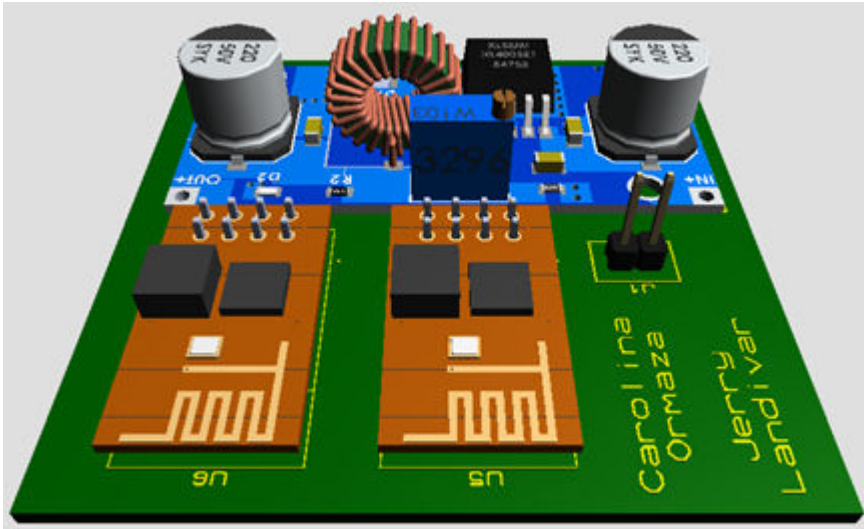


Trilateration based on RSSI values in transmitters and receivers

Jerry Landivar G., Carolina Ormaza C., Víctor Asanza, Verónica Ojeda C., Juan Carlos Aviles

- Main Code: https://github.com/vasanza/WiFi_RSSI_Localization
- SRC: https://github.com/vasanza/Matlab_Code
- DataPort: <https://dx.doi.org/10.21227/kjta-6551>
- Reference:



1- Load Raw Data

```
clear;clc;%clear all
%Prepare the raw dataset
addpath(genpath('./src'))%functions folders
datapath = fullfile('./data/');%data folder
filenames = FindCSV(datapath);%List All CSV files
allData=[];
for i=1:length(filenames)% Through all files
    data=readtable(fullfile(datapath,filenames(i).name));%Select i CSV file
    data=[data(2:size(data,1),1:3) data(2:size(data,1),5:104)];
    dataNew=table2array(data);% Array Double
    dataNew(isnan(dataNew)) = 0;%Remove NAN numbers

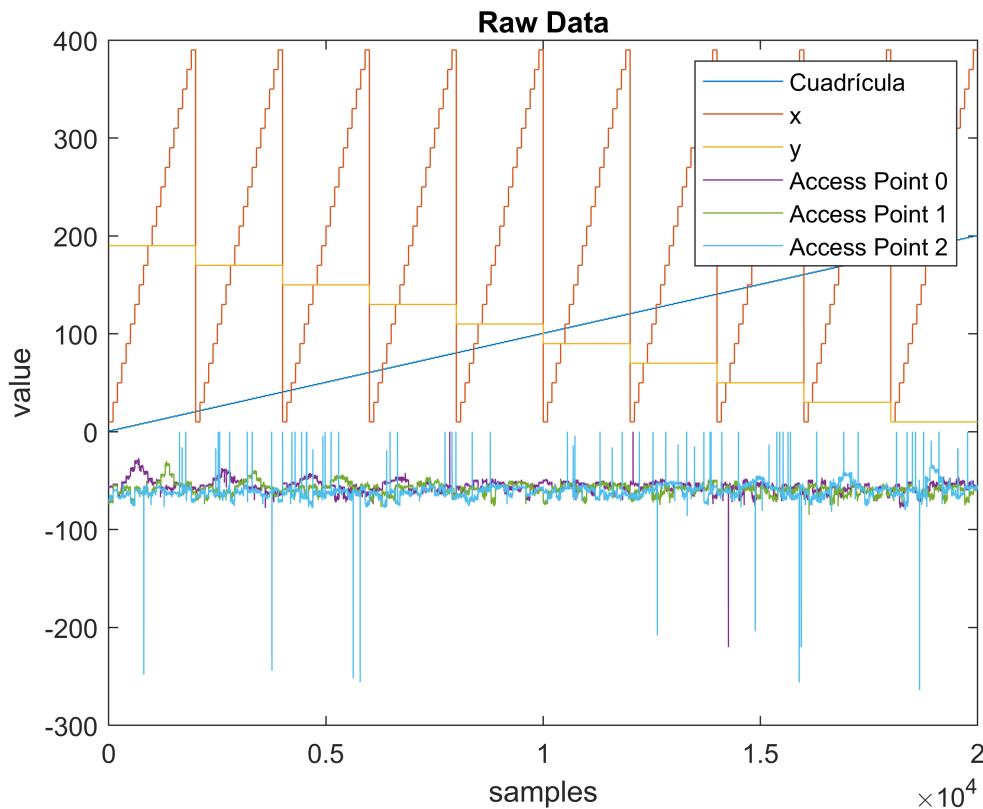
    for j=1:3:length(dataNew)-2
        AP0=dataNew(j,4:103);
        AP1=dataNew(j+1,4:103);
        AP2=dataNew(j+2,4:103);
        Q=dataNew(j,1)*ones([1,length(AP0)]);
        x=dataNew(j,2)*ones([1,length(AP0)]);
        y=dataNew(j,3)*ones([1,length(AP0)]);
        DataColum=[Q' x' y' AP0' AP1' AP2'];
        allData=[allData;DataColum];
    end
end
```

```
%Example
%Cuadrícula, X, Y, AP0, AP1, AP2
%1,10,190,56,-74,-69
%.
%.
%%1,10,190,21,-25,-32

clear data i AP0 AP1 AP2 Q x y j DataColumn dataNew
```

