Data Analysis Section

In [224...

```
# Importing the required libraries for visualization
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np

# Visualization Prefrences.
%matplotlib inline
sns.set_style("whitegrid")
plt.style.use("fivethirtyeight")
```

In [225...

```
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np

# Visualization Prefrences.
%matplotlib inline
sns.set_style("whitegrid")
plt.style.use("fivethirtyeight")
```

In [226...

```
# Data Retrieving
df = pd.read_csv("data\heart.csv")
df.head()
```

Out[226...

	age	sex	cp	trestbps	chol	fbs	restecg	thalach	exang	oldpeak	slope	ca	thal	target
0	63	1	3	145	233	1	0	150	0	2.30	0	0	1	1
1	37	1	2	130	250	0	1	187	0	3.50	0	0	2	1
2	41	0	1	130	204	0	0	172	0	1.40	2	0	2	1
3	56	1	1	120	236	0	1	178	0	0.80	2	0	2	1
4	57	0	0	120	354	0	1	163	1	0.60	2	0	2	1

In [227...

```
# Extract Descriptive Data.
pd.set_option("display.float", "{:.2f}".format)
df.describe()
```

Out[227...

	age	sex	cp	trestbps	chol	fbs	restecg	thalach	exang	oldpeak	slop
count	303.00	303.00	303.00	303.00	303.00	303.00	303.00	303.00	303.00	303.00	303.0
mean	54.37	0.68	0.97	131.62	246.26	0.15	0.53	149.65	0.33	1.04	1.4
std	9.08	0.47	1.03	17.54	51.83	0.36	0.53	22.91	0.47	1.16	0.6
min	29.00	0.00	0.00	94.00	126.00	0.00	0.00	71.00	0.00	0.00	0.0
25%	47.50	0.00	0.00	120.00	211.00	0.00	0.00	133.50	0.00	0.00	1.0
50%	55.00	1.00	1.00	130.00	240.00	0.00	1.00	153.00	0.00	0.80	1.0
75%	61.00	1.00	2.00	140.00	274.50	0.00	1.00	166.00	1.00	1.60	2.0

	age	sex	cp	trestbps	chol	fbs	restecg	thalach	exang	oldpeak	slop
max	77.00	1.00	3.00	200.00	564.00	1.00	2.00	202.00	1.00	6.20	2.0

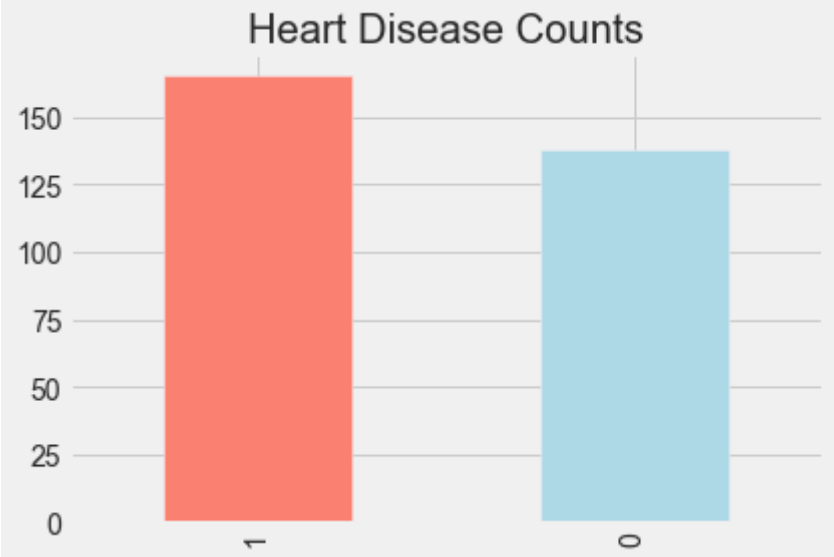
In [228…

```
#Viewing the status of people in the data set :
print(df.target.value_counts())
df.target.value_counts().plot(kind="bar", color=["salmon", "lightblue"], title =
```

```
1    165
0    138
Name: target, dtype: int64
```

Out[228…

```
<matplotlib.axes._subplots.AxesSubplot at 0x23680d30be0>
```



In [229…

```
# Check for Null Values
df.isna().sum()
```

Out[229…

```
age         0
sex         0
cp          0
trestbps    0
chol        0
fbs         0
restecg     0
thalach     0
exang       0
oldpeak     0
slope       0
ca          0
thal        0
target      0
dtype: int64
```

In [230…

```
# Categorical and Numerical Continious Features
categorical_val = []
continous_val = []
for column in df.columns:
    print('==============================')
    print(f"{column} : {df[column].unique()}")
    if len(df[column].unique()) <= 10:
        categorical_val.append(column)
    else:
        continous_val.append(column)
```

