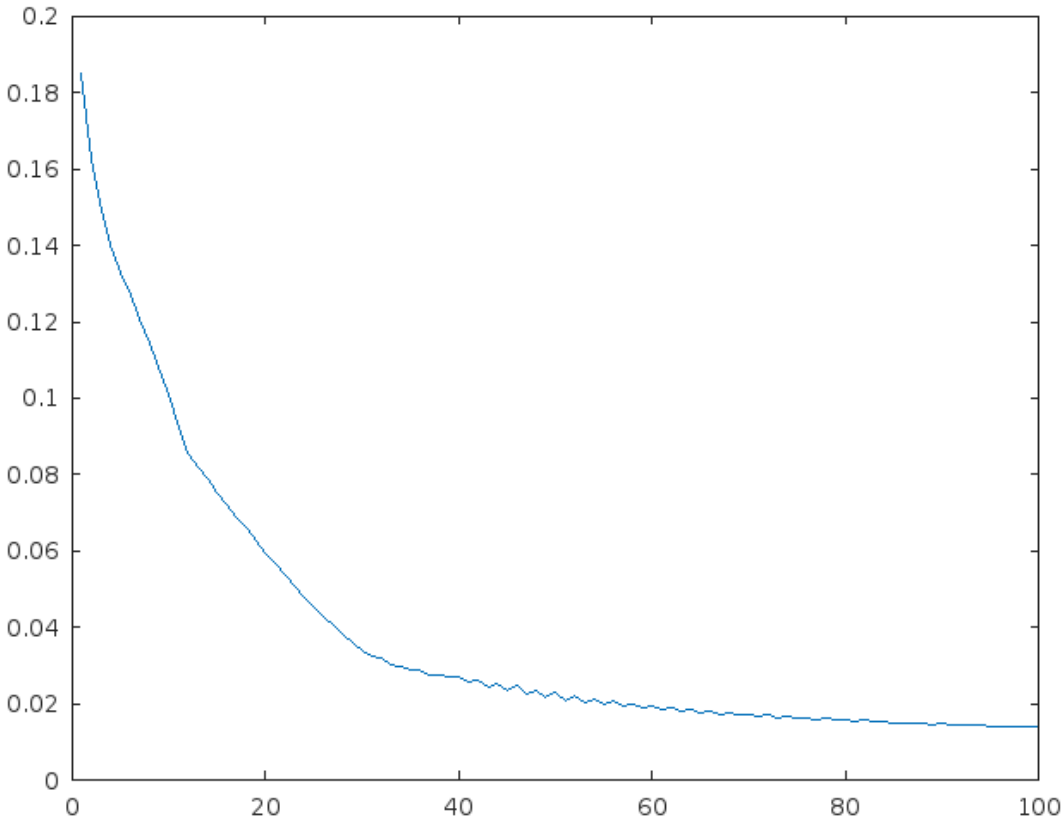
Generate FIS Using FCM Clustering

```
[ys, ERROR] = run_anfis(X_train, y_train, X_test, 'FCMClustering');
figure(fig_number)
plot(y_test)
hold on
plot(ys)
legend('y_{test}','Anfis Output');
drawnow();
figure(fig_number+1)
plot(ERROR.^2)
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
fig_number = fig_number + 2;
```

```
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
```

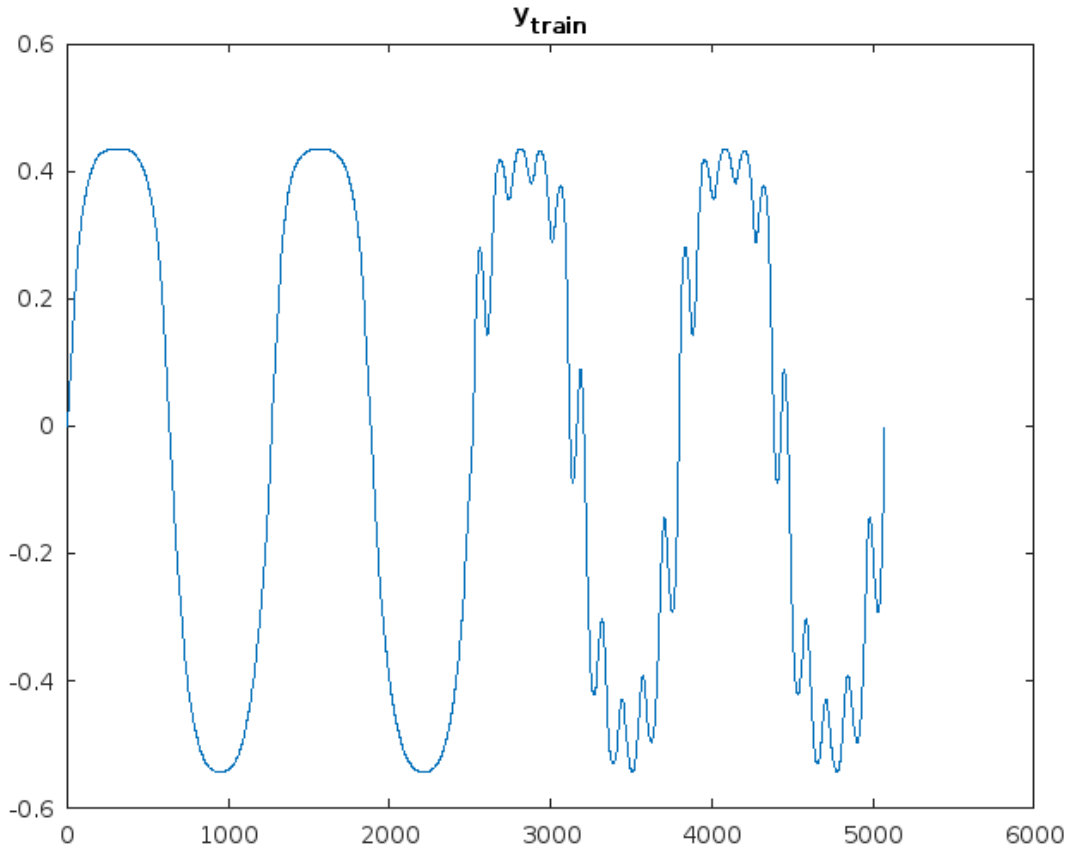
```
 Number of fuzzy rules: 23

Minimal training RMSE = 0.117529
MSE: 3.86E-01
```

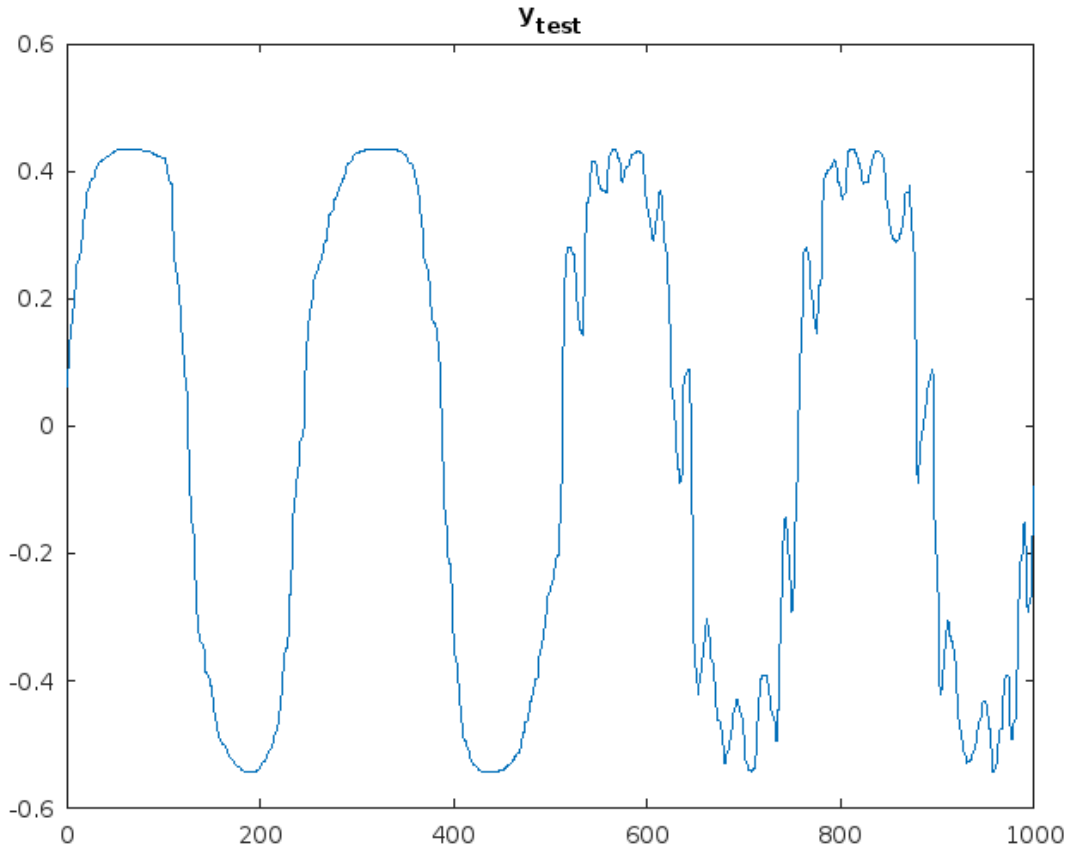




QUESTÃO 3: Modelo de sistema dinâmico

```
%_____________________________________________________________________
X_train = table2array(readtable('ex3_X_train.csv'));
y_train = table2array(readtable('ex3_y_train.csv'));
X_test = table2array(readtable('ex3_X_test.csv'));
y_test = table2array(readtable('ex3_y_test.csv'));
figure(fig_number)
plot(y_train);
title("y_{train}");
drawnow();
fig_number = fig_number + 1;
figure(fig_number)
plot(y_test);
title("y_{test}");
drawnow();
fig_number = fig_number + 1;
```


y train
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0
1000
2000
3000
4000
5000
6000

