Creating a Bland-Altman and Scatter Plot

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This code was developed by Miodrag Bolic for the book PERVASIVE CARDIOVASCULAR AND RESPIRATORY MONITORING DEVICES

The author would like to thank Dhrumil Naik for his assistance in developing this notebook.


```
% Changing the path from main_folder to a particular chapter
main_path=fileparts(which('Main_Content.mlx'));
if ~isempty(main_path)
    %addpath(append(main_path,'/Chapter2'))
    cd (append(main_path,'/Chapter1/BlandAltman'))
    addpath(append(main_path,'/Service'))
end
SAVE_FLAG=0; % saving the figures in a file
```

Introduction

The **Bland-Altman plo**t and analysis is used to compare two measurements of the same variable. For example in bioinstrumentation, an expensive measurement system might be compared with a less expensive one or an intrusive measurement system might be compared to a less intrusive one.

Adding the Measurement Data

For this example we are adding two measurement data from two different systems on the same variable. Suppose you want to evaluate the agreement between a continuous random variable (x1) and a second random variable (x2) which each measure the same variable, such as blood pressure.

```
method_1 = [122 121 95 127 140 139 122 130 119 126 107   ...
```

```
    123 131 123 127 142 104 117 139 143 181 149 173 160 ...
    158 139 153 138 228 190 103 131 131 126 121 97 116 ...
    215 141 153 113 109 145 192 112 152 141 206 151 112 ...
    162 117 119 136 112 120 117 194 167 173 228 77 154 ...
    154 145 200 188 149 136 128 204 184 163 93 178 202 ...
    162 227 133 202 158 124 114 137 121];

method_2 = [100 108 76 108 124 122 116 114 100 108 100 ...
    108 112 104 106 122 100 118 140 150 166 148 174 174 ...
    140 128 146 146 220 208 94 114 126 124 110 90 106 218 ...
    130 136 100 100 124 164 100 136 114 148 160 84 156 110 ...
    100 100 86 106 108 168 166 146 204 96 134 138 134 156 ...
    124 114 112 112 202 132 158 88 170 182 112 120 110 112 ...
    154 116 108 106 122];
x = min(method_1):1:max(method_1);
```

This same data can be imported through a text file as well. Two columnns in this data set will be considered.

```
a=load("BlandAltmanBPData.txt");
method1=a(:,8)';
method2=a(:,2)';
x1 = min(method1):1:max(method2);
```

Finding the Mean and Difference

The Bland-Altman plot is formed by plotting the differences (x1 - x2) on the vertical axis versus the means [(x1+x2)/2] on the horizontal axis.

An array will be created for this mean and difference data, as well as the mean of differences, standard deviation of differences, and μ-2σ and μ +2σ.

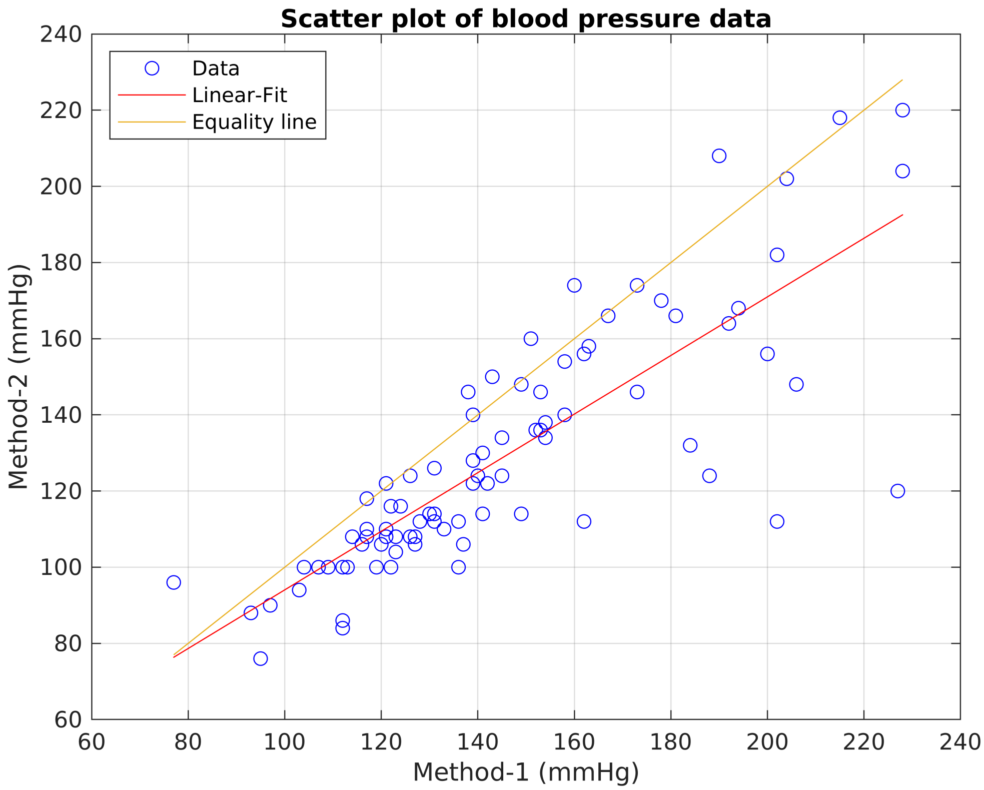
```
meanArray = mean([method1;method2]);
diffArray = method1-method2;
meanOfDiffs = mean(diffArray);
stdOfDiffs = std(diffArray);
confRange = [meanOfDiffs + 2.0 * stdOfDiffs, meanOfDiffs - 2.0 * stdOfDiffs];
```

