Diagnosing Breast Cancer using Julia

Loading necessary packages and reading the [dataset (https://www.kaggle.com/uciml/breast-cancer-wisconsin-data)](https://www.kaggle.com/uciml/breast-cancer-wisconsin-data).

In [188]:
```
using CSV
using DataFrames
df = CSV.read("wdbc.csv");
```

Setting Random Seed to produce same output everytime, it helps in debugging

In [189]:
```
RANDOM_STATE = 100
using Random
Random.seed!(RANDOM_STATE)
```

Out[189]:
```
MersenneTwister(UInt32[0x00000064], Random.DSFMT.DSFMT_state(Int32[-2036630343, 1072818225, 1299231502, 1073
154435, 1563612565, 1073206618, 176198161, 1073683625, 381415896, 1073699088  …  163992627, 1073241259, 3858
18456, 1072878963, 399273729, 595433664, 390891112, 1704156657, 382, 0]), [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.
0, 0.0, 0.0, 0.0  …  0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0], UInt128[0x00000000000000000000000000
000000, 0x00000000000000000000000000000000, 0x00000000000000000000000000000000, 0x00000000000000000000000000
000000, 0x00000000000000000000000000000000, 0x00000000000000000000000000000000, 0x00000000000000000000000000
000000  …  0x00000000000000000000000000000000, 0x00000000000000000000000000000000, 0x00000000000000000000000000
000000, 0x00000000000000000000000000000000, 0x00000000000000000000000000000000, 0x00000000000000000000000000
000000, 0x00000000000000000000000000000000, 0x00000000000000000000000000000000, 0x00000000000000000000000000
000000, 0x00000000000000000000000000000000], 1002, 0)
```

First 5 samples of the dataset

In [190]:
```
first(df,5)
```

Out[190]: 5 rows × 32 columns (omitted printing of 25 columns)

	id	diagnosis	radius_mean	texture_mean	perimeter_mean	area_mean	smoothness_mean
	Int64	String	Float64	Float64	Float64	Float64	Float64
1	842302	M	17.99	10.38	122.8	1001.0	0.1184
2	842517	M	20.57	17.77	132.9	1326.0	0.08474
3	84300903	M	19.69	21.25	130.0	1203.0	0.1096
4	84348301	M	11.42	20.38	77.58	386.1	0.1425
5	84358402	M	20.29	14.34	135.1	1297.0	0.1003

Printing the number of instances and number of columns

In [191]:
```
# size function returns the number of row and columns of the dataset
row, col = size(df)
println("Number of Instances: ", row)
println("Number of Columns: ", col)
```

```
Number of Instances: 569
Number of Columns: 32
```

Headers / Column names of the dataset

In [192]:
```
println(names(df))
```

```
Symbol[:id, :diagnosis, :radius_mean, :texture_mean, :perimeter_mean, :area_mean, :smoothness_mean, :compact
ness_mean, :concavity_mean, Symbol("concave points_mean"), :symmetry_mean, :fractal_dimension_mean, :radius_
se, :texture_se, :perimeter_se, :area_se, :smoothness_se, :compactness_se, :concavity_se, Symbol("concave po
ints_se"), :symmetry_se, :fractal_dimension_se, :radius_worst, :texture_worst, :perimeter_worst, :area_wors
t, :smoothness_worst, :compactness_worst, :concavity_worst, Symbol("concave points_worst"), :symmetry_worst,
:fractal_dimension_worst]
```