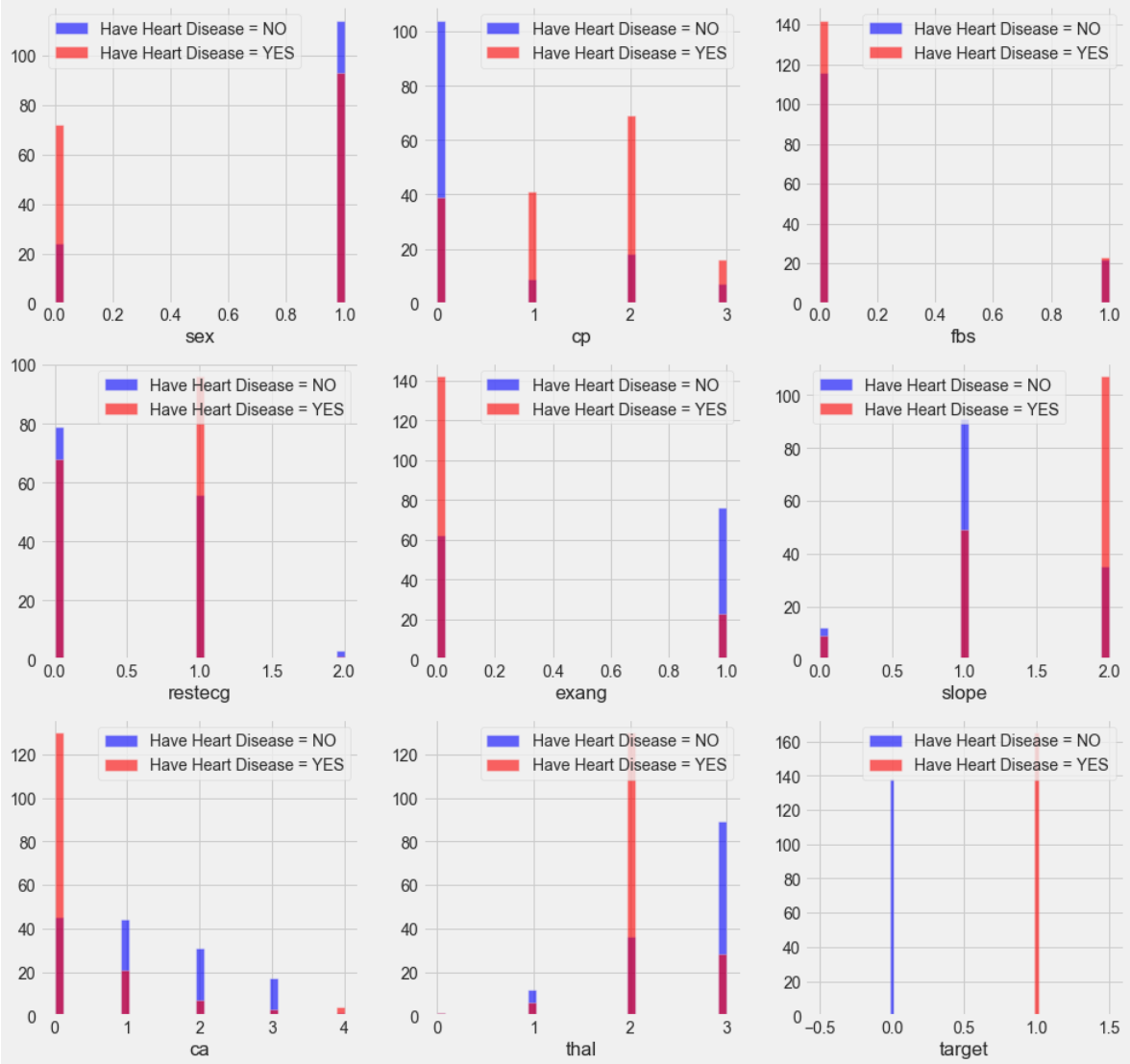
```
print('==============================')
print(f"Categorical Features : {categorical_val}")
print(f"Continous Features : {continous_val}")
```

```
==============================
age : [63 37 41 56 57 44 52 54 48 49 64 58 50 66 43 69 59 42 61 40 71 51 65 53
 46 45 39 47 62 34 35 29 55 60 67 68 74 76 70 38 77]
==============================
sex : [1 0]
==============================
cp : [3 2 1 0]
==============================
trestbps : [145 130 120 140 172 150 110 135 160 105 125 142 155 104 138 128 108 1
34
 122 115 118 100 124  94 112 102 152 101 132 148 178 129 180 136 126 106
 156 170 146 117 200 165 174 192 144 123 154 114 164]
==============================
chol : [233 250 204 236 354 192 294 263 199 168 239 275 266 211 283 219 340 226
 247 234 243 302 212 175 417 197 198 177 273 213 304 232 269 360 308 245
 208 264 321 325 235 257 216 256 231 141 252 201 222 260 182 303 265 309
 186 203 183 220 209 258 227 261 221 205 240 318 298 564 277 214 248 255
 207 223 288 160 394 315 246 244 270 195 196 254 126 313 262 215 193 271
 268 267 210 295 306 178 242 180 228 149 278 253 342 157 286 229 284 224
 206 167 230 335 276 353 225 330 290 172 305 188 282 185 326 274 164 307
 249 341 407 217 174 281 289 322 299 300 293 184 409 259 200 327 237 218
 319 166 311 169 187 176 241 131]
==============================
fbs : [1 0]
==============================
restecg : [0 1 2]
==============================
thalach : [150 187 172 178 163 148 153 173 162 174 160 139 171 144 158 114 151 16
1
 179 137 157 123 152 168 140 188 125 170 165 142 180 143 182 156 115 149
 146 175 186 185 159 130 190 132 147 154 202 166 164 184 122 169 138 111
 145 194 131 133 155 167 192 121  96 126 105 181 116 108 129 120 112 128
 109 113  99 177 141 136  97 127 103 124  88 195 106  95 117  71 118 134
  90]
==============================
exang : [0 1]
==============================
oldpeak : [2.3 3.5 1.4 0.8 0.6 0.4 1.3 0.  0.5 1.6 1.2 0.2 1.8 1.  2.6 1.5 3.  2.
4
 0.1 1.9 4.2 1.1 2.  0.7 0.3 0.9 3.6 3.1 3.2 2.5 2.2 2.8 3.4 6.2 4.  5.6
 2.9 2.1 3.8 4.4]
==============================
slope : [0 2 1]
==============================
ca : [0 2 1 3 4]
==============================
thal : [1 2 3 0]
==============================
target : [1 0]
==============================
Categorical Features : ['sex', 'cp', 'fbs', 'restecg', 'exang', 'slope', 'ca', 't
hal', 'target']
Continous Features : ['age', 'trestbps', 'chol', 'thalach', 'oldpeak']
```

