+ Code + Text

RAM
Disk

```
from google.colab import drive
drive.mount('/content/drive')
```

4s

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.mount("/content/drive", force_remount=True).
```

```
import numpy as np
import pandas as pd
import seaborn as sns
import plotly.express as px
import matplotlib.pyplot as plt
import warnings
warnings.filterwarnings('ignore')

%matplotlib inline
import time
import random

random.seed(100)
path="/content/drive/MyDrive/winequality-red.csv"
df=pd.read_csv(path)
df.head()
print('Dataset has', df.shape[0] , 'rows and', df.shape[1], 'columns')
```

0s

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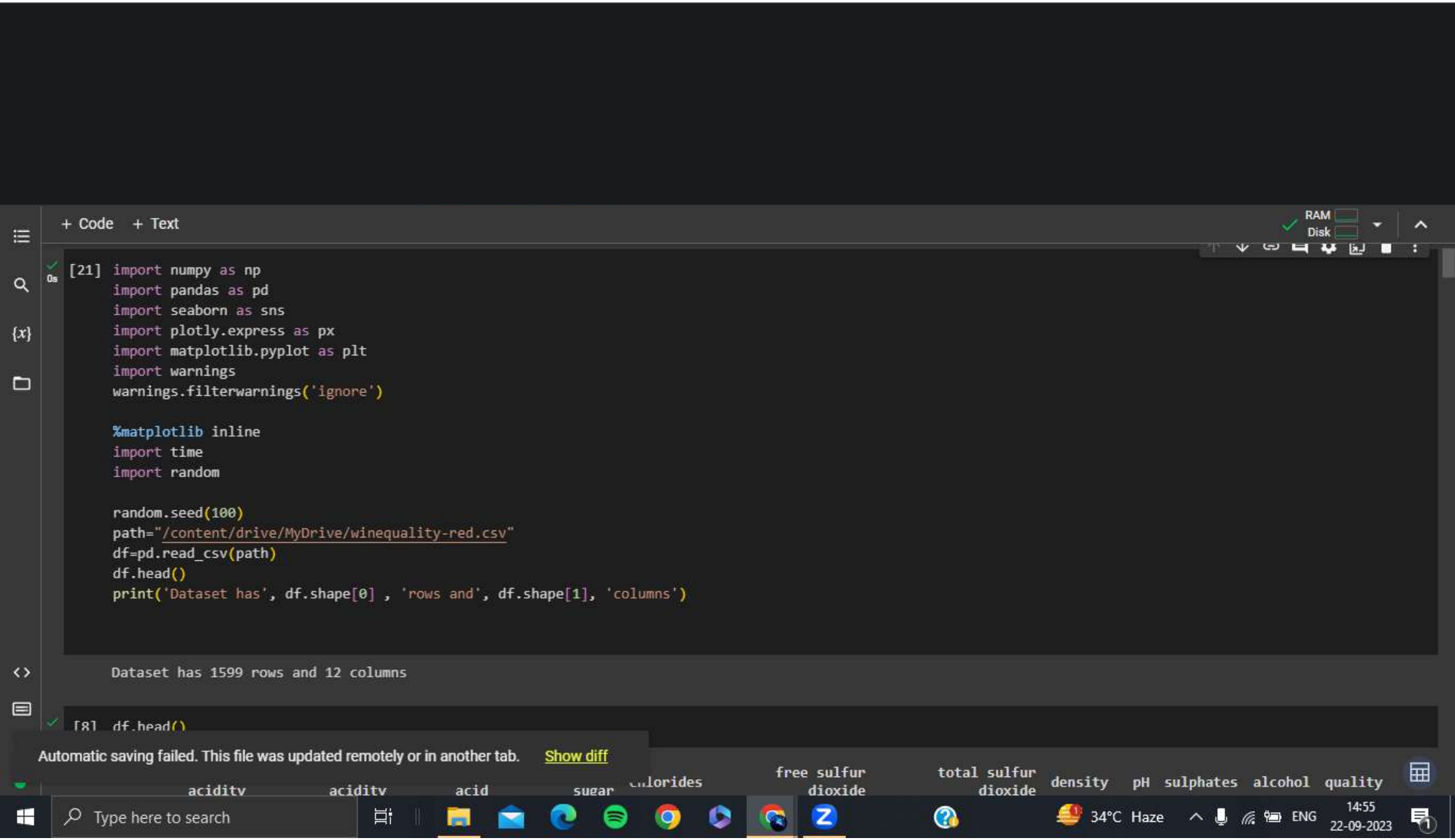
34°C Haze ENG 14:55 22-09-2023


+ Code + Text
RAM
Disk
[21] import numpy as np
import pandas as pd
import seaborn as sns
import plotly.express as px
import matplotlib.pyplot as plt
import warnings
warnings.filterwarnings('ignore')
%matplotlib inline
import time
import random
random.seed(100)
path="/content/drive/MyDrive/winequality-red.csv"
df=pd.read_csv(path)
df.head()
print('Dataset has', df.shape[0] , 'rows and', df.shape[1], 'columns')
Dataset has 1599 rows and 12 columns
[8] df.head()
Automatic saving failed. This file was updated remotely or in another tab.
Show diff
acidity
acidity
acid
sugar
chlorides
free sulfur dioxide
total sulfur dioxide
density
pH
sulphates
alcohol
quality
Type here to search
34°C Haze
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Dataset has 1599 rows and 12 columns