Description of dataset

In [193]:
```
println(describe(df))
```

```
32×8 DataFrame
| Row | variable                | mean       | min       | median   | max       | nunique | nmissing | eltype |
|     | Symbol                  | Union…     | Any       | Union…   | Any       | Union…  | Nothing  | DataType |
|-----|-------------------------|------------|-----------|----------|-----------|---------|----------|--------|
| 1   | id                      | 3.03718e7  | 8670      | 906024.0 | 911320502 |         |          | Int64  |
| 2   | diagnosis               |            | B         |          | M         | 2       |          | String |
| 3   | radius_mean             | 14.1273    | 6.981     | 13.37    | 28.11     |         |          | Float64 |
| 4   | texture_mean            | 19.2896    | 9.71      | 18.84    | 39.28     |         |          | Float64 |
| 5   | perimeter_mean          | 91.969     | 43.79     | 86.24    | 188.5     |         |          | Float64 |
| 6   | area_mean               | 654.889    | 143.5     | 551.1    | 2501.0    |         |          | Float64 |
| 7   | smoothness_mean         | 0.0963603  | 0.05263   | 0.09587  | 0.1634    |         |          | Float64 |
| 8   | compactness_mean        | 0.104341   | 0.01938   | 0.09263  | 0.3454    |         |          | Float64 |
| 9   | concavity_mean          | 0.0887993  | 0.0       | 0.06154  | 0.4268    |         |          | Float64 |
| 10  | concave points_mean     | 0.0489191  | 0.0       | 0.0335   | 0.2012    |         |          | Float64 |
| 11  | symmetry_mean           | 0.181162   | 0.106     | 0.1792   | 0.304     |         |          | Float64 |
| 12  | fractal_dimension_mean  | 0.0627976  | 0.04996   | 0.06154  | 0.09744   |         |          | Float64 |
| 13  | radius_se               | 0.405172   | 0.1115    | 0.3242   | 2.873     |         |          | Float64 |
| 14  | texture_se              | 1.21685    | 0.3602    | 1.108    | 4.885     |         |          | Float64 |
| 15  | perimeter_se            | 2.86606    | 0.757     | 2.287    | 21.98     |         |          | Float64 |
| 16  | area_se                 | 40.3371    | 6.802     | 24.53    | 542.2     |         |          | Float64 |
| 17  | smoothness_se           | 0.00704098 | 0.001713  | 0.00638  | 0.03113   |         |          | Float64 |
| 18  | compactness_se          | 0.0254781  | 0.002252  | 0.02045  | 0.1354    |         |          | Float64 |
| 19  | concavity_se            | 0.0318937  | 0.0       | 0.02589  | 0.396     |         |          | Float64 |
| 20  | concave points_se       | 0.0117961  | 0.0       | 0.01093  | 0.05279   |         |          | Float64 |
| 21  | symmetry_se             | 0.0205423  | 0.007882  | 0.01873  | 0.07895   |         |          | Float64 |
| 22  | fractal_dimension_se    | 0.0037949  | 0.0008948 | 0.003187 | 0.02984   |         |          | Float64 |
| 23  | radius_worst            | 16.2692    | 7.93      | 14.97    | 36.04     |         |          | Float64 |
| 24  | texture_worst           | 25.6772    | 12.02     | 25.41    | 49.54     |         |          | Float64 |
| 25  | perimeter_worst         | 107.261    | 50.41     | 97.66    | 251.2     |         |          | Float64 |
| 26  | area_worst              | 880.583    | 185.2     | 686.5    | 4254.0    |         |          | Float64 |
| 27  | smoothness_worst        | 0.132369   | 0.07117   | 0.1313   | 0.2226    |         |          | Float64 |
| 28  | compactness_worst       | 0.254265   | 0.02729   | 0.2119   | 1.058     |         |          | Float64 |
| 29  | concavity_worst         | 0.272188   | 0.0       | 0.2267   | 1.252     |         |          | Float64 |
| 30  | concave points_worst    | 0.114606   | 0.0       | 0.09993  | 0.291     |         |          | Float64 |
| 31  | symmetry_worst          | 0.290076   | 0.1565    | 0.2822   | 0.6638    |         |          | Float64 |
| 32  | fractal_dimension_worst | 0.0839458  | 0.05504   | 0.08004  | 0.2075    |         |          | Float64 |
```