2- Plot Raw Data (Dataset)

```
figure
plot(allData(:,:));title('Raw Data');xlabel('samples');ylabel('value');
%Cuadrícula; x; y; Access Point 0; Access Point 1; Access Point 2
legend('Cuadrícula', 'x', 'y', 'Access Point 0', 'Access Point 1', 'Access Point 2');
```



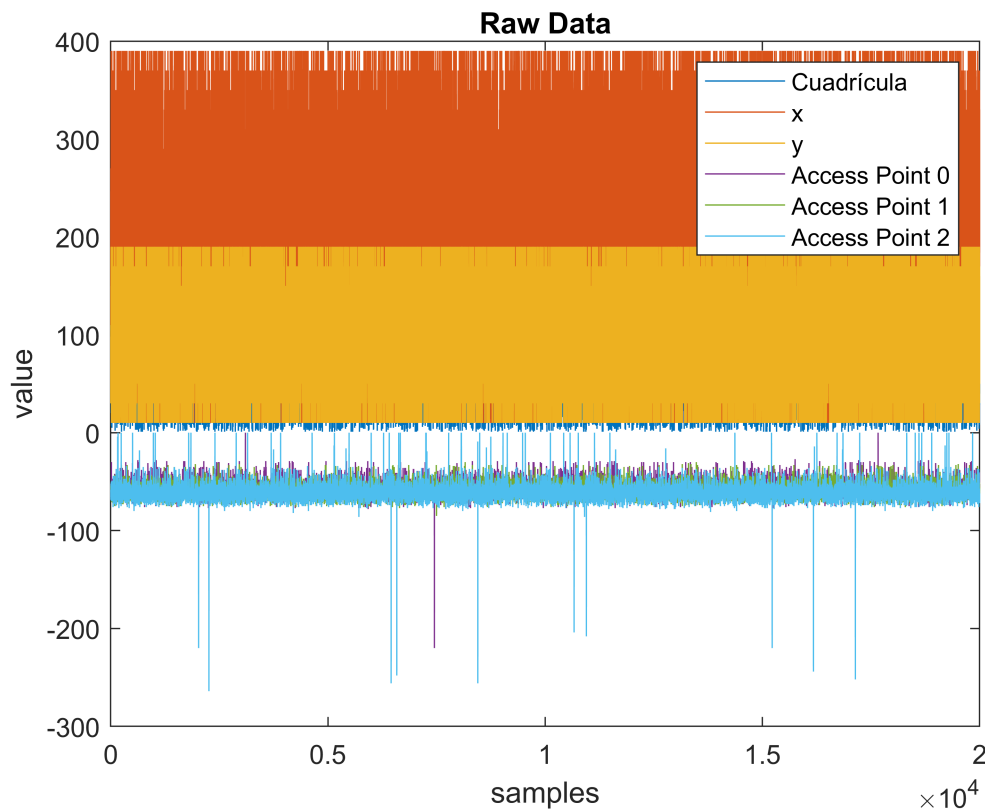
```
clear legend filenames datapath
```

3- Randomize rows

```
[RallData, IndexRows]=fRandomize_DataRows(allData);

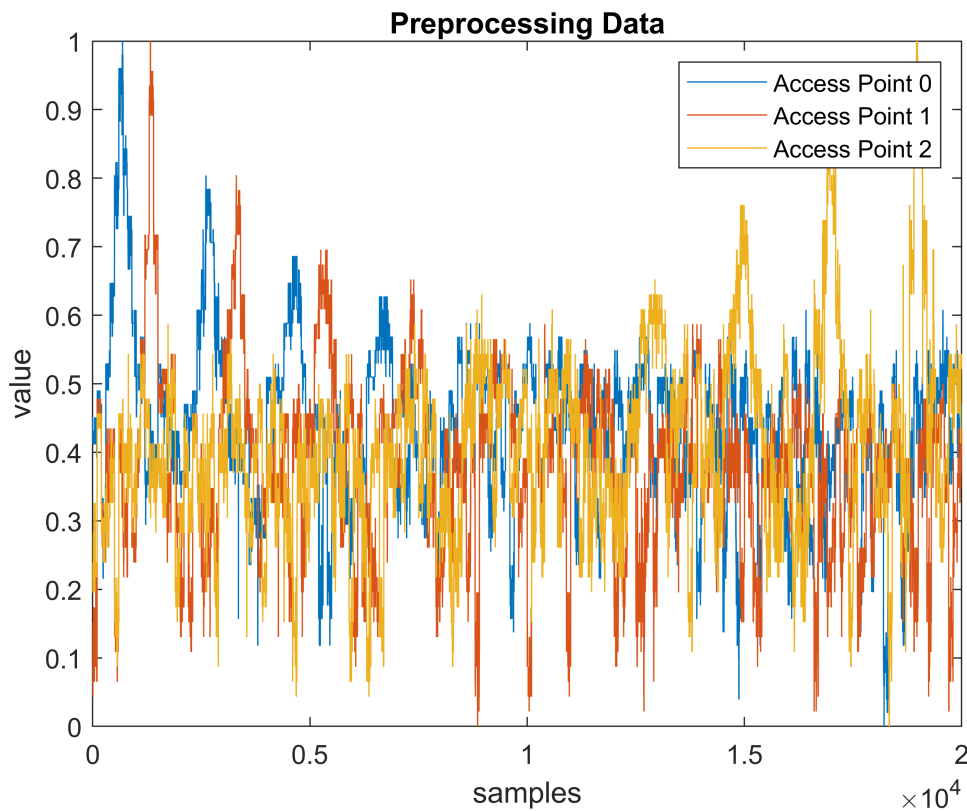
figure
plot(RallData(:,:));title('Raw Data');xlabel('samples');ylabel('value');
%Cuadrícula; x; y; Access Point 0; Access Point 1; Access Point 2
```

```
legend('Cuadrícula', 'x', 'y', 'Access Point 0', 'Access Point 1', 'Access Point 2');
```