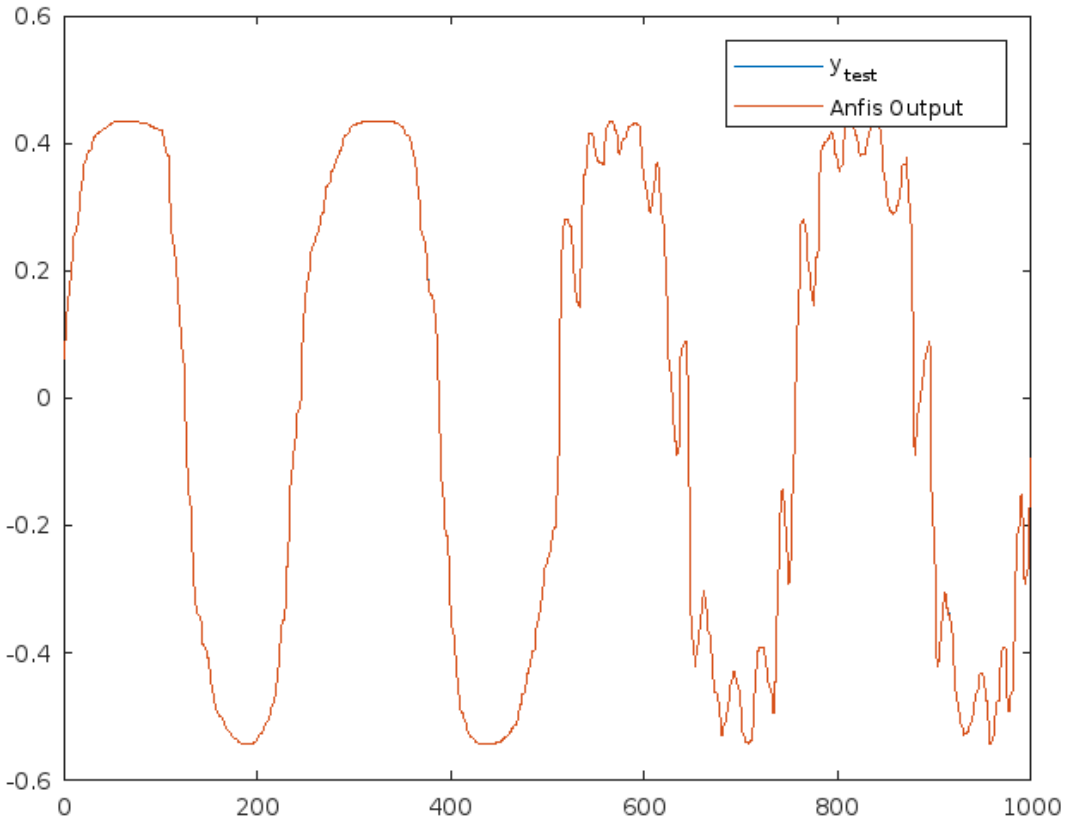


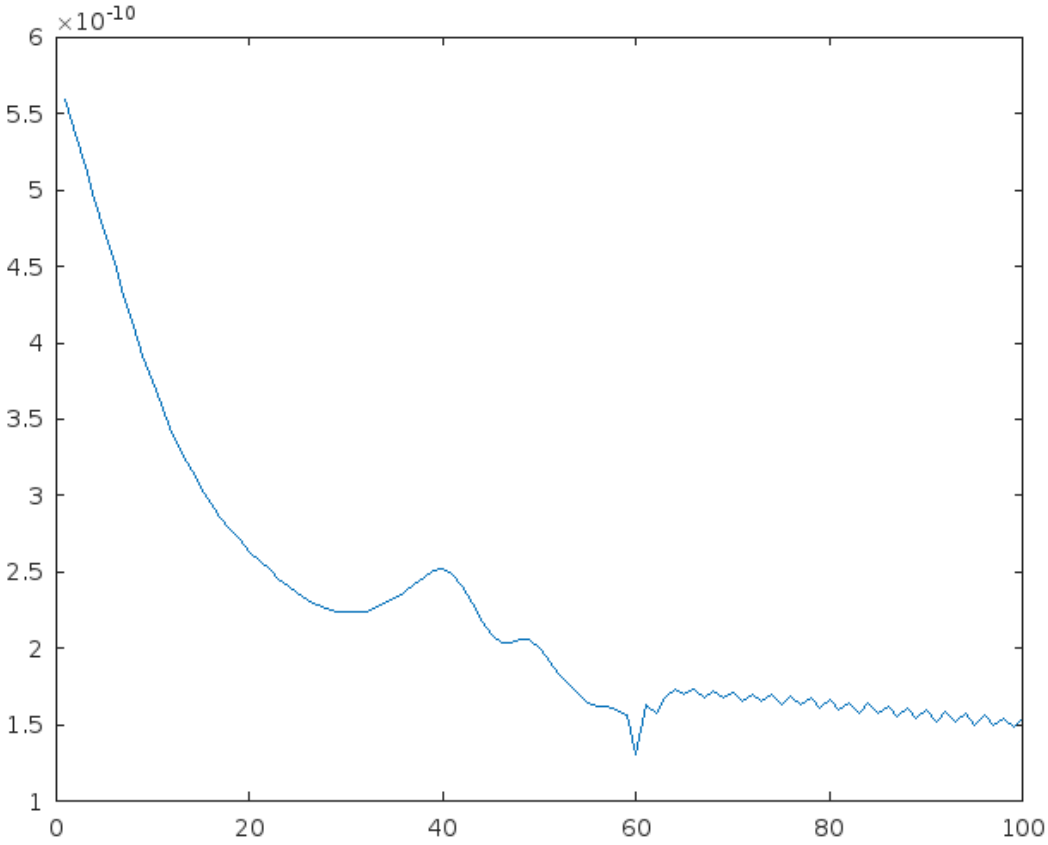
Generate FIS Using Grid Partitioning

```
[ys, ERROR] = run_anfis(X_train, y_train, X_test, 'GridPartition',  2);
figure(fig_number)
plot(y_test)
hold on
plot(ys)
legend('y_{test}','Anfis Output');
drawnow();
figure(fig_number+1)
plot(ERROR.^2)
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
fig_number = fig_number + 2;
```

```
ANFIS info:
 Number of nodes: 92
 Number of linear parameters: 192
 Number of nonlinear parameters: 30
 Total number of parameters: 222
 Number of training data pairs: 5074
 Number of checking data pairs: 0
```

```
 Number of fuzzy rules: 32

Minimal training RMSE = 1.13997e-05
MSE: 1.19E-10
```