In [231…

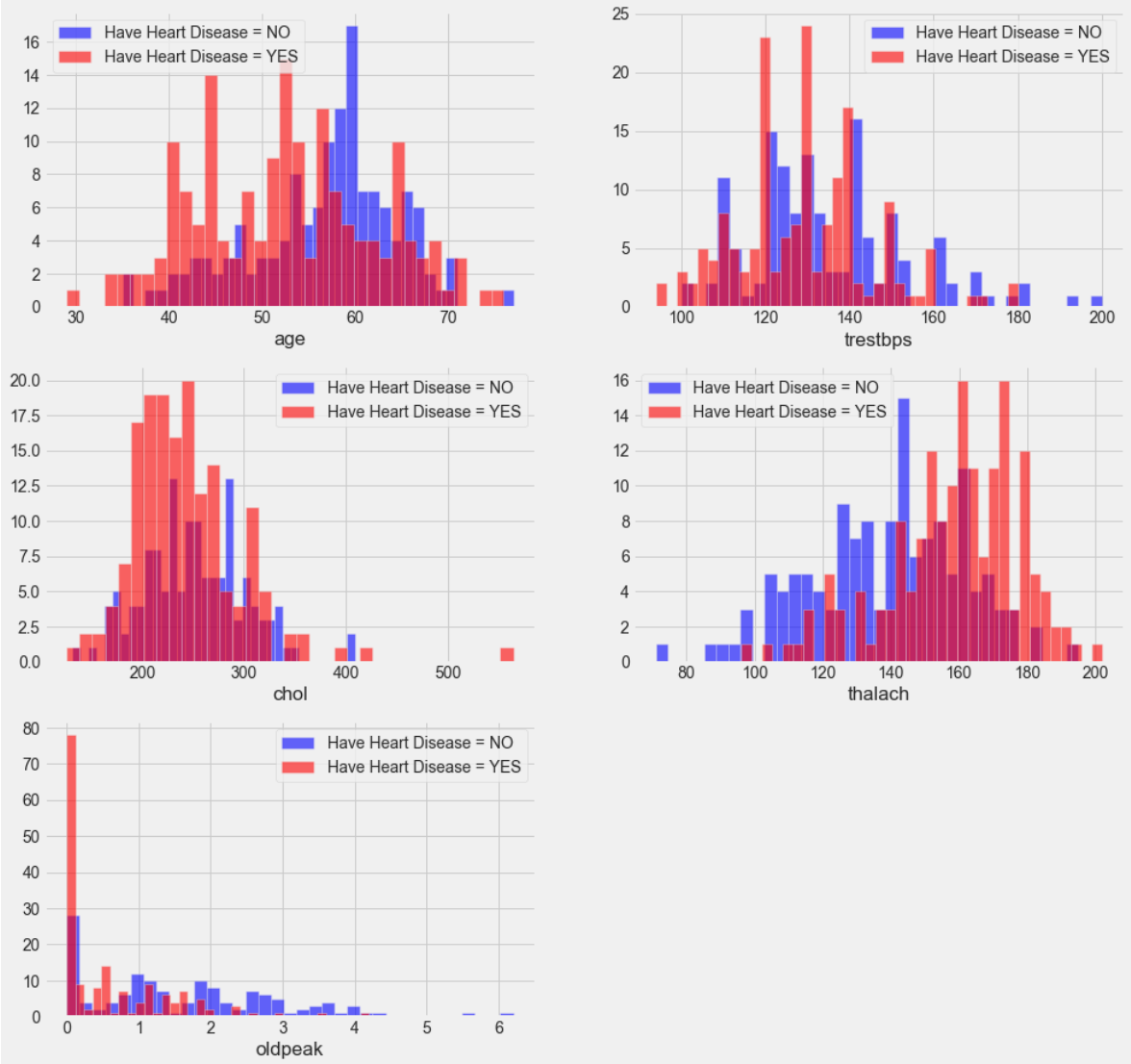
```
#Study of the relationship of categorical features and heart disease:

plt.figure(figsize=(15, 15))
```

```
for i, column in enumerate(categorical_val, 1):
    plt.subplot(3, 3, i)
    df[df["target"] == 0][column].hist(bins=35, color='blue', label='Have Heart D
    df[df["target"] == 1][column].hist(bins=35, color='red', label='Have Heart Di
    plt.legend()
    plt.xlabel(column)
```