4- Preprocessing Raw Data (Filtering and Normalization)

```
InputData=[];
for i=1:100:size(allData(:,4:6),1)-99
    InputData = [InputData; [hampel(allData(i:i+99,4)) hampel(allData(i:i+99,5)) hampel(allData(i:i+99,6))]];
end
DeNormMax=max(InputData(:,,:));
DeNormMin=min(InputData(:,,:));
InputDataNorm = fNormalization(InputData(:,,:));%Data Normalization
% Access Point 0; Access Point 1; Access Point 2
Output = allData(:,1:3);%Data Output -> Cuadrícula; x; y;
plot(InputDataNorm(:,,:));title('Preprocessing Data');xlabel('samples');ylabel('value');
legend('Access Point 0', 'Access Point 1', 'Access Point 2');
```



```
clear DataColumn i allData
```

[5] - Feature Extraction (RSSI measurements have already been averaged)

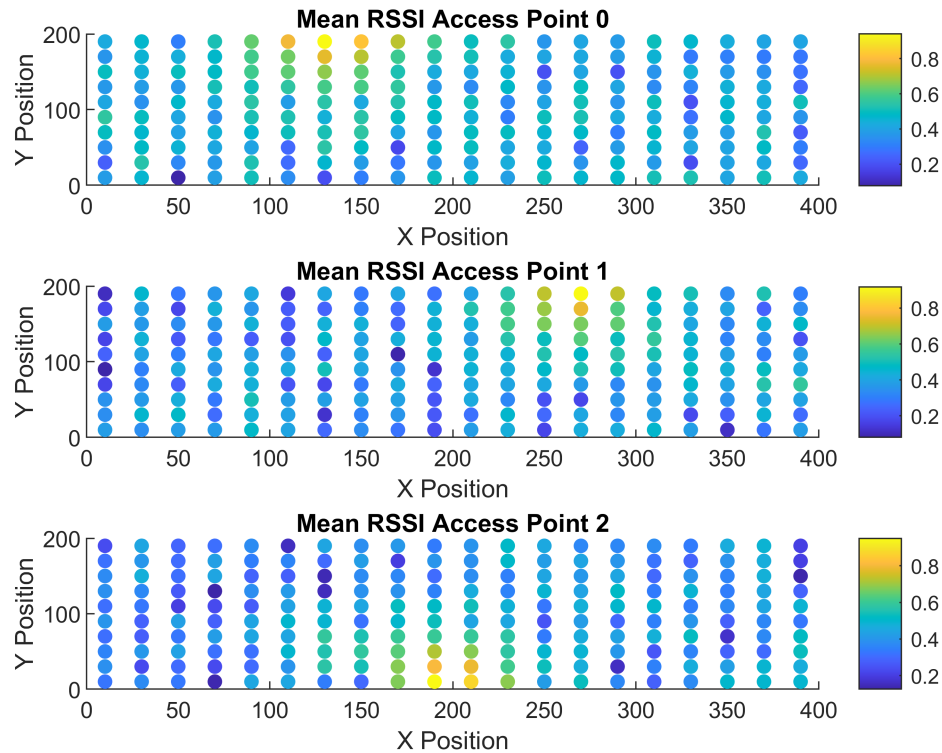
```
%Prepare the raw dataset
allDataMean=[];x=[];y=[];
for i=1:100:size(InputDataNorm,1)-99
    DataMean = mean(InputDataNorm(i:i+99,:));
    %DataMean = mean(InputData(i:i+99,:));
    allDataMean=[allDataMean;DataMean];
    x=[x;Output(i,2)];
    y=[y;Output(i,3)];
end

figure
subplot(3,1,1);AP=0;
z=allDataMean(:,AP+1);
scatter(x,y,30,z,'filled');
title('Mean RSSI Access Point 0');xlabel('X Position');zlabel('Mean RSSI');ylabel('Y Position');
colorbar()
subplot(3,1,2);AP=1;
z=allDataMean(:,AP+1);
scatter(x,y,30,z,'filled');
title('Mean RSSI Access Point 1');xlabel('X Position');zlabel('Mean RSSI');ylabel('Y Position');
```

```

colorbar()
subplot(3,1,3);AP=2;
z=allDataMean(:,AP+1);
scatter(x,y,30,z,'filled');
title('Mean RSSI Access Point 2');xlabel('X Position');ylabel('Y Position');
colorbar()

```



```

clear i NewFeaturesLabels DataMean AP x y z

```

6- Statital Features Information

```

%'Mean RSSI Access Point 0'
AP0s = datastats(allDataMean(:,1))

```

```

AP0s = struct with fields:
    num: 200
    max: 0.9412
    min: 0.0771
    mean: 0.4394
    median: 0.4403
    range: 0.8641
    std: 0.1157

```

```

%'Mean RSSI Access Point 1'
AP1s = datastats(allDataMean(:,2))

```

```

AP1s = struct with fields:
    num: 200
    max: 0.9185

```

```
min: 0.0800
mean: 0.3800
median: 0.3909
range: 0.8385
std: 0.1268
```

```
%'Mean RSSI Access Point 3'
```

```
AP2s = datastats(allDataMean(:,3))
```

```
AP2s = struct with fields:
```

```
num: 200
max: 0.9504
min: 0.1278
mean: 0.4095
median: 0.3991
range: 0.8226
std: 0.1308
```

```
clear AP0s AP1s AP2s
```

7 - Feature Selection (Please set the maximum correlation value allowed.)