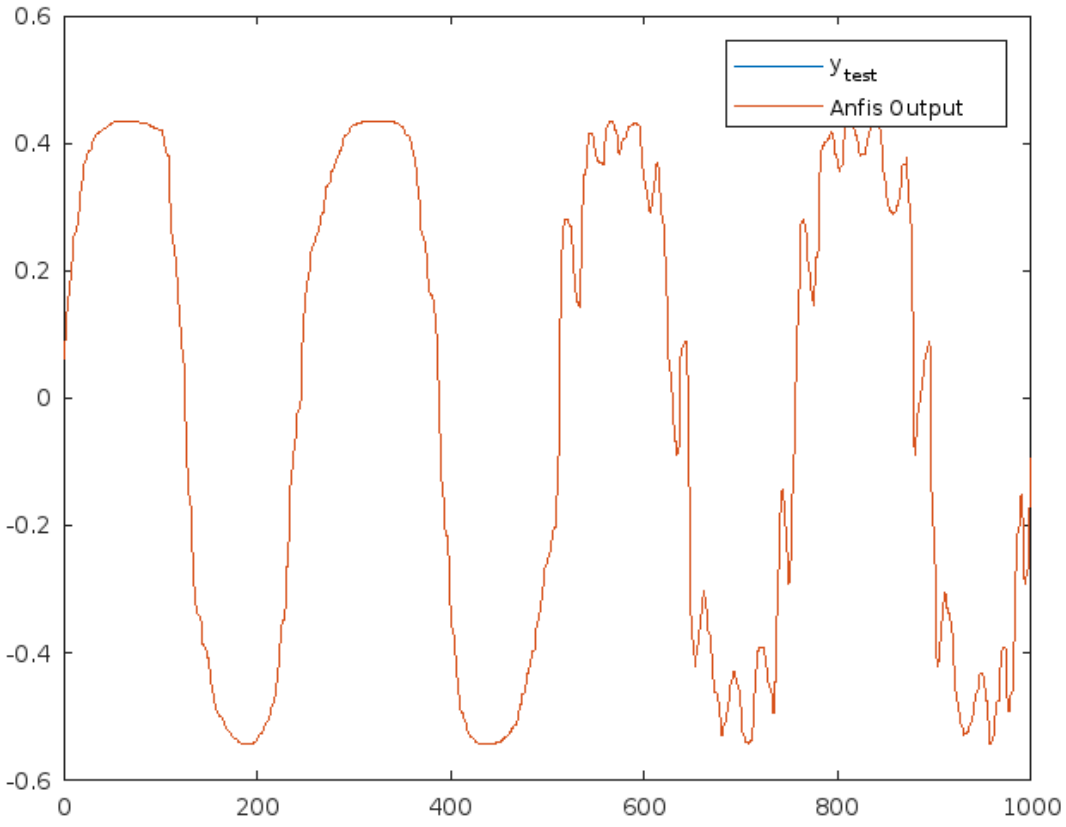


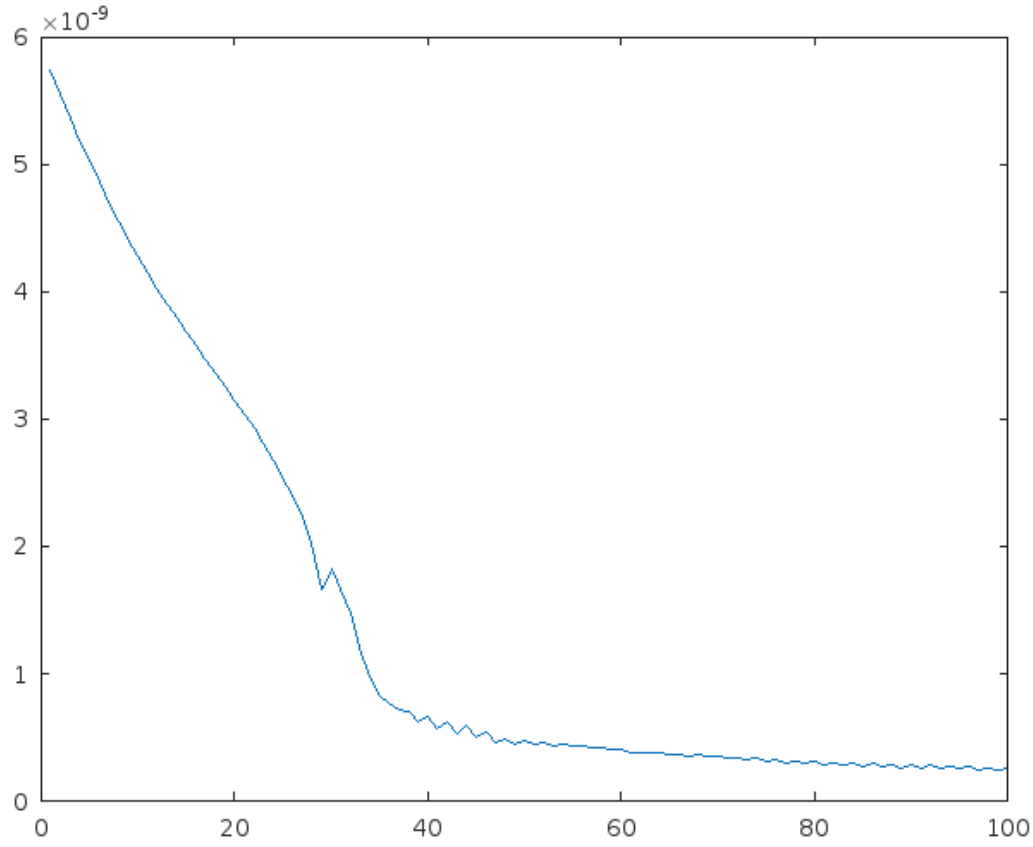
Generate FIS Using Subtractive Clustering

```
[ys, ERROR] = run_anfis(X_train, y_train, X_test, 'SubtractiveClustering');
figure(fig_number)
plot(y_test)
hold on
plot(ys)
legend('y_{test}','Anfis Output');
drawnow();
figure(fig_number+1)
plot(ERROR.^2)
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
fig_number = fig_number + 2;
```

```
ANFIS info:
 Number of nodes: 68
 Number of linear parameters: 30
 Number of nonlinear parameters: 50
 Total number of parameters: 80
 Number of training data pairs: 5074
 Number of checking data pairs: 0
```

```
 Number of fuzzy rules: 5

Minimal training RMSE = 1.57355e-05
MSE: 2.35E-10
```



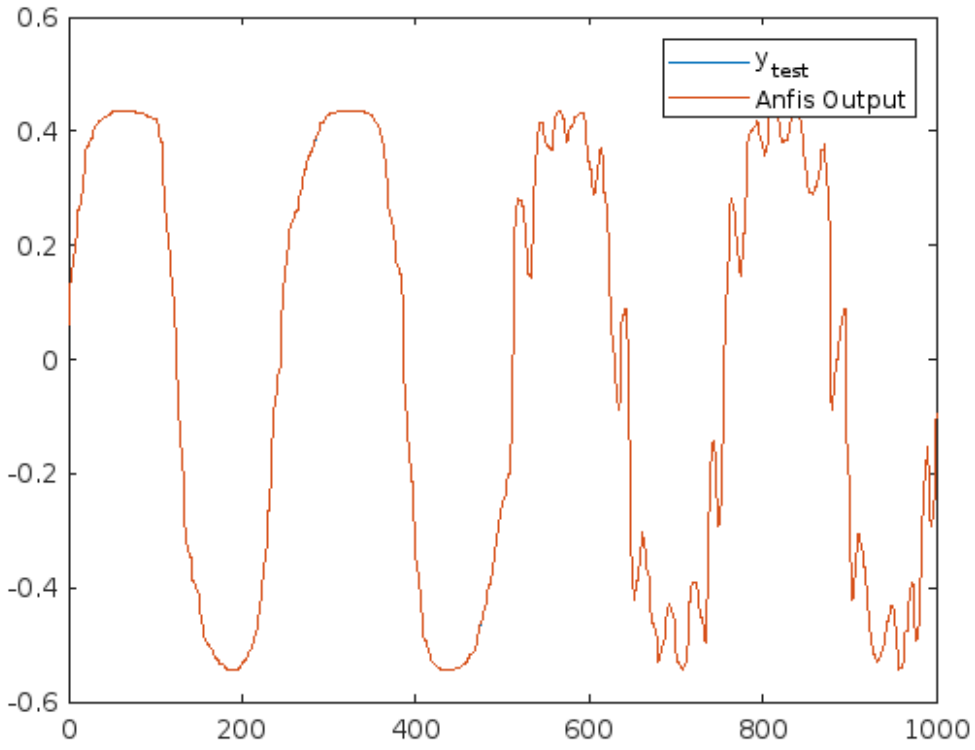


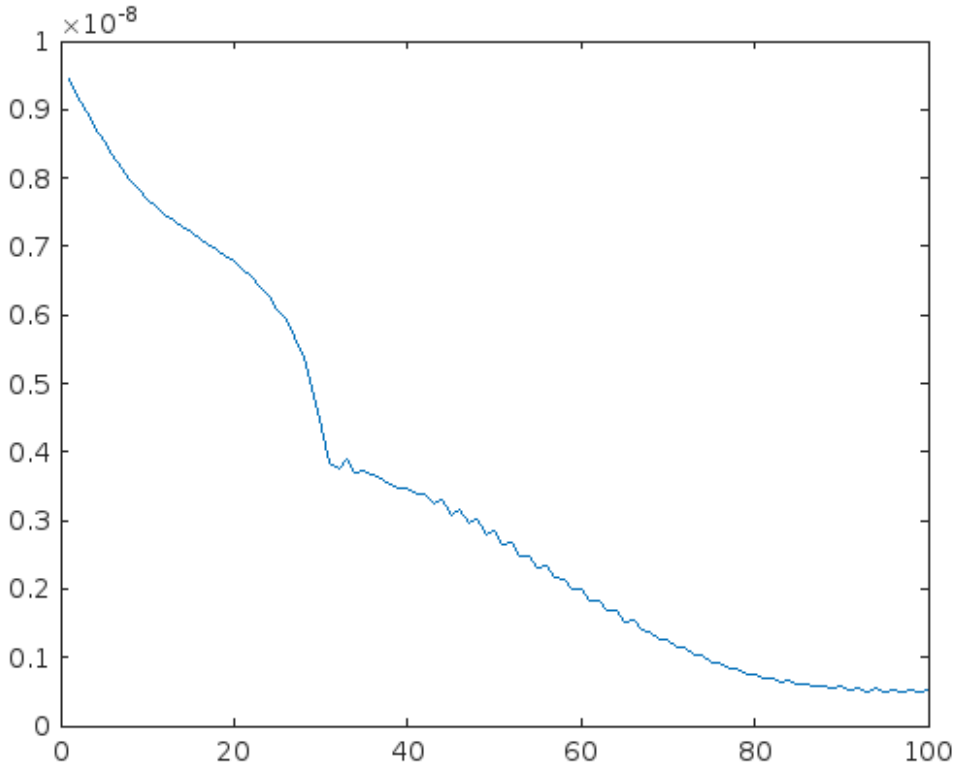
Generate FIS Using FCM Clustering

```
[ys, ERROR] =run_anfis(X_train, y_train, X_test, 'FCMClustering');
figure(fig_number)
plot(y_test)
hold on
plot(ys)
legend('y_{test}','Anfis Output');
drawnow();
figure(fig_number+1)
plot(ERROR.^2)
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
fig_number = fig_number + 2;
```

```
ANFIS info:
 Number of nodes: 68
 Number of linear parameters: 30
 Number of nonlinear parameters: 50
 Total number of parameters: 80
 Number of training data pairs: 5074
 Number of checking data pairs: 0
```