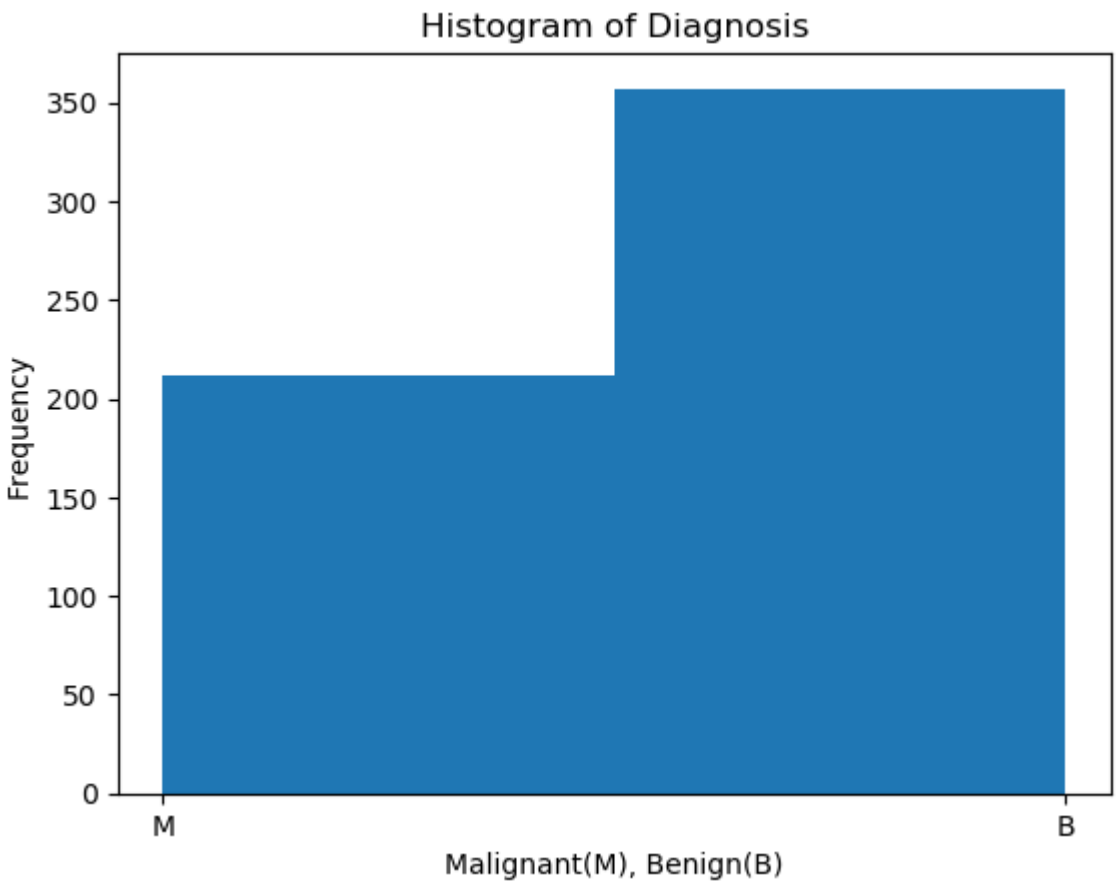
Frequencey of each class

In [194]:
```
using FreqTables
frequency_digonosis = freqtable(df[:diagnosis])
```

Out[194]:
```
2-element Named Array{Int64,1}
Dim1 |
-----|---
B    | 357
M    | 212
```

Histogram of the frequency of each class

In [195]:
```
using PyPlot
PyPlot.plt.hist(df[:diagnosis], 2)
plt.title("Histogram of Diagnosis")
plt.xlabel("Malignant(M), Benign(B)")
plt.ylabel("Frequency")
```



Out[195]: PyObject Text(24.000000000000007, 0.5, 'Frequency')

Data Preprocessing

Converting the categorical feature "diagnosis" to integer by doing label encoding