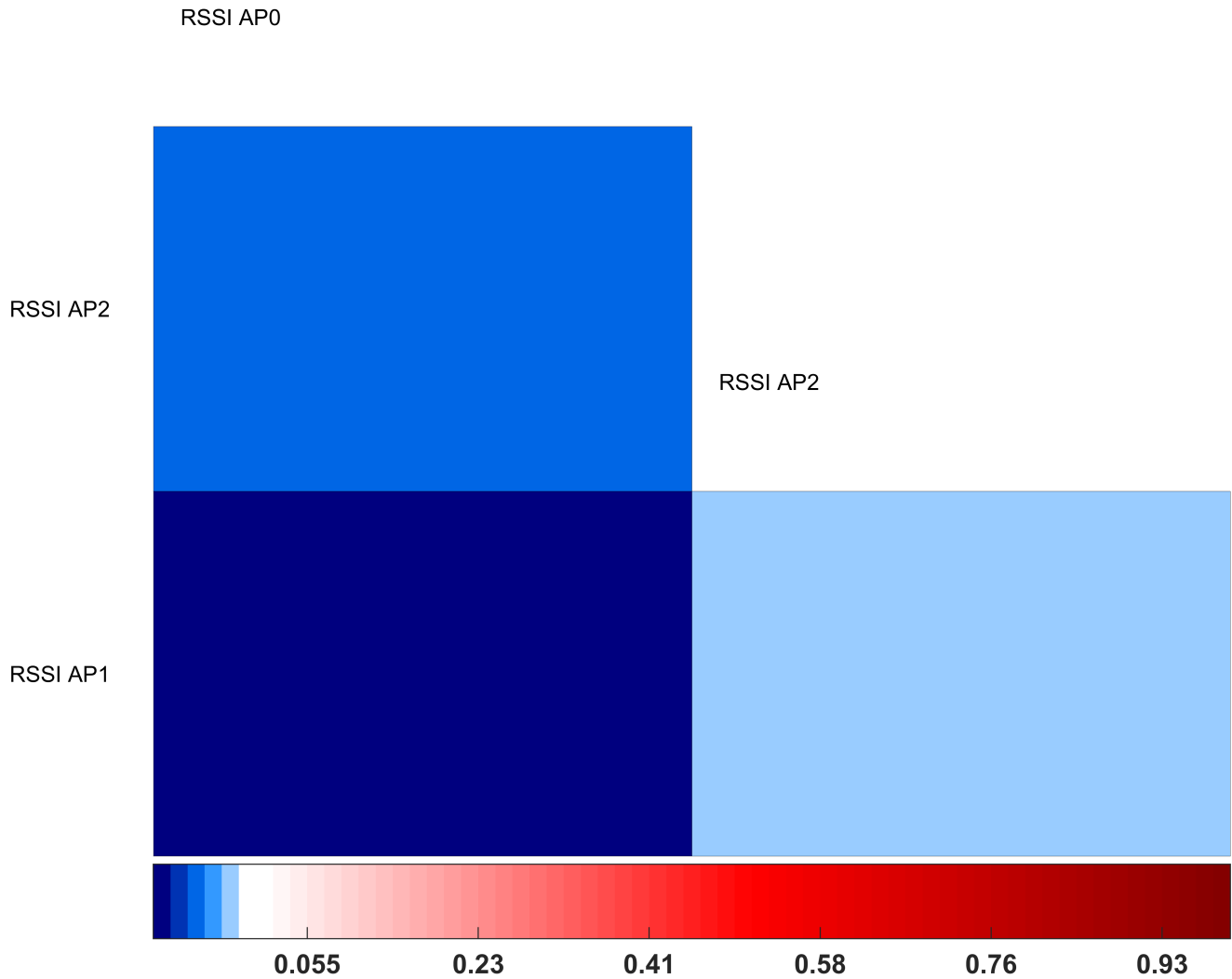
```
threshold = 0.75;%75<-----Maximum correlation value allowed
```

```
% Labels
```

```
FeaturesLabels = {'RSSI AP0','RSSI AP1','RSSI AP2'};
```

```
[NewDataFeatures,NewFeaturesLabels,LabelsRemove] = Feature_Selection(InputDataNorm,FeaturesLabels,threshold);
```

Electrical Consumption Parameters



```
LabelsRemove(:)
```

```
ans =
```

```
0×1 empty cell array
```

```
clear threshold LabelsRemove ans allFeatureNorm FeaturesLabels NewFeaturesLabels
```