In [232…

```
#Study of the relationship of continuous features and heart disease:

plt.figure(figsize=(15, 15))

for i, column in enumerate(continous_val, 1):
    plt.subplot(3, 2, i)
    df[df["target"] == 0][column].hist(bins=35, color='blue', label='Have Heart D
    df[df["target"] == 1][column].hist(bins=35, color='red', label='Have Heart Di
    plt.legend()
    plt.xlabel(column)
```

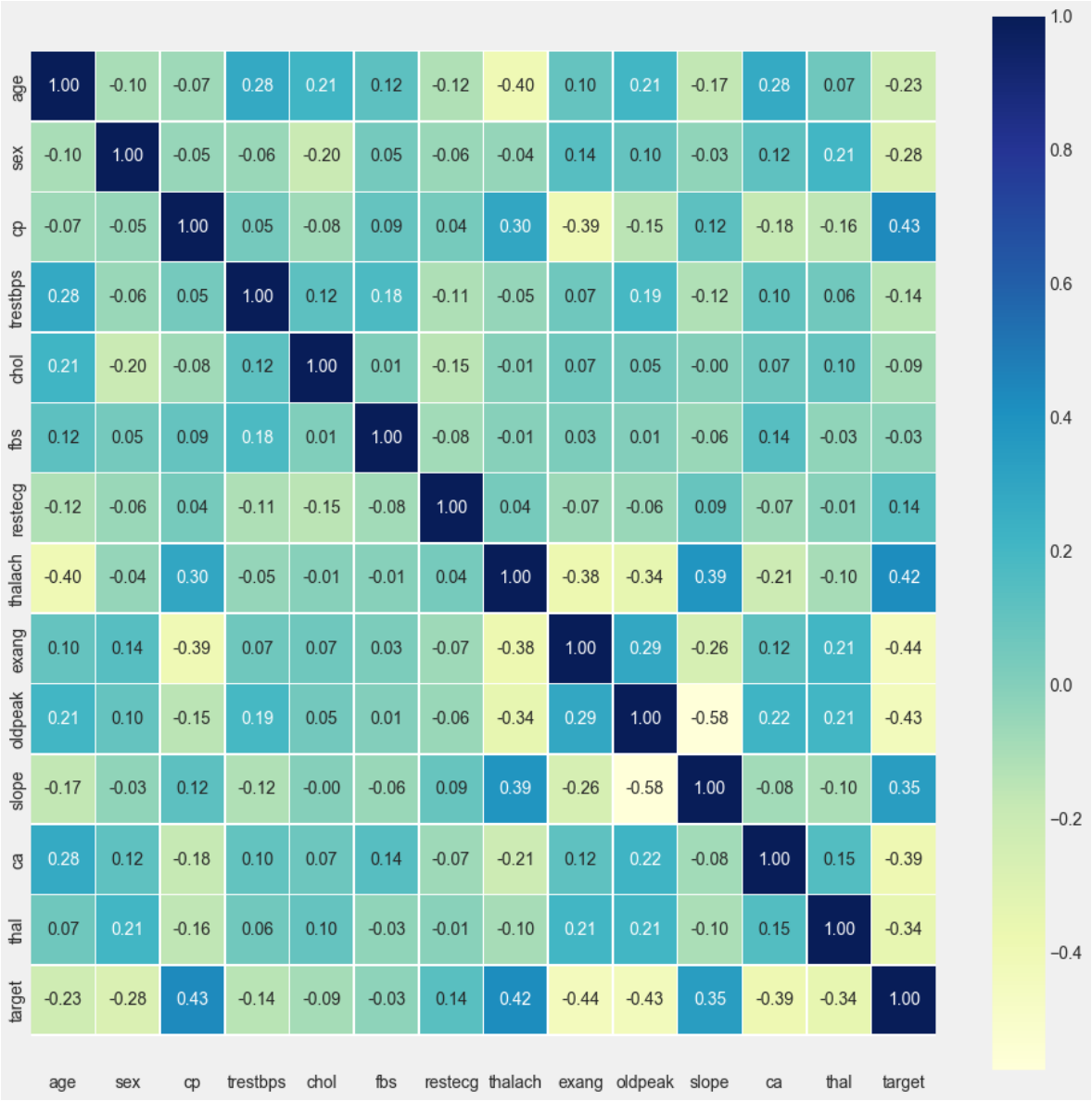


In [233…

```
# Studying the correlations between features using Heat Map!
corr_matrix = df.corr()