Creating a Scatter Plot

Scatter plot visualizes paired observations in horizontal axis and in vertical axis. In case of good agreement, we expect data to be scattered symmetrically around the 45 degree line.

```
figure
[p,S] = polyfit(method1, method2, 1);
[yfit,delta] = polyval(p, method1, S);
plot(method1, method2, 'bo');  % Plot method 1 and method 2 data
hold on;
plot(method1, yfit,'r-');
plot(x,x)
```

```
title("Scatter plot of blood pressure data")
legend('Data','Linear-Fit','Equality line', 'Location','northwest'); grid;
xlabel('Method-1 (mmHg)'); ylabel('Method-2 (mmHg)')
```




```
annonation_save('a)',"Fig1.7a.jpg", SAVE_FLAG);
```

What can you observe from this plot?

The data points are mainly on one side of the 45 degree line. Data points are far from the equality line and also their trend is not parallel to the equality line. This indicates different proportional biases.

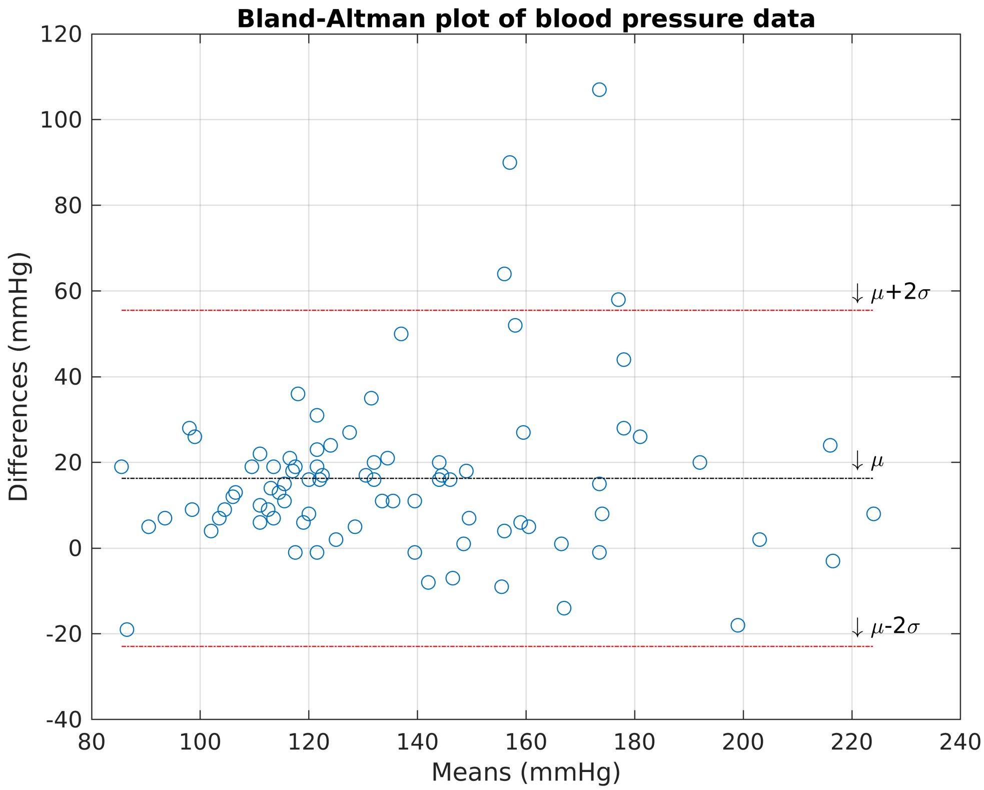
Creating a Bland-Altman Plot

Bland-Altman plot will show the average versus the difference. Both types of plots complement each other for the diagnosis of systematic and random errors. In a Bland-Altman plot, if there is a linear trend along average horizontal line, we can have two indications: (i) unequal proportional biases, or (ii) unequal precision.