8 - Regression Learner (Input output Data)

```
training_size=0.85; %85 (Training and testing), 15% Validation
```

```
%-----Randomly arrange rows-----
```

```

RandomNewDataFeatures=NewDataFeatures(IndexRows,:);
RandomOutput=Output(IndexRows,:);
% -----inputs: All previously selected features-----
input_train=RandomNewDataFeatures(1:round(size(RandomNewDataFeatures,1)*training_size)-1,:);

% -----output: Energy in the next time step-----
output_train_x=RandomOutput(1:round(size(RandomOutput,1)*training_size)-1,2);%column 2 is x
output_train_y=RandomOutput(1:round(size(RandomOutput,1)*training_size)-1,3);%column 3 is y

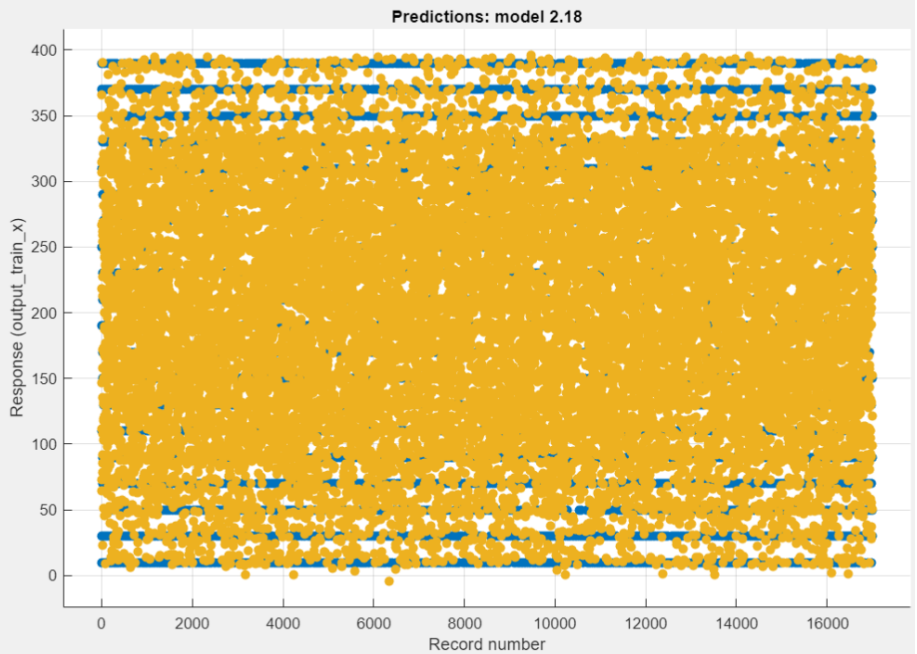
%regressionLearner
clear allDataMean InputDataNorm InputData Output NewDataFeatures

```

RMSE (Training) - X position:

<div>☆ 2.1 Linear Regression</div> <div>RMSE (Validation): 107.57</div> <div>Last change: Linear 3/3 features</div>	<div>☆ 2.13 SVM</div> <div>RMSE (Validation): 105.85</div> <div>Last change: Coarse Gaussian SVM 3/3 features</div>
<div>☆ 2.2 Linear Regression</div> <div>RMSE (Validation): 107.1</div> <div>Last change: Interactions Linear 3/3 features</div>	<div>☆ 2.14 Ensemble</div> <div>RMSE (Validation): 94.493</div> <div>Last change: Boosted Trees 3/3 features</div>
<div>☆ 2.3 Linear Regression</div> <div>RMSE (Validation): 107.58</div> <div>Last change: Robust Linear 3/3 features</div>	<div>☆ 2.15 Ensemble</div> <div>RMSE (Validation): 77.991</div> <div>Last change: Bagged Trees 3/3 features</div>
<div>☆ 2.4 Stepwise Linear Regression</div> <div>RMSE (Validation): 107.08</div> <div>Last change: Stepwise Linear 3/3 features</div>	<div>☆ 2.16 Gaussian Process Regre...</div> <div>RMSE (Validation): 76.756</div> <div>Last change: Squared Exponential GPR 3/3 features</div>
<div>☆ 2.5 Tree</div> <div>RMSE (Validation): 75.055</div> <div>Last change: Fine Tree 3/3 features</div>	<div>☆ 2.17 Gaussian Process Regress...</div> <div>RMSE (Validation): 73.77</div> <div>Last change: Matern 5/2 GPR 3/3 features</div>
<div>☆ 2.6 Tree</div> <div>RMSE (Validation): 77.284</div> <div>Last change: Medium Tree 3/3 features</div>	<div>☆ 2.18 Gaussian Process Regre...</div> <div>RMSE (Validation): 70.454</div> <div>Last change: Exponential GPR 3/3 features</div>
<div>☆ 2.7 Tree</div> <div>RMSE (Validation): 82.509</div> <div>Last change: Coarse Tree 3/3 features</div>	<div>☆ 2.19 Gaussian Process Regression</div> <div>Canceled</div> <div>Last change: Rational Quadratic GPR 3/3 features</div>
<div>☆ 2.8 SVM</div> <div>RMSE (Validation): 108.04</div> <div>Last change: Linear SVM 3/3 features</div>	<div>☆ 2.20 Neural Network</div> <div>RMSE (Validation): 103.63</div> <div>Last change: Narrow Neural Network 3/3 features</div>
<div>☆ 2.9 SVM</div> <div>RMSE (Validation): 108.79</div> <div>Last change: Quadratic SVM 3/3 features</div>	<div>☆ 2.21 Neural Network</div> <div>RMSE (Validation): 98.19</div> <div>Last change: Medium Neural Network 3/3 features</div>
<div>☆ 2.10 SVM</div> <div>RMSE (Validation): 105.63</div> <div>Last change: Cubic SVM 3/3 features</div>	<div>☆ 2.22 Neural Network</div> <div>Canceled</div> <div>Last change: Wide Neural Network 3/3 features</div>
<div>☆ 2.11 SVM</div> <div>RMSE (Validation): 78.583</div> <div>Last change: Fine Gaussian SVM 3/3 features</div>	<div>☆ 2.23 Neural Network</div> <div>RMSE (Validation): 95.533</div> <div>Last change: Bilayered Neural Network 3/3 features</div>
<div>☆ 2.12 SVM</div> <div>RMSE (Validation): 94.489</div> <div>Last change: Medium Gaussian SVM 3/3 features</div>	<div>☆ 2.24 Neural Network</div> <div>Canceled</div> <div>Last change: Trilayered Neural Network 3/3 features</div>
<div>☆ 2.25 Kernel</div> <div>RMSE (Validation): 104.47</div> <div>Last change: SVM Kernel 3/3 features</div>	
<div>☆ 2.26 Kernel</div> <div>RMSE (Validation): 98.693</div> <div>Last change: Least Squares Regression Kernel 3/3 features</div>	