fig, ax = plt.subplots(figsize=(15, 15))
ax = sns.heatmap(corr_matrix,
                 annot=True,
                 linewidths=0.5,
                 fmt=".2f",
                 cmap="YlGnBu");
bottom, top = ax.get_ylim()
ax.set_ylim(bottom + 0.5, top - 0.5)
```

Out[233…

```
(14.5, -0.5)
```

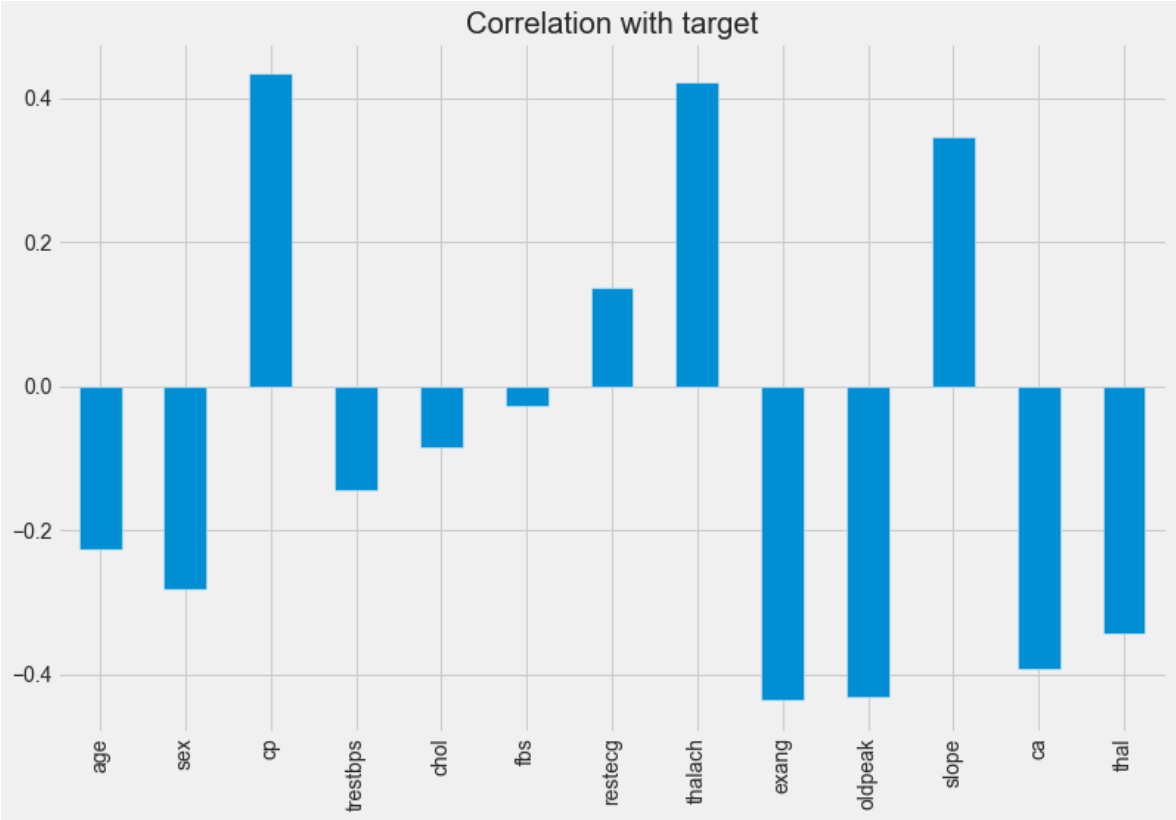


In [234…

```
df.drop('target', axis=1).corrwith(df.target).plot(kind='bar', grid=True, figsize
                                                   title="Correlation with target
```