```
df.head()
```

	fixed acidity	volatile acidity	citric acid	residual sugar	chlorides	free sulfur dioxide	total sulfur dioxide	density	pH	sulphates	alcohol	quality
0	7.4	0.70	0.00	1.9	0.076	11.0	34.0	0.9978	3.51	0.56	9.4	5
1	7.8	0.88	0.00	2.6	0.098	25.0	67.0	0.9968	3.20	0.68	9.8	5
2	7.8	0.76	0.04	2.3	0.092	15.0	54.0	0.9970	3.26	0.65	9.8	5
3	11.2	0.28	0.56	1.9	0.075	17.0	60.0	0.9980	3.16	0.58	9.8	6
4	7.4	0.70	0.00	1.9	0.076	11.0	34.0	0.9978	3.51	0.56	9.4	5

```
[9] df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1599 entries, 0 to 1598
Data columns (total 12 columns):
 #   Column                Non-Null Count  Dtype
---  ------                --------------  -----
```

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```
 2   residual sugar        1599 non-null   float64
```

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RAM
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```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1599 entries, 0 to 1598
Data columns (total 12 columns):
 #   Column                Non-Null Count  Dtype  
---  ------                --------------  -----  
 0   fixed acidity         1599 non-null   float64
 1   volatile acidity      1599 non-null   float64
 2   citric acid           1599 non-null   float64
 3   residual sugar        1599 non-null   float64
 4   chlorides             1599 non-null   float64
 5   free sulfur dioxide   1599 non-null   float64
 6   total sulfur dioxide  1599 non-null   float64
 7   density               1599 non-null   float64
 8   pH                    1599 non-null   float64
 9   sulphates             1599 non-null   float64
 10  alcohol               1599 non-null   float64
 11  quality               1599 non-null   int64  
dtypes: float64(11), int64(1)
memory usage: 150.0 KB
```

```
[10] print(df.columns)
     print(df.shape)
```

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ıal sugar',
, 'density',

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```
print(df.columns)
print(df.shape)
```

```
Index(['fixed acidity', 'volatile acidity', 'citric acid', 'residual sugar',
       'chlorides', 'free sulfur dioxide', 'total sulfur dioxide', 'density',
       'pH', 'sulphates', 'alcohol', 'quality'],
      dtype='object')
(1599, 12)
```

[13]

```
df.duplicated().sum()
```

```
240
```

[12]

```
df.describe().T
```

	count	mean	std	min	25%	50%	75%	max
fixed acidity	1599.0	8.319637	1.741096	4.60000	7.1000	7.90000	9.200000	15.90000
volatile acidity	1599.0	0.527821	0.179060	0.12000	0.3900	0.52000	0.640000	1.58000
citric acid	1599.0	0.270976	0.194801	0.00000	0.0900	0.26000	0.420000	1.00000
						000	2.600000	15.50000
chlorides	1599.0	0.087467	0.047065	0.01200	0.0700	0.07900	0.090000	0.61100