2.15 Ensemble	RMSE (Validation): 77.991
Last change: Bagged Trees	3/3 features
2.16 Gaussian Process Regre...	RMSE (Validation): 76.756
Last change: Squared Exponential GPR	3/3 features
2.17 Gaussian Process Regress...	RMSE (Validation): 73.77
Last change: Matern 5/2 GPR	3/3 features
2.18 Gaussian Process Regre...	RMSE (Validation): 70.454
Last change: Exponential GPR	3/3 features
2.19 Gaussian Process Regression	Canceled
Last change: Rational Quadratic GPR	3/3 features
2.20 Neural Network	RMSE (Validation): 103.63
Last change: Narrow Neural Network	3/3 features
2.21 Neural Network	RMSE (Validation): 98.19
Last change: Medium Neural Network	3/3 features
2.22 Neural Network	Canceled
Last change: Wide Neural Network	3/3 features
2.23 Neural Network	RMSE (Validation): 95.533
Last change: Bilayered Neural Network	3/3 features
2.24 Neural Network	Canceled
Last change: Trilayered Neural Network	3/3 features
2.25 Kernel	RMSE (Validation): 104.47
Last change: SVM Kernel	3/3 features
2.26 Kernel	RMSE (Validation): 98.693

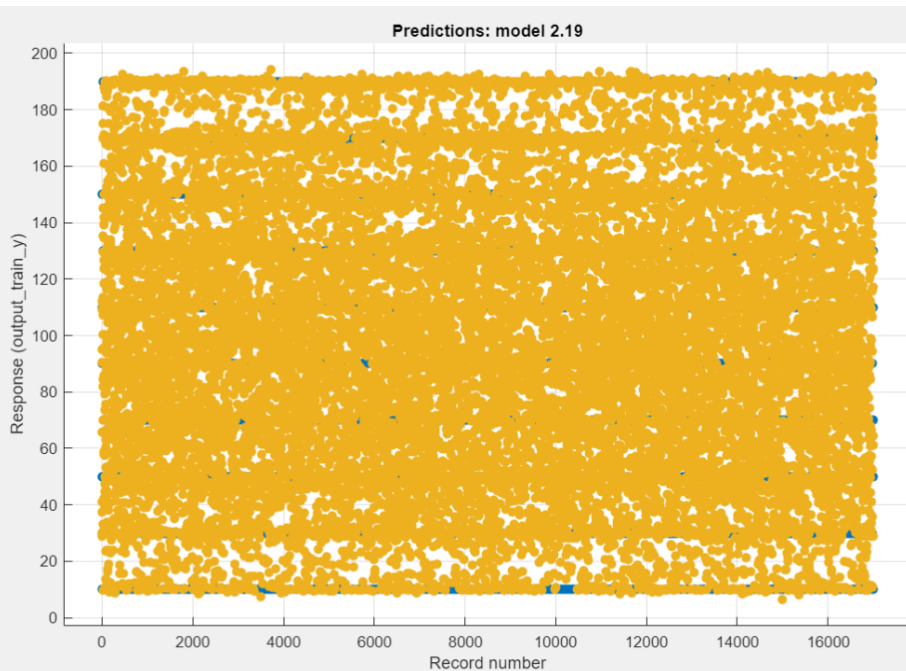


RMSE (Training) - Y position:

2.1 Linear Regression	RMSE (Validation): 50.962	2.13 SVM	RMSE (Validation): 46.781
Last change: Linear	3/3 features	Last change: Coarse Gaussian SVM	3/3 features
2.2 Linear Regression	RMSE (Validation): 49.793	2.14 Ensemble	RMSE (Validation): 43.23
Last change: Interactions Linear	3/3 features	Last change: Boosted Trees	3/3 features
2.3 Linear Regression	RMSE (Validation): 51.004	2.15 Ensemble	RMSE (Validation): 34.684
Last change: Robust Linear	3/3 features	Last change: Bagged Trees	3/3 features
2.4 Stepwise Linear Regression	RMSE (Validation): 49.793	2.16 Gaussian Process Regre...	RMSE (Validation): 32.752
Last change: Stepwise Linear	3/3 features	Last change: Squared Exponential GPR	3/3 features
2.5 Tree	RMSE (Validation): 32.39	2.17 Gaussian Process Regre...	RMSE (Validation): 31.445
Last change: Fine Tree	3/3 features	Last change: Matern 5/2 GPR	3/3 features
2.6 Tree	RMSE (Validation): 33.967	2.18 Gaussian Process Regre...	RMSE (Validation): 30.212
Last change: Medium Tree	3/3 features	Last change: Exponential GPR	3/3 features
2.7 Tree	RMSE (Validation): 36.798	2.19 Gaussian Process Regre...	RMSE (Validation): 30.169
Last change: Coarse Tree	3/3 features	Last change: Rational Quadratic GPR	3/3 features
2.8 SVM	RMSE (Validation): 51.323	2.20 Neural Network	RMSE (Validation): 45.149
Last change: Linear SVM	3/3 features	Last change: Narrow Neural Network	3/3 features
2.9 SVM	RMSE (Validation): 48.441	2.21 Neural Network	RMSE (Validation): 41.587
Last change: Quadratic SVM	3/3 features	Last change: Medium Neural Network	3/3 features
2.10 SVM	RMSE (Validation): 47.26	2.22 Neural Network	RMSE (Validation): 36.766
Last change: Cubic SVM	3/3 features	Last change: Wide Neural Network	3/3 features
2.11 SVM	RMSE (Validation): 33.299	2.23 Neural Network	RMSE (Validation): 41.739
Last change: Fine Gaussian SVM	3/3 features	Last change: Bilayered Neural Network	3/3 features
2.12 SVM	RMSE (Validation): 42.45	2.24 Neural Network	RMSE (Validation): 40.966
Last change: Medium Gaussian SVM	3/3 features	Last change: Trilayered Neural Network	3/3 features