Out[234…

```
<matplotlib.axes._subplots.AxesSubplot at 0x23694b7bf60>
```



In [235...

```
categorical_val.remove('target')
dataset = pd.get_dummies(df, columns = categorical_val)

from sklearn.preprocessing import StandardScaler

s_sc = StandardScaler()
col_to_scale = ['age', 'trestbps', 'chol', 'thalach', 'oldpeak']
dataset[col_to_scale] = s_sc.fit_transform(dataset[col_to_scale])
```

In [236...

```
dataset
```

Out[236...

	age	trestbps	chol	thalach	oldpeak	target	sex_0	sex_1	cp_0	cp_1	...	slope_2	ca
0	0.95	0.76	-0.26	0.02	1.09	1	0	1	0	0	...	0	
1	-1.92	-0.09	0.07	1.63	2.12	1	0	1	0	0	...	0	
2	-1.47	-0.09	-0.82	0.98	0.31	1	1	0	0	1	...	1	
3	0.18	-0.66	-0.20	1.24	-0.21	1	0	1	0	1	...	1	
4	0.29	-0.66	2.08	0.58	-0.38	1	1	0	1	0	...	1	
...	...	...	...	...	...	...	...	...	...	...	...	...	...
298	0.29	0.48	-0.10	-1.17	-0.72	0	1	0	1	0	...	0	
299	-1.03	-1.23	0.34	-0.77	0.14	0	0	1	0	0	...	0	
300	1.50	0.71	-1.03	-0.38	2.04	0	0	1	1	0	...	0	
301	0.29	-0.09	-2.23	-1.52	0.14	0	0	1	1	0	...	0	
302	0.29	-0.09	-0.20	1.06	-0.90	0	1	0	0	1	...	0	

303 rows × 31 columns

Machine Learning Section

1- Logistic Regression Algorithm

In [289…

```
from sklearn.model_selection import StratifiedShuffleSplit
from sklearn.metrics import classification_report, confusion_matrix, ConfusionMat
feature_cols = [col_name for col_name in dataset.columns if col_name != 'target']

# Get the split indexes
strat_shuf_split = StratifiedShuffleSplit(n_splits=1,
                                          test_size=0.3,
                                          random_state=42)

train_idx, test_idx = next(strat_shuf_split.split(dataset[feature_cols], dataset.
# Create the dataframes
X_train = dataset.loc[train_idx, feature_cols]
y_train = dataset.loc[train_idx, 'target']

X_test  = dataset.loc[test_idx, feature_cols]
y_test  = dataset.loc[test_idx, 'target']
```

In [290…

```
### BEGIN SOLUTION
from sklearn.linear_model import LogisticRegression

# Standard logistic regression
lr = LogisticRegression(solver='liblinear').fit(X_train, y_train)
y_pred_0 = lr.predict(X_test)
clf_report = pd.DataFrame(classification_report(y_test, y_pred_0, output_dict=Tru
clf_report
```

Out[290…

	0	1	accuracy	macro avg	weighted avg
precision	0.78	0.80	0.79	0.79	0.79
recall	0.76	0.82	0.79	0.79	0.79
f1-score	0.77	0.81	0.79	0.79	0.79
support	41.00	50.00	0.79	91.00	91.00

In [291…

```
from sklearn.linear_model import LogisticRegressionCV

# L1 regularized logistic regression
lr_l1 = LogisticRegressionCV(Cs=10, cv=4, penalty='l1', solver='liblinear').fit()
y_pred_1 = lr_l1.predict(X_test)
clf_report = pd.DataFrame(classification_report(y_test, y_pred_1, output_dict=Tru
clf_report
```

Out[291…

	0	1	accuracy	macro avg	weighted avg
precision	0.81	0.78	0.79	0.79	0.79
recall	0.71	0.86	0.79	0.78	0.79
f1-score	0.75	0.82	0.79	0.79	0.79
support	41.00	50.00	0.79	91.00	91.00

In [292...

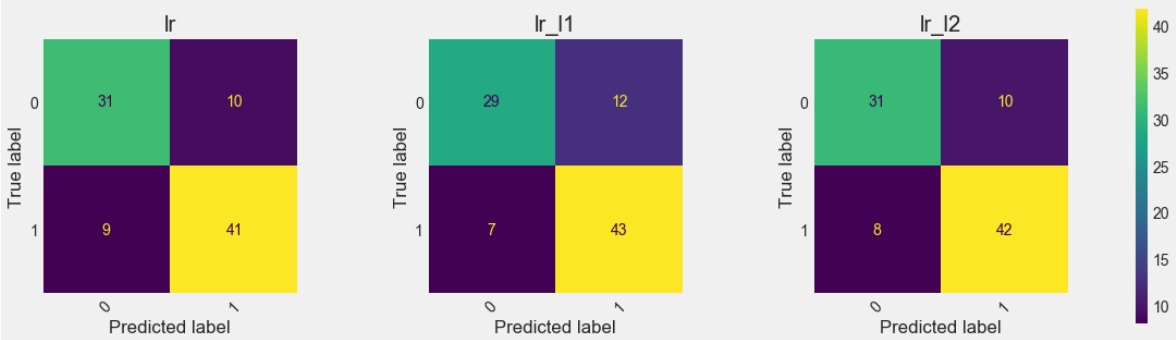
```
# L2 regularized logistic regression
lr_l2 = LogisticRegressionCV(Cs=10, cv=4, penalty='l2', solver='liblinear').fit()
y_pred_2 = lr_l2.predict(X_test)
clf_report = pd.DataFrame(classification_report(y_test, y_pred_2, output_dict=Tru
clf_report
```