In [196]:
```
using MLLabelUtils
y = convertlabel(LabelEnc.MarginBased,df[:diagnosis])
y = classify.(y, LabelEnc.ZeroOne(Int,1))
newdf = copy(df)
deletecols!(newdf, :diagnosis)
newdf[:diagnosis] = y;
```

Dataset after encodning

In [197]:
```
first(newdf,5)
```

Out[197]: 5 rows × 32 columns (omitted printing of 26 columns)

	id	radius_mean	texture_mean	perimeter_mean	area_mean	smoothness_mean
	Int64	Float64	Float64	Float64	Float64	Float64
1	842302	17.99	10.38	122.8	1001.0	0.1184
2	842517	20.57	17.77	132.9	1326.0	0.08474
3	84300903	19.69	21.25	130.0	1203.0	0.1096
4	84348301	11.42	20.38	77.58	386.1	0.1425
5	84358402	20.29	14.34	135.1	1297.0	0.1003

Description of Dataset after encodning

In [198]:
```
println(describe(newdf))
```

```
32×8 DataFrame
| Row | variable                | mean       | min       | median   | max       | nunique | nmissing | eltype  |
|     | Symbol                  | Float64    | Real      | Float64  | Real      | Nothing | Nothing  | DataType |
|-----|-------------------------|------------|-----------|----------|-----------|---------|----------|---------|
| 1   | id                      | 3.03718e7  | 8670      | 906024.0 | 911320502 |         |          | Int64   |
| 2   | radius_mean             | 14.1273    | 6.981     | 13.37    | 28.11     |         |          | Float64 |
| 3   | texture_mean            | 19.2896    | 9.71      | 18.84    | 39.28     |         |          | Float64 |
| 4   | perimeter_mean          | 91.969     | 43.79     | 86.24    | 188.5     |         |          | Float64 |
| 5   | area_mean               | 654.889    | 143.5     | 551.1    | 2501.0    |         |          | Float64 |
| 6   | smoothness_mean         | 0.0963603  | 0.05263   | 0.09587  | 0.1634    |         |          | Float64 |
| 7   | compactness_mean        | 0.104341   | 0.01938   | 0.09263  | 0.3454    |         |          | Float64 |
| 8   | concavity_mean          | 0.0887993  | 0.0       | 0.06154  | 0.4268    |         |          | Float64 |
| 9   | concave points_mean     | 0.0489191  | 0.0       | 0.0335   | 0.2012    |         |          | Float64 |
| 10  | symmetry_mean           | 0.181162   | 0.106     | 0.1792   | 0.304     |         |          | Float64 |
| 11  | fractal_dimension_mean  | 0.0627976  | 0.04996   | 0.06154  | 0.09744   |         |          | Float64 |
| 12  | radius_se               | 0.405172   | 0.1115    | 0.3242   | 2.873     |         |          | Float64 |
| 13  | texture_se              | 1.21685    | 0.3602    | 1.108    | 4.885     |         |          | Float64 |
| 14  | perimeter_se            | 2.86606    | 0.757     | 2.287    | 21.98     |         |          | Float64 |
| 15  | area_se                 | 40.3371    | 6.802     | 24.53    | 542.2     |         |          | Float64 |
| 16  | smoothness_se           | 0.00704098 | 0.001713  | 0.00638  | 0.03113   |         |          | Float64 |
| 17  | compactness_se          | 0.0254781  | 0.002252  | 0.02045  | 0.1354    |         |          | Float64 |
| 18  | concavity_se            | 0.0318937  | 0.0       | 0.02589  | 0.396     |         |          | Float64 |
| 19  | concave points_se       | 0.0117961  | 0.0       | 0.01093  | 0.05279   |         |          | Float64 |
| 20  | symmetry_se             | 0.0205423  | 0.007882  | 0.01873  | 0.07895   |         |          | Float64 |
| 21  | fractal_dimension_se    | 0.0037949  | 0.0008948 | 0.003187 | 0.02984   |         |          | Float64 |
| 22  | radius_worst            | 16.2692    | 7.93      | 14.97    | 36.04     |         |          | Float64 |
| 23  | texture_worst           | 25.6772    | 12.02     | 25.41    | 49.54     |         |          | Float64 |
| 24  | perimeter_worst         | 107.261    | 50.41     | 97.66    | 251.2     |         |          | Float64 |
| 25  | area_worst              | 880.583    | 185.2     | 686.5    | 4254.0    |         |          | Float64 |
| 26  | smoothness_worst        | 0.132369   | 0.07117   | 0.1313   | 0.2226    |         |          | Float64 |
| 27  | compactness_worst       | 0.254265   | 0.02729   | 0.2119   | 1.058     |         |          | Float64 |
| 28  | concavity_worst         | 0.272188   | 0.0       | 0.2267   | 1.252     |         |          | Float64 |
| 29  | concave points_worst    | 0.114606   | 0.0       | 0.09993  | 0.291     |         |          | Float64 |
| 30  | symmetry_worst          | 0.290076   | 0.1565    | 0.2822   | 0.6638    |         |          | Float64 |
| 31  | fractal_dimension_worst | 0.0839458  | 0.05504   | 0.08004  | 0.2075    |         |          | Float64 |
| 32  | diagnosis               | 0.372583   | 0         | 0.0      | 1         |         |          | Int64   |
```