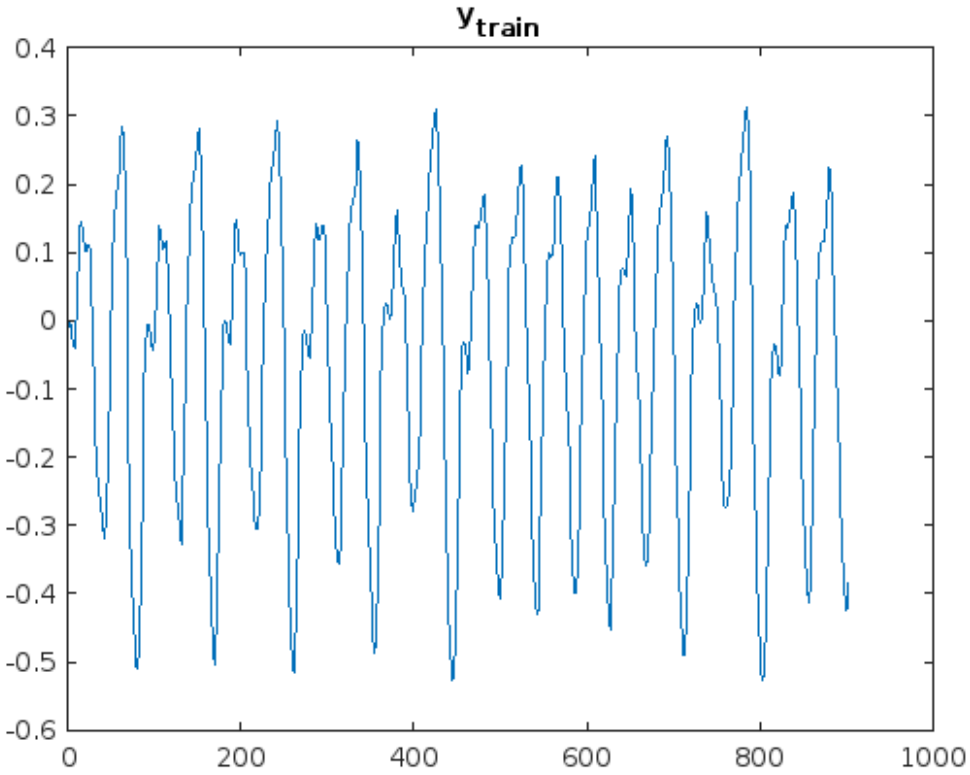
```
 Number of fuzzy rules: 5

Minimal training RMSE = 2.21524e-05
MSE: 4.83E-10
```

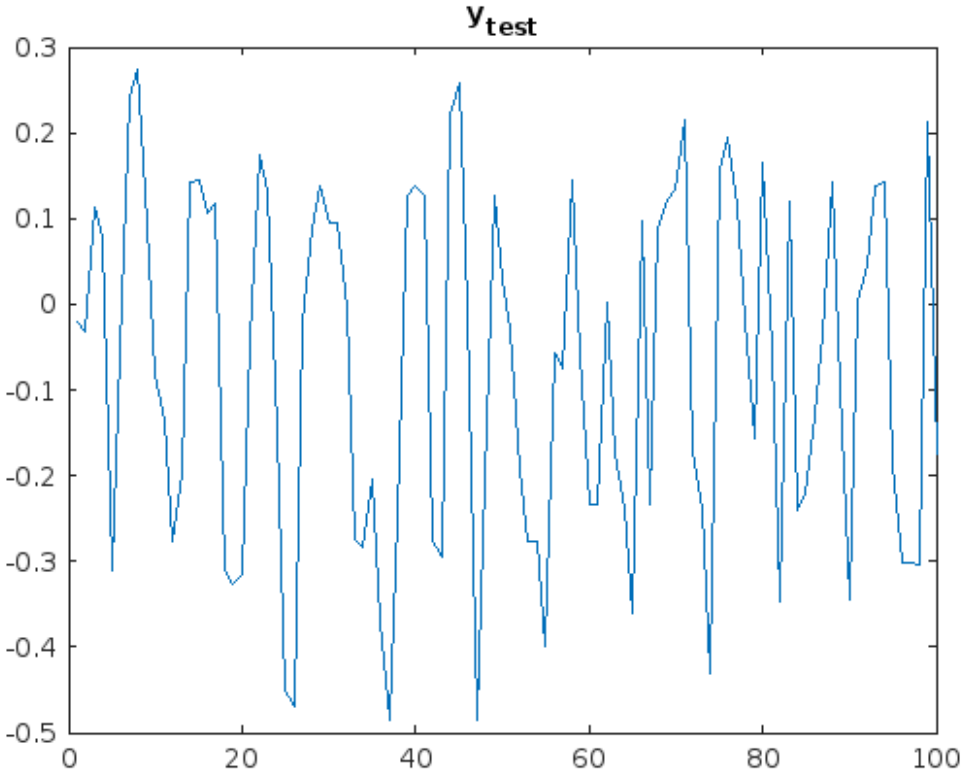




QUESTÃO 4: Previsão de uma série temporal caótica

```
%_____________________________________________________________________
X_train = table2array(readtable('ex4_X_train.csv'));
y_train = table2array(readtable('ex4_y_train.csv'));
X_test = table2array(readtable('ex4_X_test.csv'));
y_test = table2array(readtable('ex4_y_test.csv'));
figure(fig_number)
plot(y_train);
title("y_{train}");
drawnow();
fig_number = fig_number + 1;
figure(fig_number)
plot(y_test);
title("y_{test}");
drawnow();
fig_number = fig_number + 1;
```

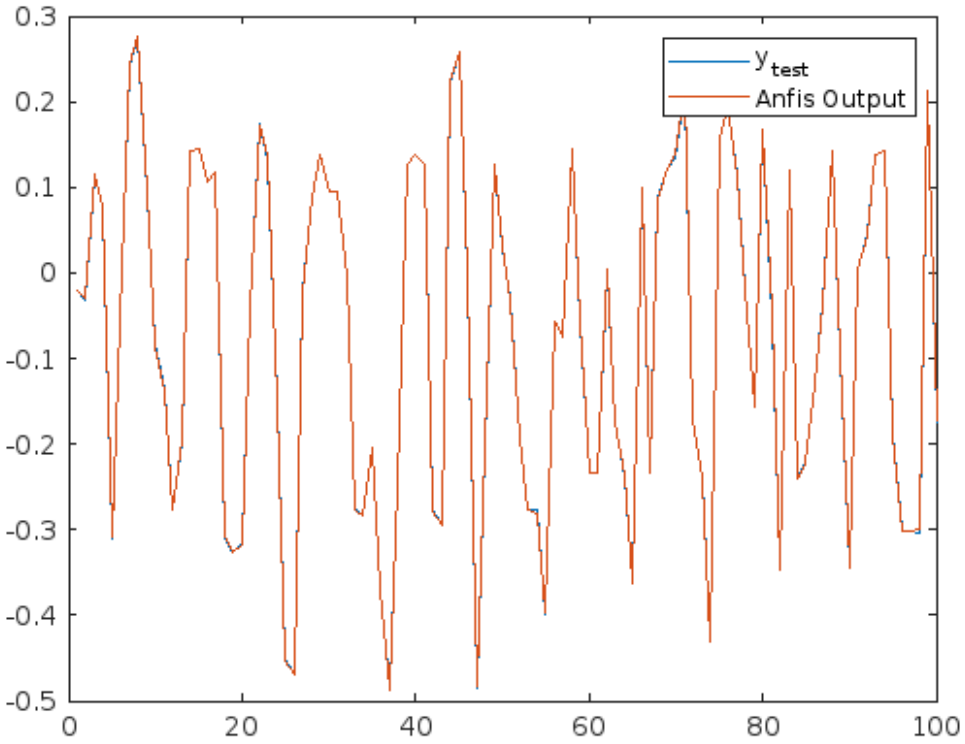

y_{train}
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
0
200
400
600
800
1000