Out[292...

	0	1	accuracy	macro avg	weighted avg
precision	0.79	0.81	0.80	0.80	0.80
recall	0.76	0.84	0.80	0.80	0.80
f1-score	0.77	0.82	0.80	0.80	0.80
support	41.00	50.00	0.80	91.00	91.00

In [294...

```
classifiers = {
    "lr": lr,
    "lr_l1": lr_l1,
    "lr_l2": lr_l2

}

f, axes = plt.subplots(1, 3, figsize=(20, 5))
for i, (key, classifier) in enumerate(classifiers.items()):
    y_pred = classifier.predict(X_test)
    cf_matrix = confusion_matrix(y_test, y_pred)
    disp = ConfusionMatrixDisplay(cf_matrix)
    disp.plot(ax=axes[i], xticks_rotation=45)
    disp.ax_.grid(False)
    disp.ax_.set_title(key)
    disp.im_.colorbar.remove()

f.colorbar(disp.im_, ax=axes)
plt.show()
```



2- KNN Algorithm

In [242...

```
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import confusion_matrix, accuracy_score, classification_repo
```

In [243...

```
### BEGIN SOLUTION
max_k = 40
f1_scores = list()
error_rates = list() # 1-accuracy

for k in range(1, max_k):
```

```
    knn = KNeighborsClassifier(n_neighbors=k, weights='distance')
    knn = knn.fit(X_train, y_train)

    y_pred = knn.predict(X_test)
    f1 = f1_score(y_pred, y_test)
    f1_scores.append((k, round(f1_score(y_test, y_pred), 4)))
    error = 1-round(accuracy_score(y_test, y_pred), 4)
    error_rates.append((k, error))

f1_results = pd.DataFrame(f1_scores, columns=['K', 'F1 Score'])
error_results = pd.DataFrame(error_rates, columns=['K', 'Error Rate'])

# Get minimum error id
min_error_id = error_results['Error Rate'].idxmin()

# Get Best K
error_results.loc[min_error_id]
```

Out[243...

```
K            25.00
Error Rate    0.16
Name: 24, dtype: float64
```

In [244...

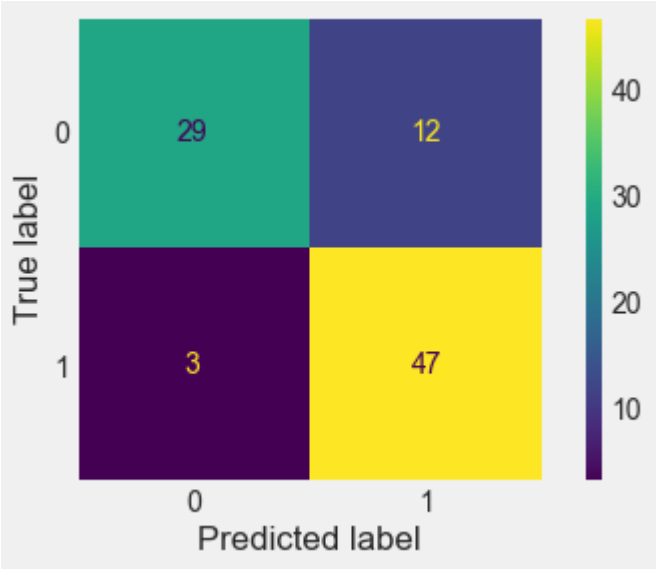
```
knn = KNeighborsClassifier(n_neighbors=25, weights='distance')
knn = knn.fit(X_train, y_train)
y_pred = knn.predict(X_test)

KNN_report = pd.DataFrame(classification_report(y_test, y_pred, output_dict=True)
KNN_report
```

Out[244...