We would expect most of the differences to lie between μ-2σ and μ +2σ , or more precisely, 95% of differences will be between μ-1.96σ and μ +1,96σ, if the differences are normally distributed (Gaussian). These lines will be included to the plot.

```
figure
plot(meanArray,diffArray,'o');
hold on;
line([min(meanArray) max(meanArray)],[confRange(1) confRange(1)],'Color','red','LineSty
```

```
line([min(meanArray) max(meanArray)],[confRange(2) confRange(2)],'Color','red','LineSty
line([min(meanArray) max(meanArray)],[meanOfDiffs meanOfDiffs],'Color','black','LineSty
grid; ylabel('Differences (mmHg)'); xlabel('Means (mmHg)');
text(220,60,{'\downarrow \mu+2\sigma'})
text(220,21,{'\downarrow \mu'})
text(220,-18,{'\downarrow \mu-2\sigma'})
title("Bland-Altman plot of blood pressure data")
hold off;
```




```
annonation_save('b)',"Fig1.7b.jpg", SAVE_FLAG);
```

What can you observe from this plot?

The mean difference in methods is significant and it is 16.3 mmHg and standard deviation is 19.6 mmHg. We can see a number of outliers as well. In addition, it seems that data are scattered more with increased blood pressure indicating the effect of heteroscedasticity.

Heteroscedasticity refers to change of variance/scatter along the vertical direction as the average increases. It indicates the variability of changes with magnitude of measurement. Reason for this is dependence of the error variation of one or both methods on the magnitude of measurement. In most of such cases, the Bland-Altman plot shows a fan shape which can be observed in the created plot.

Exercise

Exercise: Create a Bland-Altman plot for other pairs of data from the blood pressure dataset provided.

Use sliders to select different measurements, please select measurements that are pairs. For example Columns 8&2, 9&3 or 10&4.

```
a=load("BlandAltmanBPData.txt");

Column1 =8
```

```
Column1 = 8
```

```
Column2 =4
```

```
Column2 = 4
```

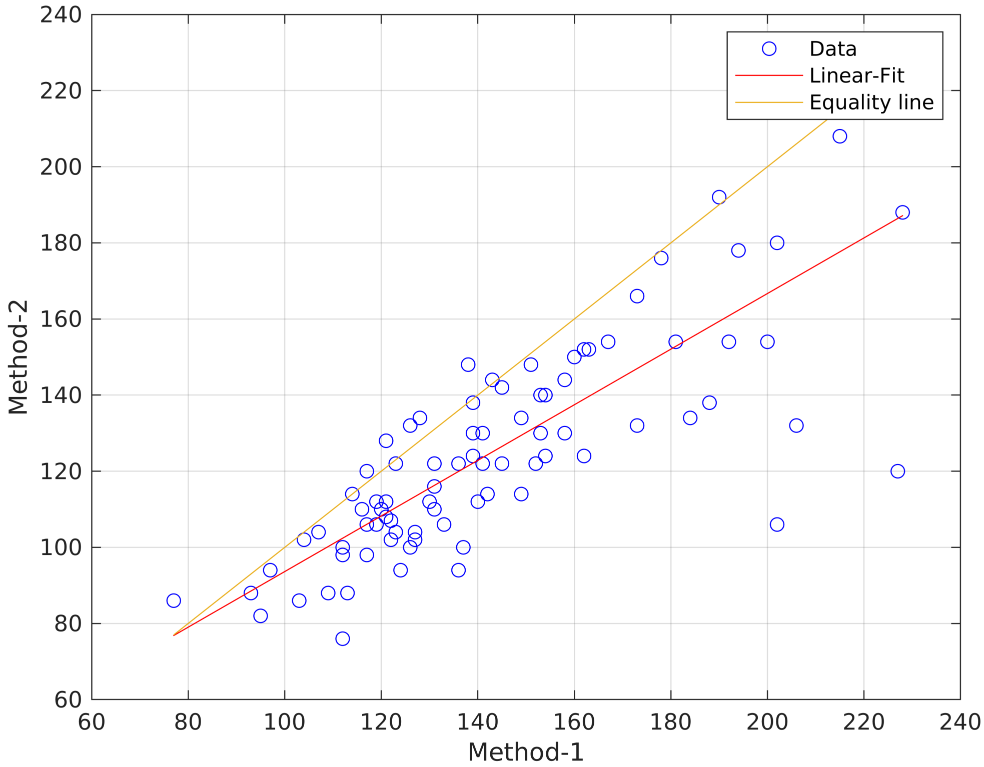
```
method10=a(:,Column1)';
method20=a(:,Column2)';
x10 = min(method10):1:max(method20);
```