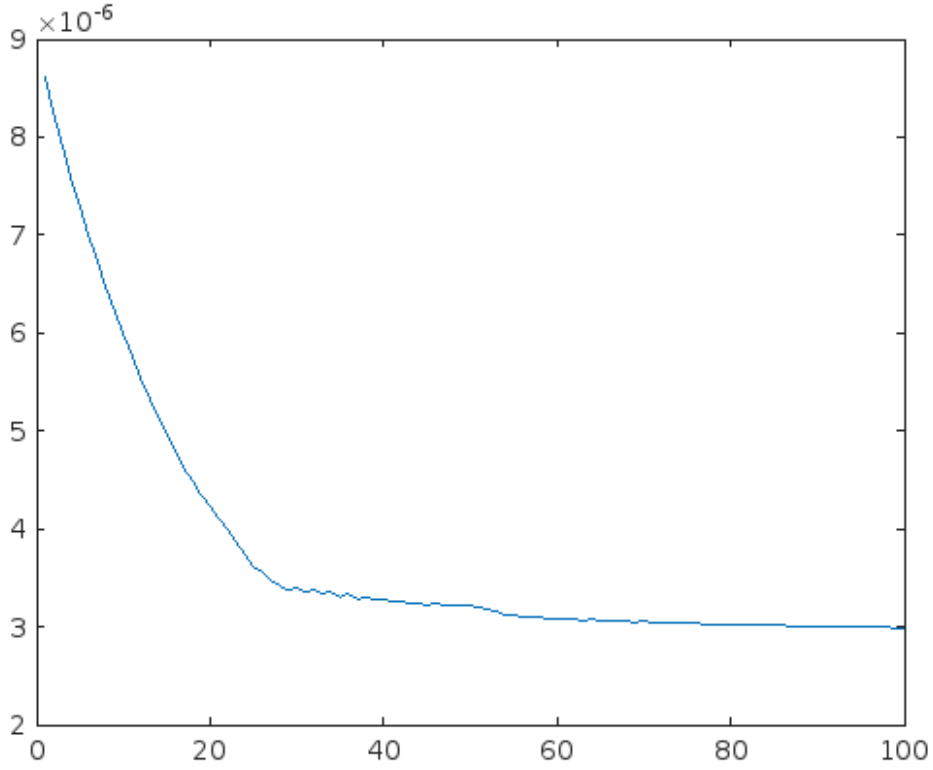

y_{test}
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
20
40
60
80
100

Generate FIS Using Grid Partitioning

```
[ys, ERROR] = run_anfis(X_train, y_train, X_test, 'GridPartition',  2);
figure(fig_number)
plot(y_test)
hold on
plot(ys)
legend('y_{test}','Anfis Output');
drawnow();
figure(fig_number+1)
plot(ERROR.^2)
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
fig_number = fig_number + 2;
```

```
ANFIS info:
 Number of nodes: 55
 Number of linear parameters: 80
 Number of nonlinear parameters: 24
 Total number of parameters: 104
 Number of training data pairs: 903
 Number of checking data pairs: 0
 Number of fuzzy rules: 16

Minimal training RMSE = 0.00172881
MSE: 2.15E-06
```

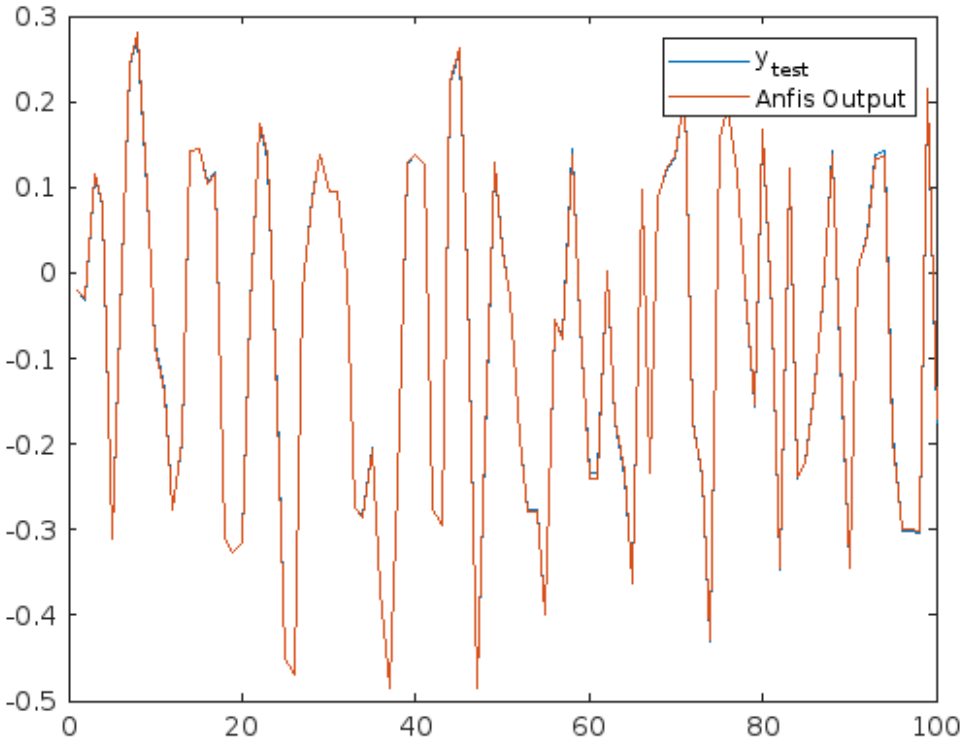

0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
20
40
60
80
100
y_{test}
Anfis Output

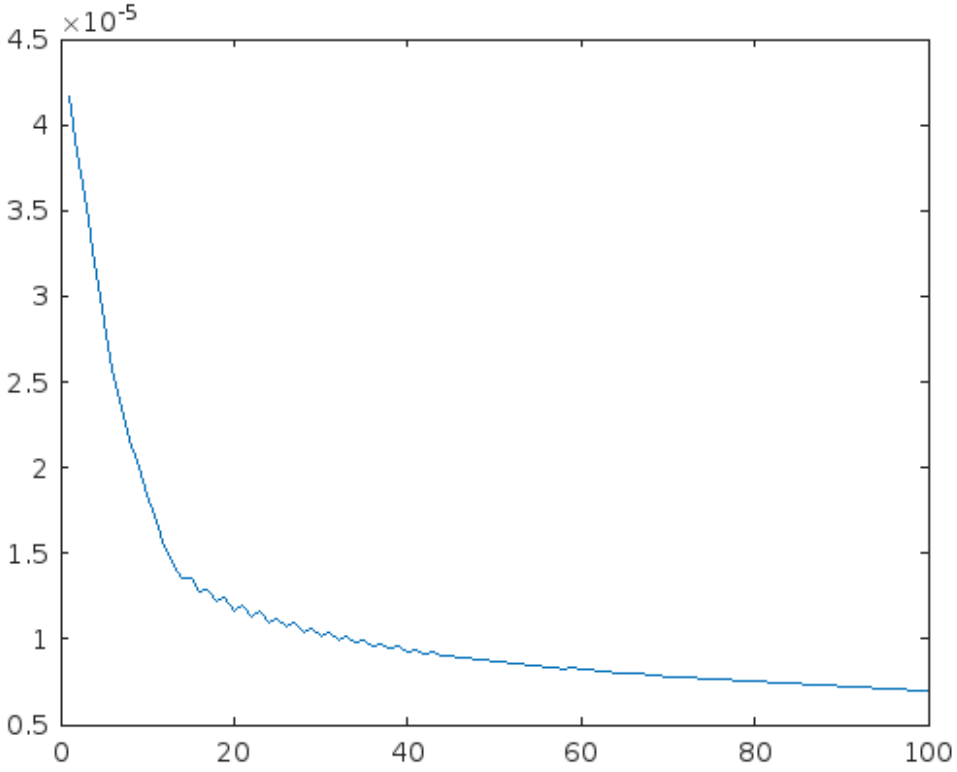

$\times 10^{-6}$
9
8
7
6
5
4
3
2
0
20
40
60
80
100

Generate FIS Using Subtractive Clustering

```
[ys, ERROR] = run_anfis(X_train, y_train, X_test, 'SubtractiveClustering');
figure(fig_number)
plot(y_test)
hold on
plot(ys)
legend('y_{test}','Anfis Output');
drawnow();
figure(fig_number+1)
plot(ERROR.^2)
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
fig_number = fig_number + 2;
```

```
ANFIS info:
 Number of nodes: 107
 Number of linear parameters: 50
 Number of nonlinear parameters: 80
 Total number of parameters: 130
 Number of training data pairs: 903
 Number of checking data pairs: 0
 Number of fuzzy rules: 10

Minimal training RMSE = 0.00264106
MSE: 7.95E-06
```