☆ 2.25 Kernel	RMSE (Validation): 45.211
Last change: SVM Kernel	3/3 features
☆ 2.26 Kernel	RMSE (Validation): 43.543
Last change: Least Squares Regression Kernel	3/3 features

☆ 2.15 Ensemble	RMSE (Validation): 34.684
Last change: Bagged Trees	3/3 features
☆ 2.16 Gaussian Process Regre...	RMSE (Validation): 32.752
Last change: Squared Exponential GPR	3/3 features
☆ 2.17 Gaussian Process Regre...	RMSE (Validation): 31.445
Last change: Matern 5/2 GPR	3/3 features
☆ 2.18 Gaussian Process Regre...	RMSE (Validation): 30.212
Last change: Exponential GPR	3/3 features
☆ 2.19 Gaussian Process Regre...	RMSE (Validation): 30.169
Last change: Rational Quadratic GPR	3/3 features
☆ 2.20 Neural Network	RMSE (Validation): 45.149
Last change: Narrow Neural Network	3/3 features
☆ 2.21 Neural Network	RMSE (Validation): 41.587
Last change: Medium Neural Network	3/3 features
☆ 2.22 Neural Network	RMSE (Validation): 36.766
Last change: Wide Neural Network	3/3 features
☆ 2.23 Neural Network	RMSE (Validation): 41.739
Last change: Bilayered Neural Network	3/3 features
☆ 2.24 Neural Network	RMSE (Validation): 40.966
Last change: Trilayered Neural Network	3/3 features
☆ 2.25 Kernel	RMSE (Validation): 45.211
Last change: SVM Kernel	3/3 features
☆ 2.26 Kernel	RMSE (Validation): 43.543



RMSE (Testing) - XY position:

```
% -----inputs: All previously selected features-----
input_val=RandomNewDataFeatures(round(size(RandomNewDataFeatures,1)*training_size):size(RandomNewDataFeatures,1));

% -----output: Energy in the next time step-----
output_val_x=RandomOutput(round(size(RandomOutput,1)*training_size):size(RandomOutput,1),2);%c
output_val_y=RandomOutput(round(size(RandomOutput,1)*training_size):size(RandomOutput,1),3);%c

% Generate model X position
[model_x_position, RMSE_x_position] = trainRegressionModel_X_GPR70(input_train, output_train_x);
RMSE_x_position
```

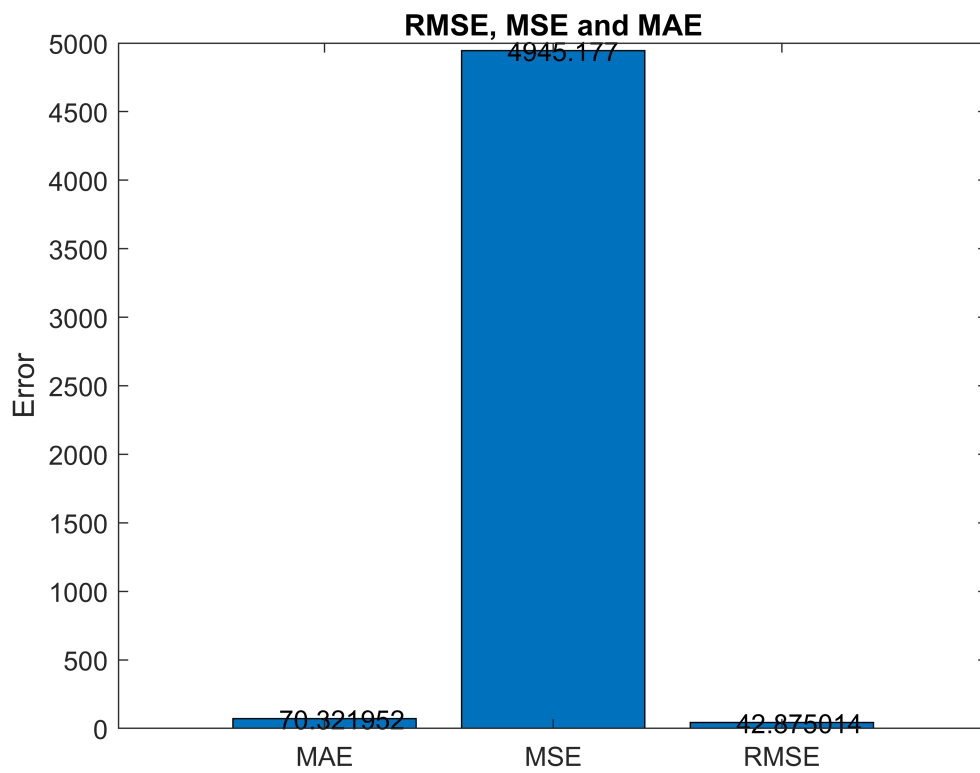
```
RMSE_x_position = 70.6551
```

```
% Generate model Y position
[model_y_position, RMSE_y_position] = trainRegressionModel_Y_GPR30(input_train, output_train_y);
RMSE_y_position
```