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[12]

	count	mean	std	min	25%	50%	75%	max
fixed acidity	1599.0	8.319637	1.741096	4.60000	7.1000	7.90000	9.200000	15.90000
volatile acidity	1599.0	0.527821	0.179060	0.12000	0.3900	0.52000	0.640000	1.58000
citric acid	1599.0	0.270976	0.194801	0.00000	0.0900	0.26000	0.420000	1.00000
residual sugar	1599.0	2.538806	1.409928	0.90000	1.9000	2.20000	2.600000	15.50000
chlorides	1599.0	0.087467	0.047065	0.01200	0.0700	0.07900	0.090000	0.61100
free sulfur dioxide	1599.0	15.874922	10.460157	1.00000	7.0000	14.00000	21.000000	72.00000
total sulfur dioxide	1599.0	46.467792	32.895324	6.00000	22.0000	38.00000	62.000000	289.00000
density	1599.0	0.996747	0.001887	0.99007	0.9956	0.99675	0.997835	1.00369
pH	1599.0	3.311113	0.154386	2.74000	3.2100	3.31000	3.400000	4.01000
sulphates	1599.0	0.658149	0.169507	0.33000	0.5500	0.62000	0.730000	2.00000
alcohol	1599.0	10.422983	1.065668	8.40000	9.5000	10.20000	11.100000	14.90000
quality	1599.0	5.636023	0.807569	3.00000	5.0000	6.00000	6.000000	8.00000

[14] df.nunique()

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volatile acidity 143

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RAM Disk

```
df.nunique()
```

```
fixed acidity           96
volatile acidity       143
citric acid             80
residual sugar          91
chlorides              153
free sulfur dioxide     60
total sulfur dioxide   144
density                436
pH                      89
sulphates               96
alcohol                 65
quality                  6
dtype: int64
```

```
[23]
from sklearn.preprocessing import LabelEncoder
bins = (2, 6.5, 8)
group_names = ['bad', 'good']
df['quality'] = pd.cut(df['quality'], bins = bins, labels = group_names)
label_quality = LabelEncoder()
df['quality'] = label_quality.fit_transform(df['quality'])
df['quality'].value_counts()
```

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```
Name: quality, dtype: int64
```

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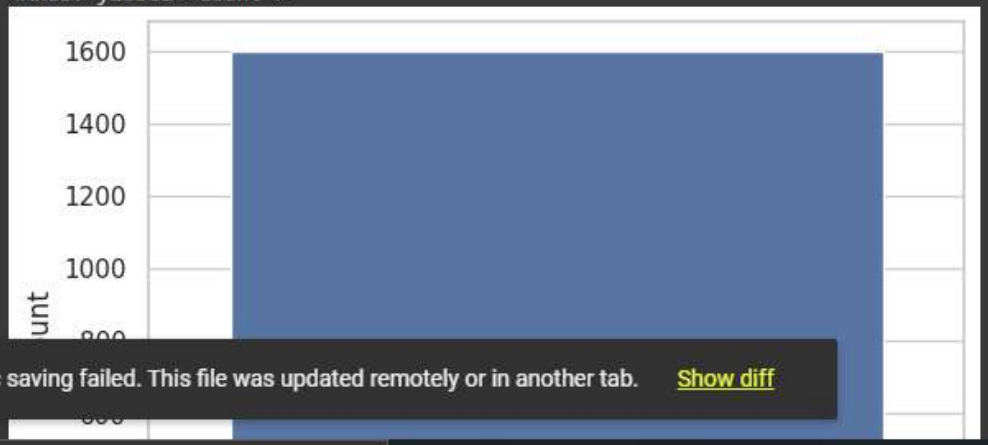
RAM Disk

```
group_names = ['bad', 'good']
df['quality'] = pd.cut(df['quality'], bins = bins, labels = group_names)
label_quality = LabelEncoder()
df['quality'] = label_quality.fit_transform(df['quality'])
df['quality'].value_counts()
```