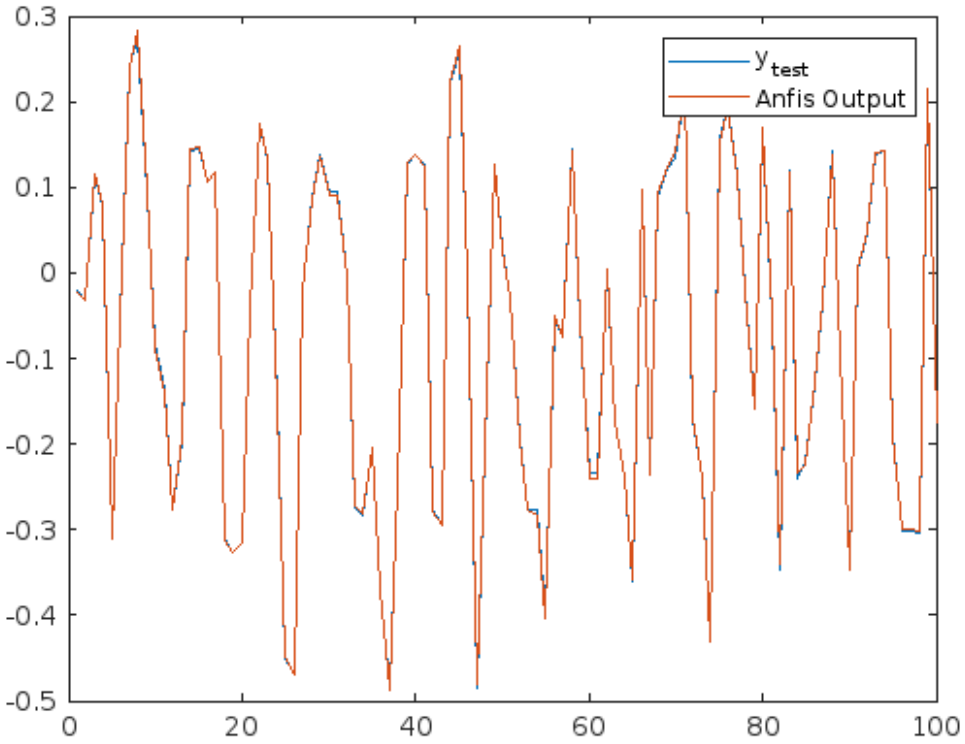

0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
20
40
60
80
100
y test
Anfis Output

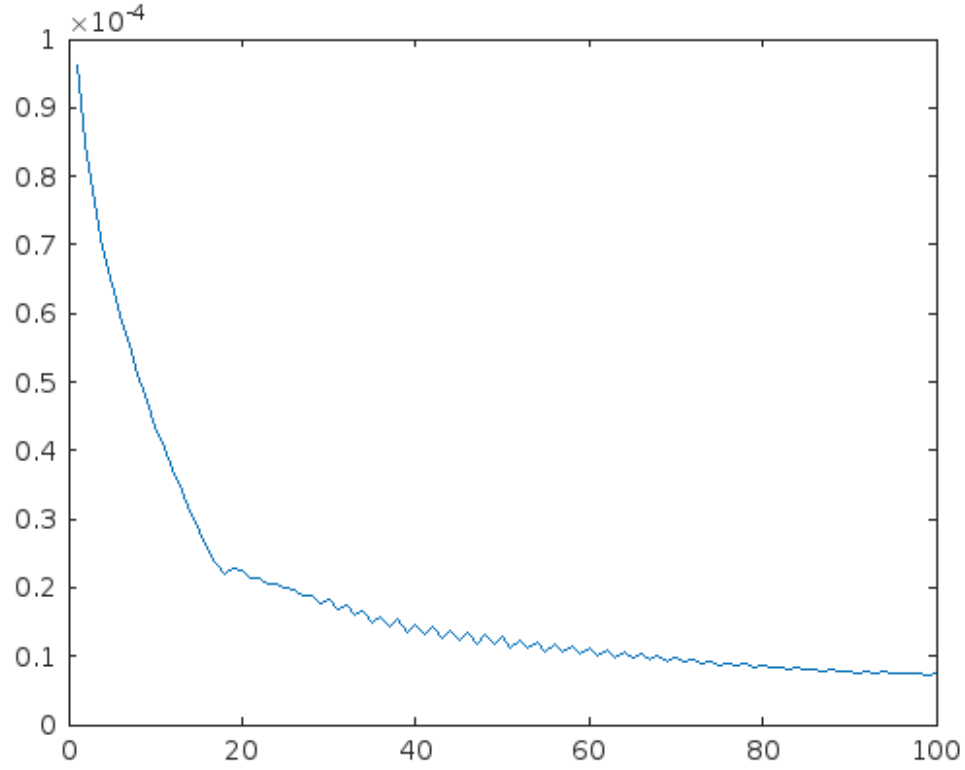

×10-5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
20
40
60
80
100

Generate FIS Using FCM Clustering

```
[ys, ERROR] =run_anfis(X_train, y_train, X_test, 'FCMClustering');
figure(fig_number)
plot(y_test)
hold on
plot(ys)
legend('y_{test}','Anfis Output');
drawnow();
figure(fig_number+1)
plot(ERROR.^2)
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
fig_number = fig_number + 2;
```

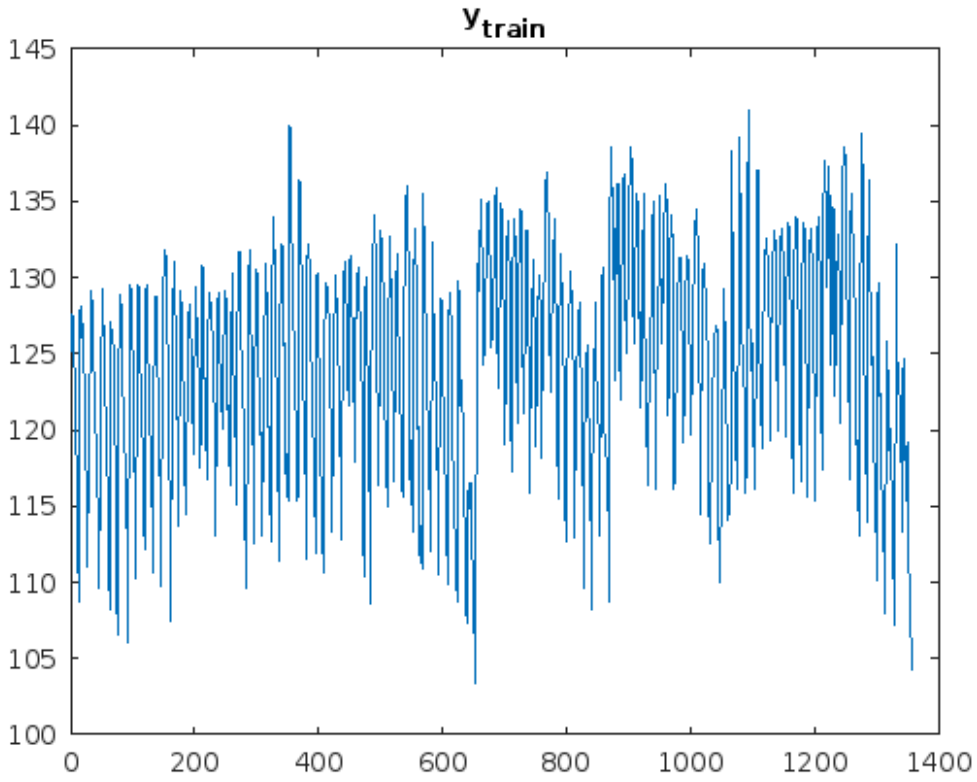
```
ANFIS info:
 Number of nodes: 107
 Number of linear parameters: 50
 Number of nonlinear parameters: 80
 Total number of parameters: 130
 Number of training data pairs: 903
 Number of checking data pairs: 0
 Number of fuzzy rules: 10

Minimal training RMSE = 0.00270777
MSE: 8.89E-06
```

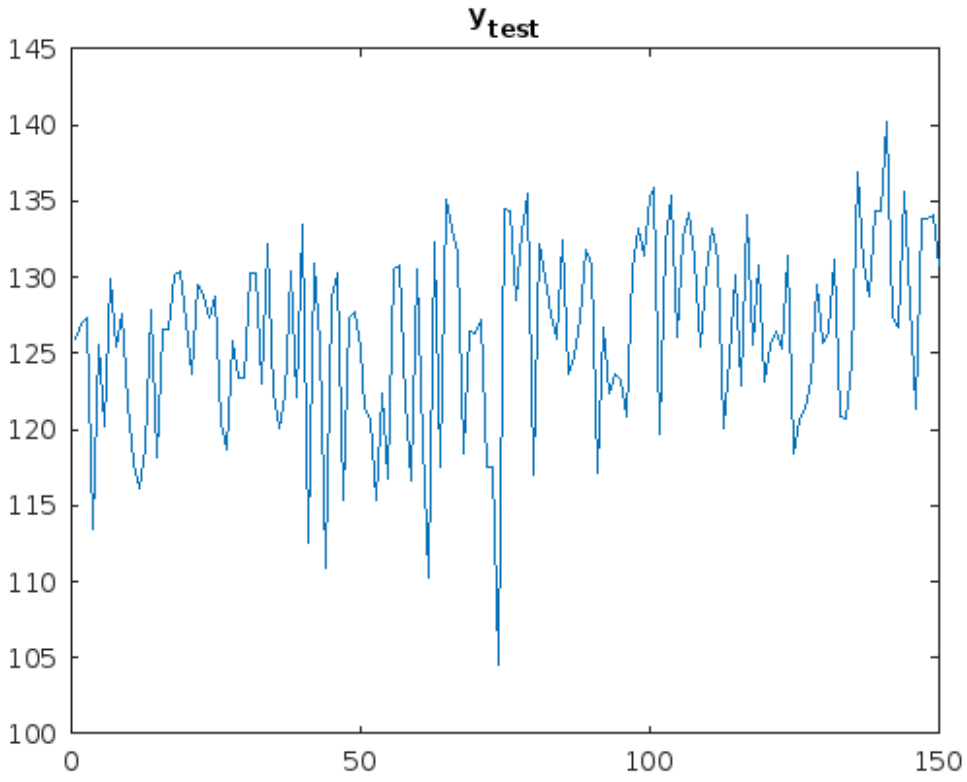

y test
Anfis Output
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
20
40
60
80
100