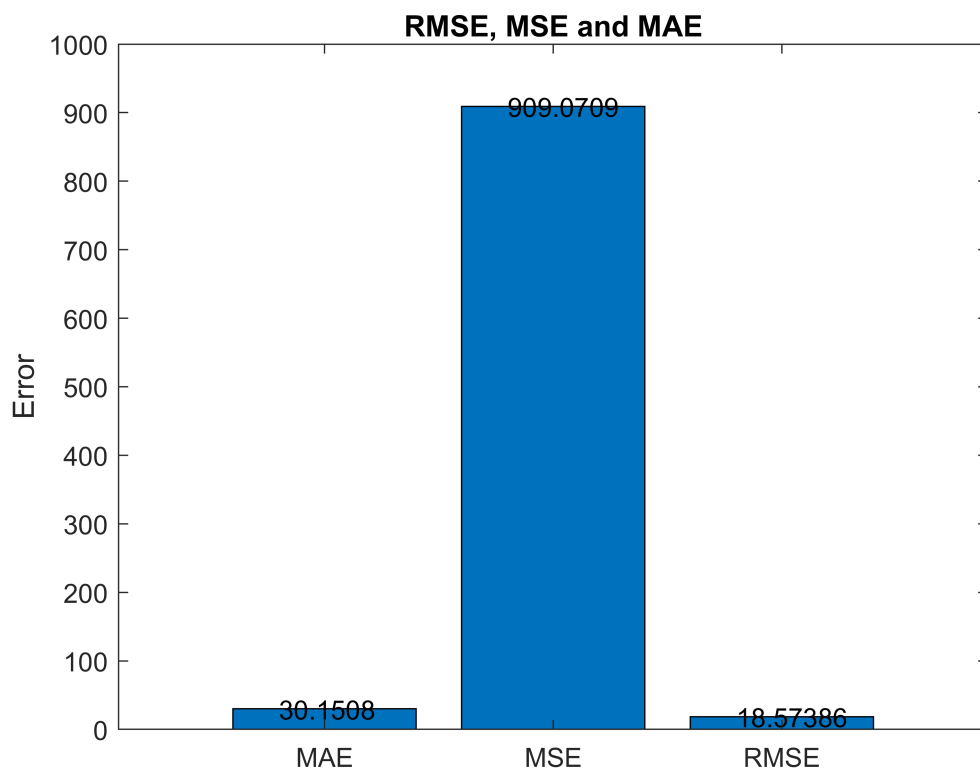
```
RMSE_y_position = 30.2005
```

```
estimate_x_position=model_x_position.predictFcn(input_val);
estimate_y_position=model_y_position.predictFcn(input_val);

[rmse_x,mse_x,mae_X]=fBar_RmseMseMae(estimate_x_position,output_val_x);
```

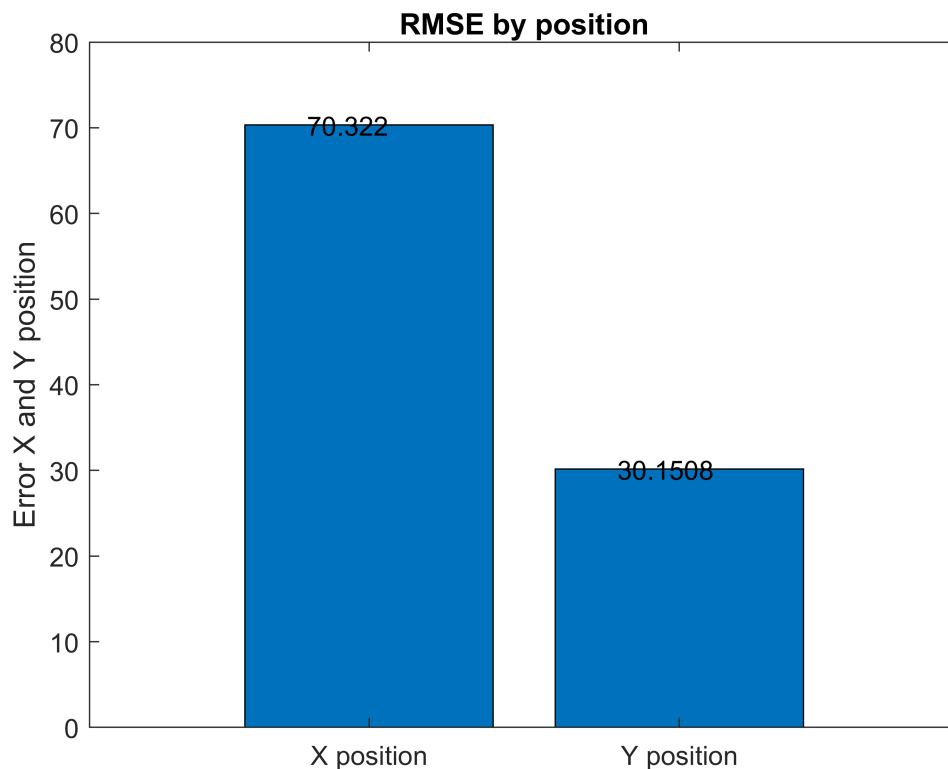


```
[rmse_y,mse_y,mae_y]=fBar_RmseMseMae(estimate_y_position,output_val_y);
```



All Values

```
values = [rmse_x rmse_y];%1-R2
figure;
c = categorical({'X position','Y position'});
b=bar(c,values);
ylabel('Error X and Y position')
title('RMSE by position')
xtips1 = b(1).XEndPoints - 0.2;
ytips1 = b(1).YEndPoints + 0.0003;
labels1 = string(b(1).YData);
text(xtips1,ytips1,labels1,'VerticalAlignment','middle')
```



```
clear DeNormMin DeNormMax training_size mae_y mae_X mse_y mse_x RallData xtips1 ytips1
clear labels1 c b values
```

FutureWork

```
%To perform measurements over larger areas
%Increase the number of receivers to improve prediction accuracy
% Use more than one transmitter, to track more objects
```