Spliting the dataset into train, test

Shuffling the Dataset

In [199]:
```
using MLDataUtils
newdf_s = shuffleobs(newdf);
first(newdf_s,10)
```

Out[199]: 10 rows × 32 columns (omitted printing of 26 columns)

	id	radius_mean	texture_mean	perimeter_mean	area_mean	smoothness_mean
	Int64	Float64	Float64	Float64	Float64	Float64
1	88649001	19.55	28.77	133.6	1207.0	0.0926
2	8612080	12.0	15.65	76.95	443.3	0.09723
3	8810158	13.11	22.54	87.02	529.4	0.1002
4	889403	15.61	19.38	100.0	758.6	0.0784
5	894335	12.43	17.0	78.6	477.3	0.07557
6	871149	10.9	12.96	68.69	366.8	0.07515
7	86135501	14.48	21.46	94.25	648.2	0.09444
8	8810987	13.86	16.93	90.96	578.9	0.1026
9	864018	11.34	21.26	72.48	396.5	0.08759
10	88995002	20.73	31.12	135.7	1419.0	0.09469

Spliting into train and test

In [200]:
```
train, test = splitobs(newdf_s, at = 0.70);
```

Seperating the features and class label

In [201]:
```
X_train = convert(Matrix, train[:,2:31]);
y_train = convert(Matrix, train[:,32:32]);
X_test = convert(Matrix, test[:,2:31]);
y_test = convert(Matrix, test[:,32:32]);
```

Converting (n,1) dimension to (n,) as per the classifiers requirements

In [202]:
```
y_train = vec(y_train);
y_test = vec(y_test);
```

Applying algorithms to train models

Loading necessary packages and creating an object of Classifier

In [213]:
```
using DecisionTree
using ScikitLearn: fit!, predict
rfc = RandomForestClassifier(n_trees = 110, n_subfeatures = 20, max_depth = 7);
```

Fitting the classifiers on training data samples

In [214]:
```
fit!(rfc, X_train, y_train);
```

predicting the test data samples

In [215]:
```
y_pred = predict(rfc, X_test);
println("A portion of prediction:")
y_pred[1:10]
```

```
A portion of prediction:
```

Out[215]:
```
10-element Array{Int64,1}:
 1
 0
 1
 1
 1
 0
 1
 1
 0
 0
```

Performance and Results

Computing a confusion matrix

In [216]:
```
cm  = confusion_matrix(y_test, y_pred)
```

```
2×2 Array{Int64,2}:
 106   2
   4  59
```

Out[216]:
```
Classes:  [0, 1]
Matrix:
Accuracy: 0.9649122807017544
Kappa:    0.9241011984021305
```