```
0    1382
1     217
Name: quality, dtype: int64
```

```
sns.countplot(df['quality'])
```

```
<Axes: ylabel='count'>
```



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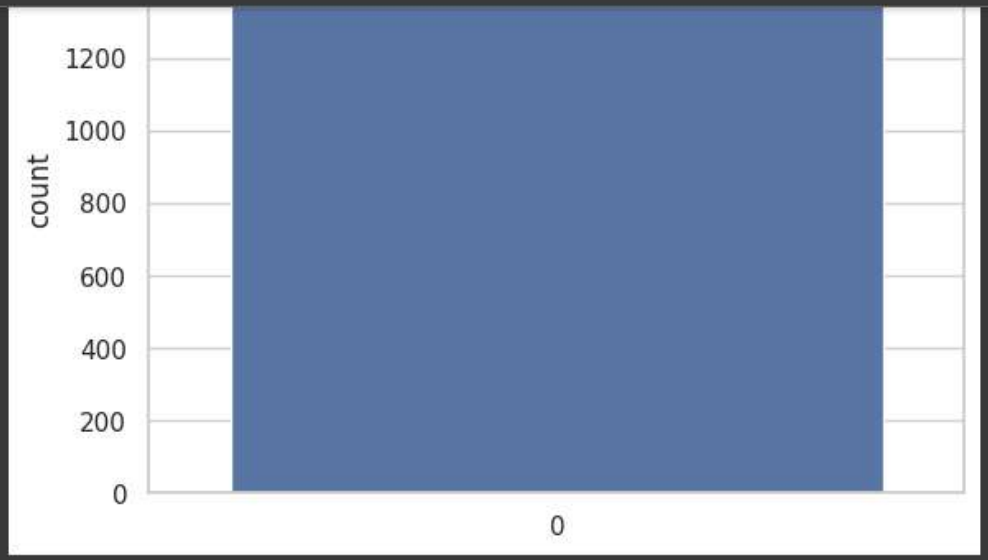
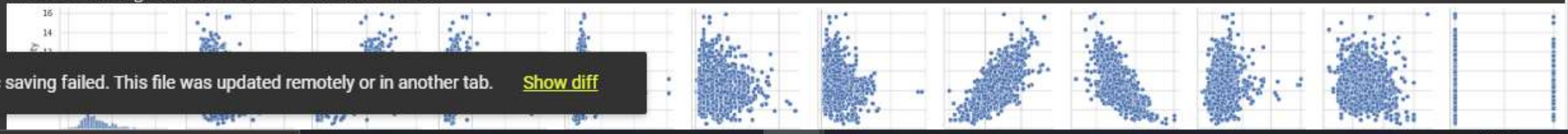