Finding the Mean and Difference

```
meanArray1 = mean([method10;method20]);
diffArray1 = method10-method20;
meanOfDiffs1 = mean(diffArray1);
stdOfDiffs1 = std(diffArray1);
confRange1 = [meanOfDiffs1 + 2.0 * stdOfDiffs1, meanOfDiffs1 - 2.0 * stdOfDiffs1];
```

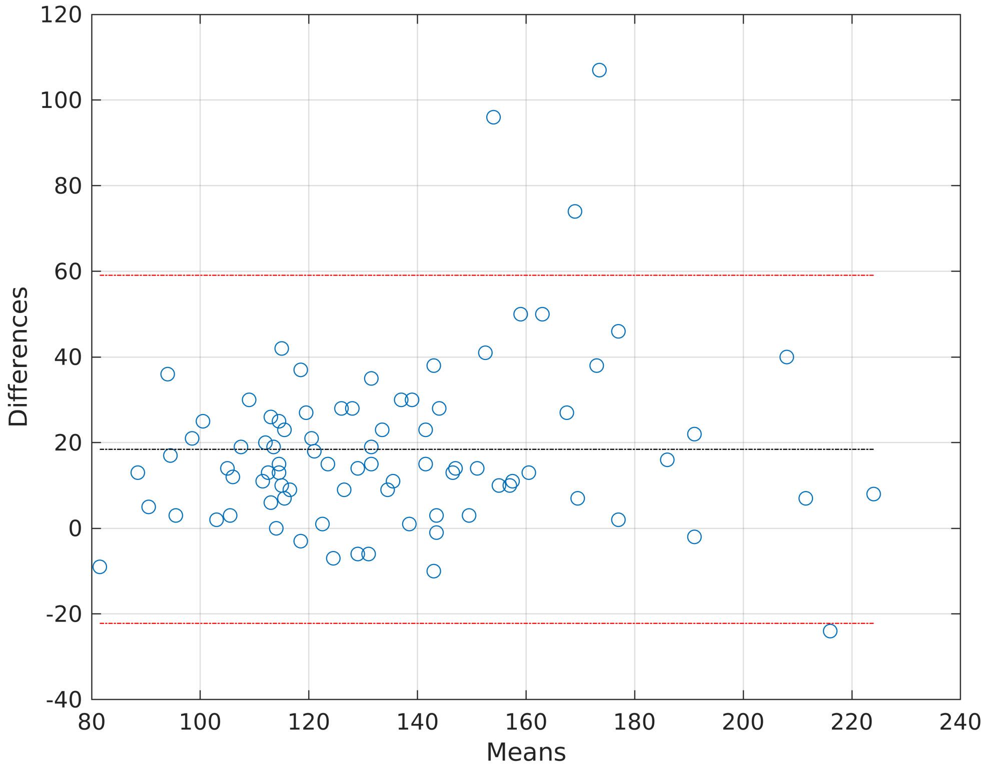
Creating a Scatter Plot

```
figure
[p,S] = polyfit(method10, method20, 1);
[yfit,delta] = polyval(p, method10, S);
plot(method10, method20, 'bo');  % Plot method 1 and method 2 data
hold on;
plot(method10, yfit,'r-');
plot(x,x)
legend('Data','Linear-Fit','Equality line'); grid;
xlabel('Method-1'); ylabel('Method-2')
```



Creating a Bland-Altman Plot

```
figure
plot(meanArray1,diffArray1,'o');
hold on;
line([min(meanArray1) max(meanArray1)],[confRange1(1) confRange1(1)],'Color','red','Lin
line([min(meanArray1) max(meanArray1)],[confRange1(2) confRange1(2)],'Color','red','Lin
line([min(meanArray1) max(meanArray1)],[meanOfDiffs1 meanOfDiffs1],'Color','black','Lin
grid; ylabel('Differences'); xlabel('Means');
hold off;
```



120
100
80
60
40
20
0
-20
-40
Differences
80
100
120
140
160
180
200
220
240
Means