×10-4
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100

QUESTÃO 5: Data set UCI

```
%_____________________________________________________________________
X_train = table2array(readtable('ex5_X_train.csv'));
y_train = table2array(readtable('ex5_y_train.csv'));
X_test = table2array(readtable('ex5_X_test.csv'));
y_test = table2array(readtable('ex5_y_test.csv'));
figure(fig_number)
plot(y_train);
title("y_{train}");
drawnow();
fig_number = fig_number + 1;
figure(fig_number)
plot(y_test);
title("y_{test}");
drawnow();
fig_number = fig_number + 1;
```



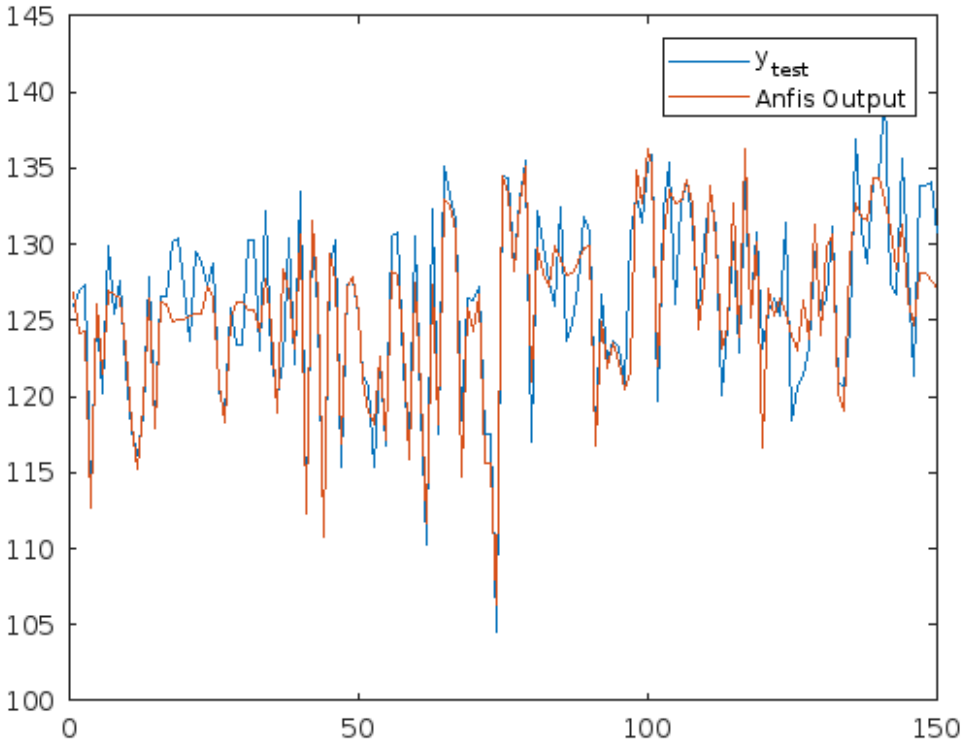


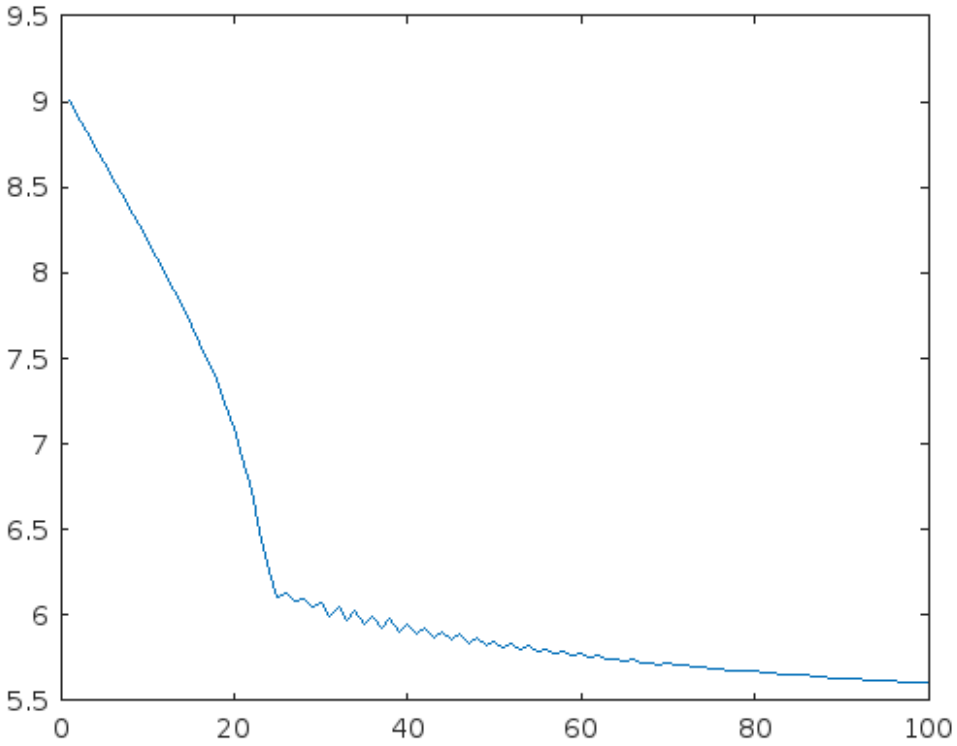
Generate FIS Using Grid Partitioning

```
[ys, ERROR] = run_anfis(X_train, y_train, X_test, 'GridPartition',  2);
figure(fig_number)
plot(y_test)
hold on
plot(ys)
legend('y_{test}','Anfis Output');
drawnow();
figure(fig_number+1)
plot(ERROR.^2)
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
fig_number = fig_number + 2;
```

```
ANFIS info:
 Number of nodes: 92
 Number of linear parameters: 192
 Number of nonlinear parameters: 30
 Total number of parameters: 222
 Number of training data pairs: 1358
 Number of checking data pairs: 0
 Number of fuzzy rules: 32

Minimal training RMSE = 2.36704
```