	0	1	accuracy	macro avg	weighted avg
precision	0.91	0.80	0.84	0.85	0.85
recall	0.71	0.94	0.84	0.82	0.84
f1-score	0.79	0.86	0.84	0.83	0.83
support	41.00	50.00	0.84	91.00	91.00

In [245...

```
cm = confusion_matrix(y_test, y_pred, labels=knn.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=knn.classes_)
disp.plot()
plt.grid(False)
plt.show()
```



3- XGBoost Algorthim

In [246...

```
%pip install xgboost
```

```
Requirement already satisfied: xgboost in c:\users\mohamad\appdata\local\programs
\python\python36\lib\site-packages (0.90)
Requirement already satisfied: scipy in c:\users\mohamad\appdata\local\programs\p
ython\python36\lib\site-packages (from xgboost) (1.4.1)
Requirement already satisfied: numpy in c:\users\mohamad\appdata\local\programs\p
ython\python36\lib\site-packages (from xgboost) (1.19.5)
Note: you may need to restart the kernel to use updated packages.
```

In [284...

```
import xgboost as xgb
from sklearn.model_selection import GridSearchCV

param_grid = {
    "max_depth": [5],
    "learning_rate": [0.05],
    "gamma": [0, 0.25, 1, 10],
    "reg_lambda": [0],
    "scale_pos_weight": [1, 3, 5, 7, 10],
    "subsample": [0.1,0.2, 0.3, 0.4, 0.5, 0.8],
    "colsample_bytree": [0.5,0.7],
}


# Init classifier
xgb_cl = xgb.XGBClassifier(objective="binary:logistic")

# Init Grid Search
grid_cv = GridSearchCV(xgb_cl, param_grid, n_jobs=-1, cv=3, scoring="roc_auc")

# Fit
_ = grid_cv.fit(X_train, y_train)
```

In [285...

```
grid_cv.best_params_
```

Out[285...

```
{'colsample_bytree': 0.5,
 'gamma': 0.25,
 'learning_rate': 0.05,
 'max_depth': 5,
```

```
'reg_lambda': 0,
'scale_pos_weight': 7,
'subsample': 0.2}
```

In [287…

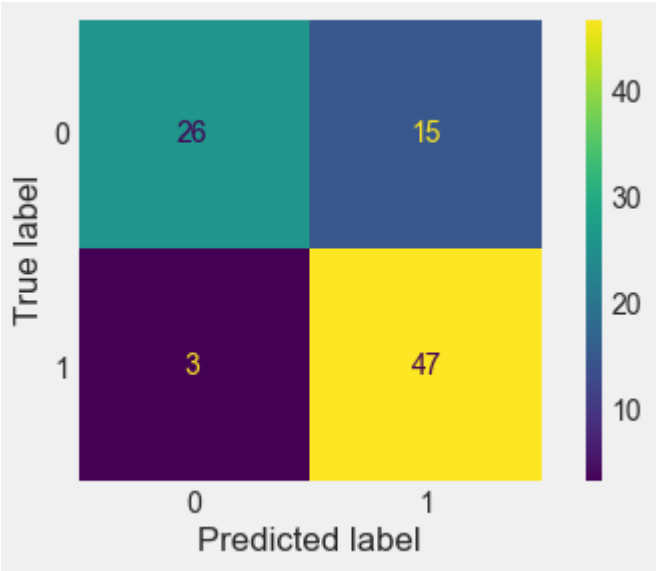
```
final_xgb_cl = xgb.XGBClassifier(
    **grid_cv.best_params_,
    objective="binary:logistic",
)

_ = final_xgb_cl.fit(X_train, y_train)

y_pred = final_xgb_cl.predict(X_test)

xgb_report = pd.DataFrame(classification_report(y_test, y_pred, output_dict=True)
xgb_report
```

Out[287…

	0	1	accuracy	macro avg	weighted avg
precision	0.90	0.76	0.80	0.83	0.82
recall	0.63	0.94	0.80	0.79	0.80
f1-score	0.74	0.84	0.80	0.79	0.80
support	41.00	50.00	0.80	91.00	91.00

In [288…

```
cm = confusion_matrix(y_test, y_pred, labels=final_xgb_cl.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=final_xgb_cl.cl
disp.plot()
plt.grid(False)
plt.show()
```



4- SVC Algorthim

In [252…

```
from sklearn.svm import SVC

kwargs = {'kernel': 'rbf'}
svc = SVC(**kwargs)

SVC_cl = svc.fit(X_train, y_train)
y_pred = SVC_cl.predict(X_test)
```

```
SVC_cl_report = pd.DataFrame(classification_report(y_test, y_pred, output_dict=Tr
SVC_cl_report
```

Out[252...

	0	1	accuracy	macro avg	weighted avg
precision	0.79	0.81	0.80	0.80	0.80
recall	0.76	0.84	0.80	0.80	0.80
f1-score	0.77	0.82	0.80	0.80	0.80
support	41.00	50.00	0.80	91.00	91.00

In [253...

```
cm = confusion_matrix(y_test, y_pred, labels=SVC_cl.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=SVC_cl.classes_
disp.plot()
plt.grid(False)
plt.show()
```