Defining functions for calculating different performance metrices

In [217]:
```
using PyCall
math = pyimport("math")

function accuracy_(tn,fp,fn,tp)
    return ((tp+tn)/(tp+fp+fn+tn))
end

#True Positive Rate or Recall
function sensitivity(tp,fn)
    return (tp / (tp + fn))
end

tprate = sensitivity
recall = sensitivity

#True Negative Rate
function specificity(tn,fp)
    return (tn / (fp + tn))
end

function mcc(tn,fp,fn,tp)
    return (tp*tn-fp*fn)/math.sqrt((tp+fp)*(tp+fn)*(tn+fp)*(tn+fn))
end

function auc_score(tn,fp,fn,tp)
    return (sensitivity(tp,fn) + specificity(tn,fp)) / 2
end

function gmean_score(tn,fp,fn,tp)
    return math.sqrt(sensitivity(tp,fn) * specificity(tn,fp))
end

function precision(tp, fp)
    return (tp / (tp + fp))
end

function f1score(tp, fp, fn)
    return (2*tp/(2*tp + fp + fn))
end

function fprate(tn,fp)
    return (fp / (fp + tn))
end
```

Out[217]:
```
fprate (generic function with 1 method)
```

Definfing a function for producing all scores at once.

In [218]:
```
function getAllScore(tp,tn,fp,fn)
    acc = accuracy_(tn,fp,fn,tp)
    sn = sensitivity(tp,fn)
    sp = specificity(tn,fp)
    auc = auc_score(tn,fp,fn,tp)
    gmean = gmean_score(tn,fp,fn,tp)
    preci = precision(tp, fp)
    f1 = f1score(tp,fp,fn)
    fpr = fprate(tn,fp)
    return acc, sn, sp, auc, gmean, preci, f1, fpr
end
```

Out[218]:
```
getAllScore (generic function with 1 method)
```

Loading MLBase to compute roc performance parameter

In [219]:
```
using MLBase
r = roc(vec(y_test), y_pred)
```

Out[219]:
```
ROCNums{Int64}
  p = 63
  n = 108
  tp = 59
  tn = 106
  fp = 2
  fn = 4
```

Calling the getAllScore function

In [220]:
```
allScoresTuples = getAllScore(r.tp, r.tn, r.fp, r.fn)
allScoresArray = [i for i in allScoresTuples]
allScores = transpose(allScoresArray)
```

Out[220]:
```
1×8 LinearAlgebra.Transpose{Float64,Array{Float64,1}}:
 0.964912  0.936508  0.981481  0.958995  …  0.967213  0.951613  0.0185185
```

Storing the all scores into a dataframe

In [221]:
```
columnNames = ["accuracy", "sensitivity", "specificity", "auc", "gmean", "precision", "f1_score", "fpr"]
resultDF = DataFrame(allScores, Symbol.(columnNames), )
```

Out[221]: 1 rows × 8 columns

	accuracy	sensitivity	specificity	auc	gmean	precision	f1_score	fpr
	Float64	Float64	Float64	Float64	Float64	Float64	Float64	Float64
1	0.964912	0.936508	0.981481	0.958995	0.958731	0.967213	0.951613	0.0185185

Drawing a ROC curve with auc score

In [226]:
```
fprArr = [0, fprate(r.tn,r.fp), 1]
tprArr = [0, tprate(r.tp,r.fn), 1]
auc_ = round(auc_score(r.tn,r.fp,r.fn,r.tp), digits=3)
p = plot(fprArr,tprArr,label= string( "RandomForest", " ROC (auc =", auc_, ")" ) )
xlabel("1 - Specificity or (False Positive Rate)")
ylabel("Sensitivity(True Positive Rate)")
plt.plot([0, 1], [0, 1],"r--")
plt.xlim([0.0, 1.05])
plt.ylim([0.0, 1.05])
PyPlot.title("Receiver Operating Characteristic")
grid("on")
legend()
```