MSE: 7.31E+00


145
140
135
130
125
120
115
110
105
100
0
50
100
150
y test
Anfis Output

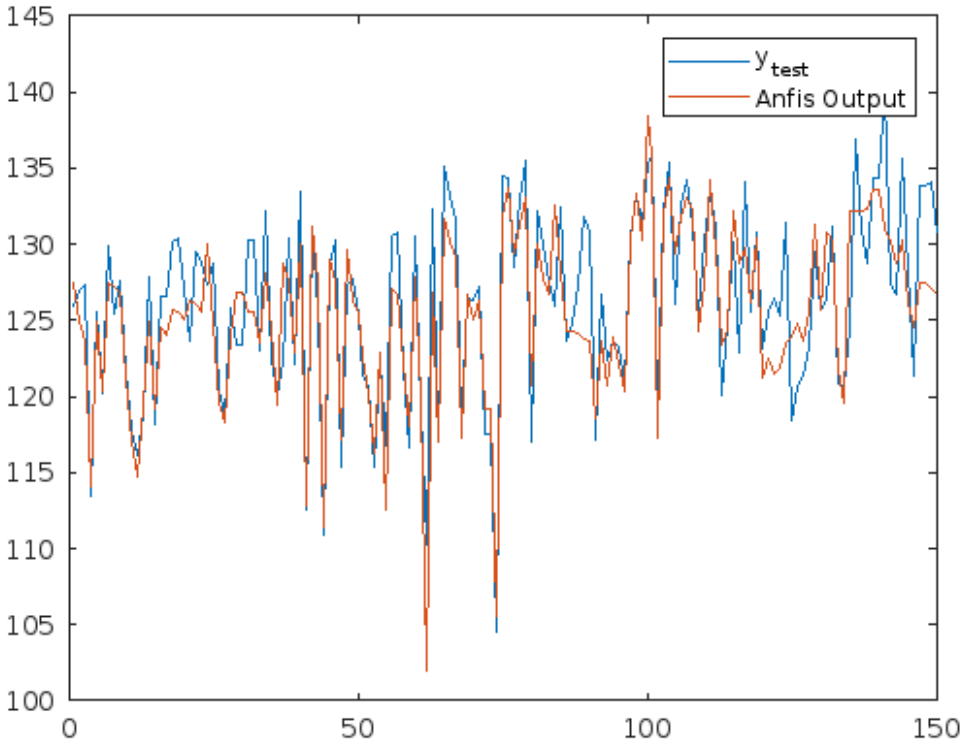


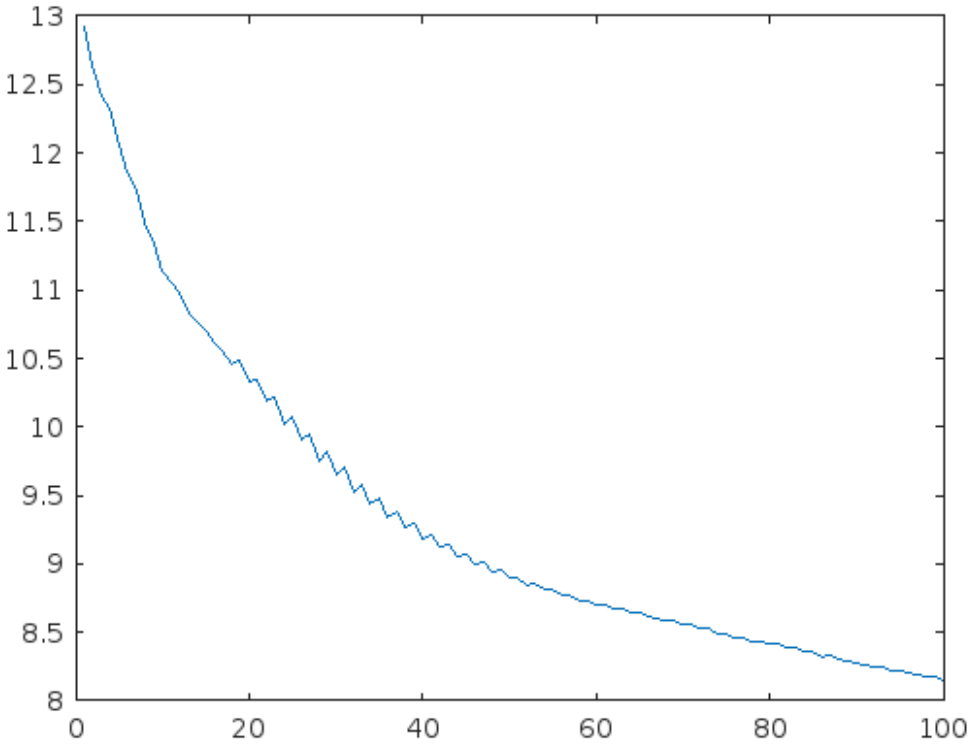
Generate FIS Using Subtractive Clustering

```
[ys, ERROR] = run_anfis(X_train, y_train, X_test, 'SubtractiveClustering');
figure(fig_number)
plot(y_test)
hold on
plot(ys)
legend('y_{test}','Anfis Output');
drawnow();
figure(fig_number+1)
plot(ERROR.^2)
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
fig_number = fig_number + 2;
```

```
ANFIS info:
 Number of nodes: 200
 Number of linear parameters: 96
 Number of nonlinear parameters: 160
 Total number of parameters: 256
 Number of training data pairs: 1358
 Number of checking data pairs: 0
 Number of fuzzy rules: 16

Minimal training RMSE = 2.85522
```

MSE: 9.74E+00


145
140
135
130
125
120
115
110
105
100
0
50
100
150
y test
Anfis Output

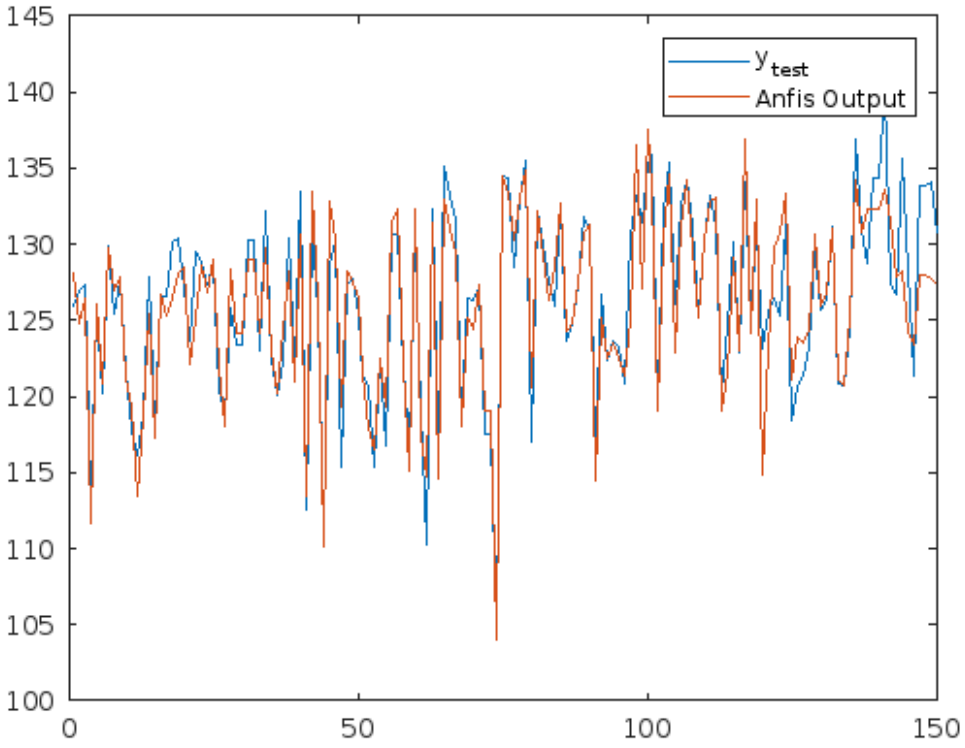


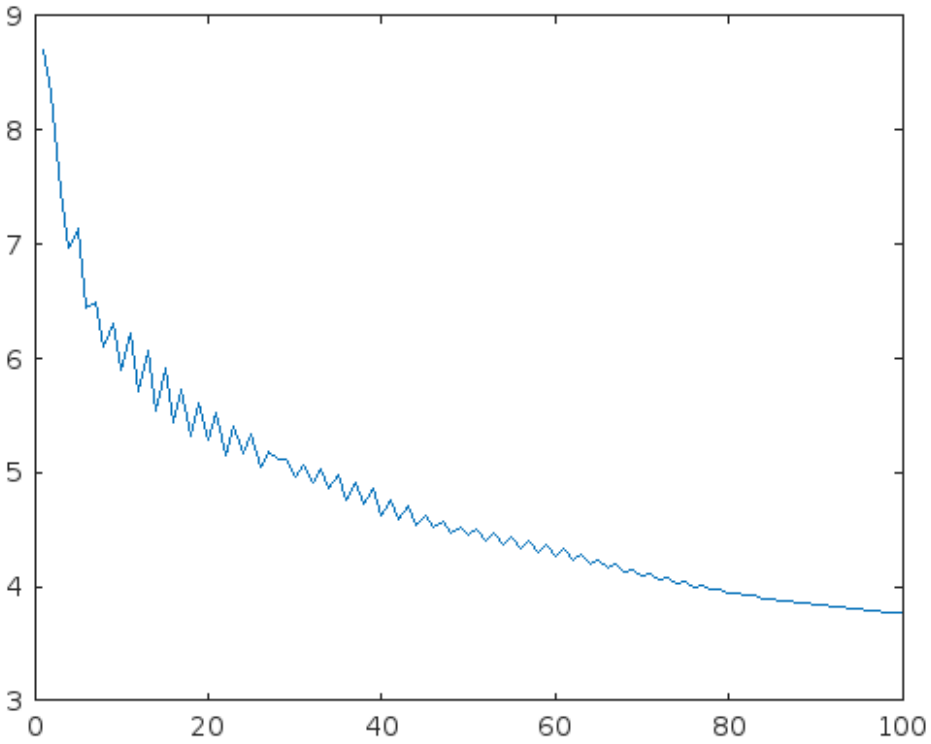
Generate FIS Using FCM Clustering

```
[ys, ERROR] =run_anfis(X_train, y_train, X_test, 'FCMClustering');
figure(fig_number)
plot(y_test)
hold on
plot(ys)
legend('y_{test}','Anfis Output');
drawnow();
figure(fig_number+1)
plot(ERROR.^2)
drawnow();
fprintf('MSE: %.2E', immse(ys,y_test));
fig_number = fig_number + 2;
```

```
ANFIS info:
 Number of nodes: 200
 Number of linear parameters: 96
 Number of nonlinear parameters: 160
 Total number of parameters: 256
 Number of training data pairs: 1358
 Number of checking data pairs: 0
 Number of fuzzy rules: 16

Minimal training RMSE = 1.94068
```

MSE: 5.54E+00


145
140
135
130
125
120
115
110
105
100
0
50
100
150
y test
Anfis Output



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