```
sns.pairplot(df)
```

```
<seaborn.axisgrid.PairGrid at 0x78f158f97b20>
```



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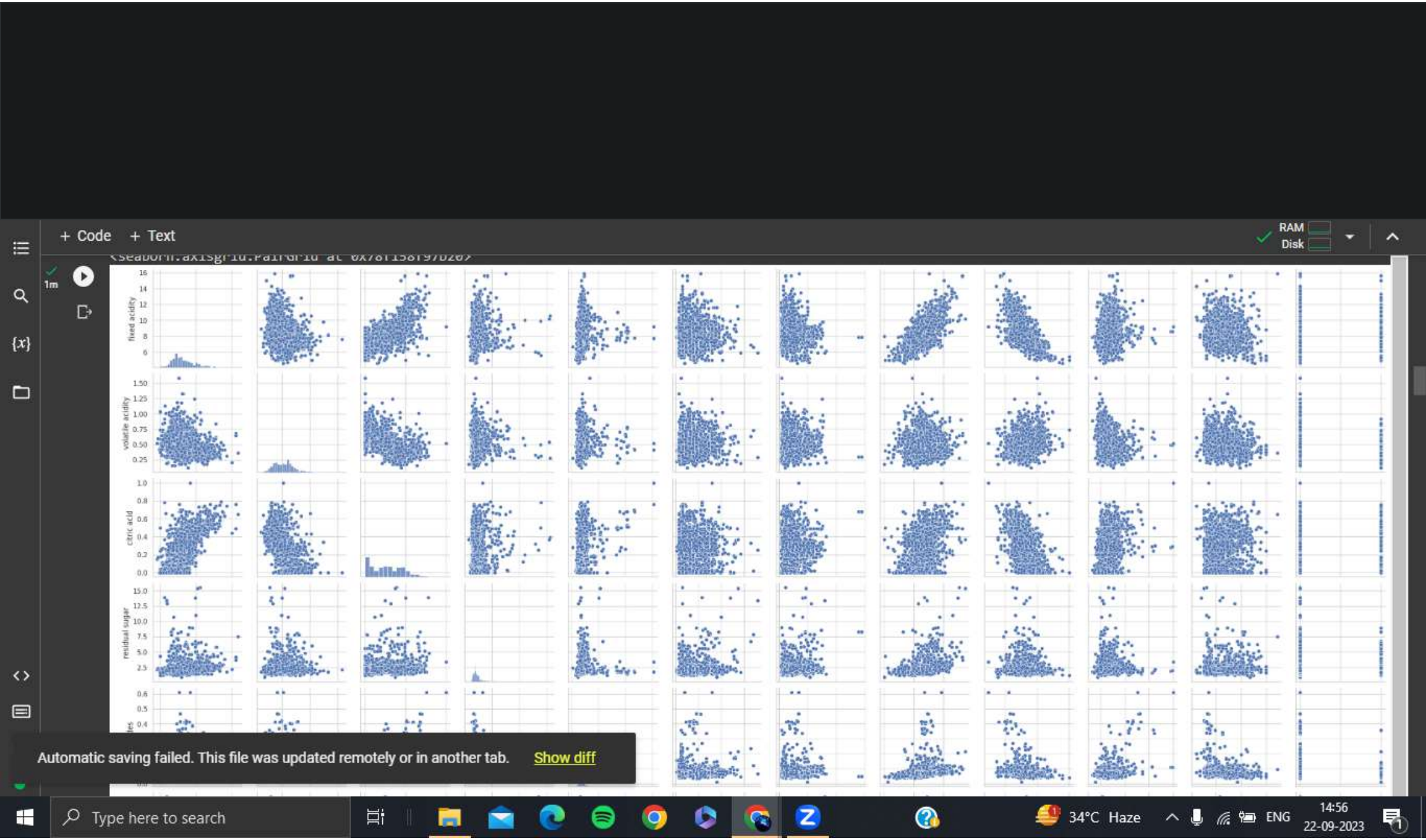
+ Code
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RAM
Disk
1m
fixed acidity
volatile acidity
citric acid
residual sugar
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Show diff
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ENG
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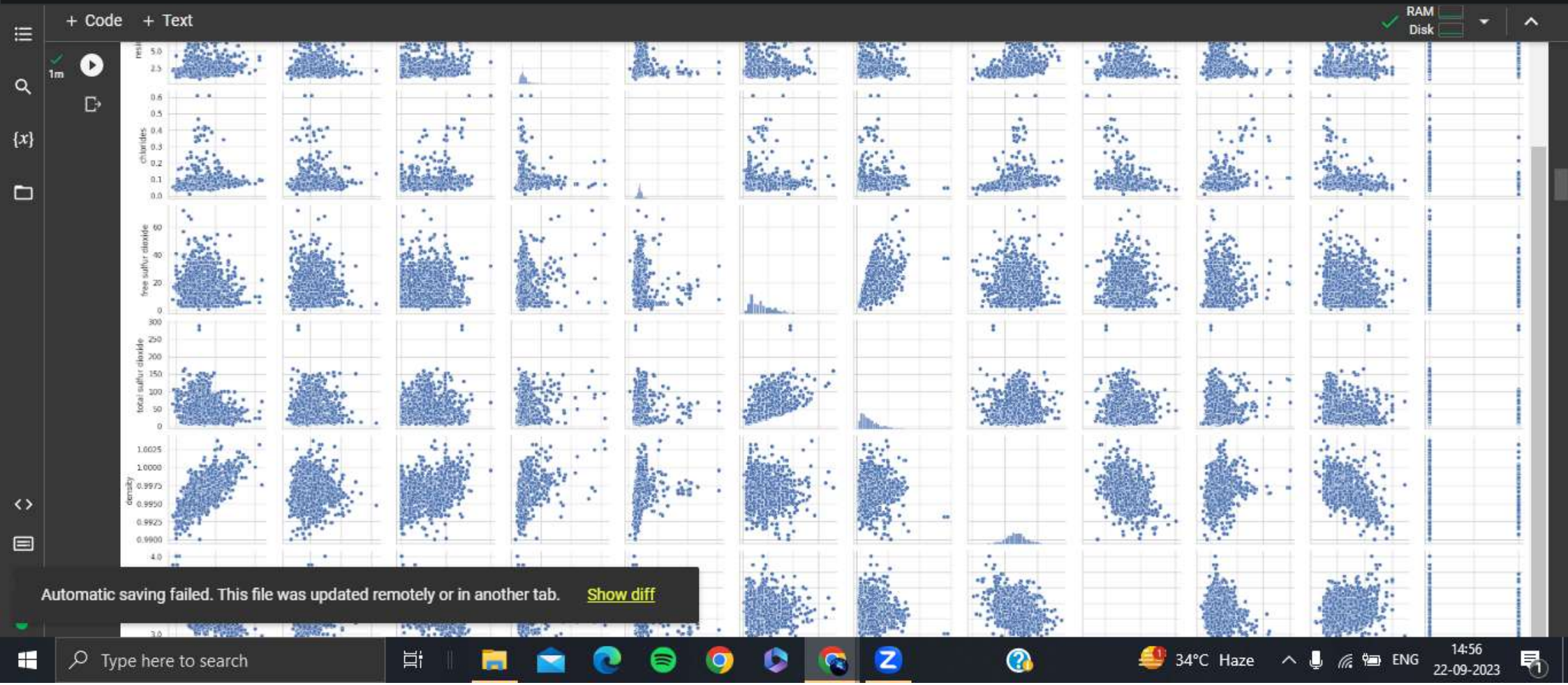

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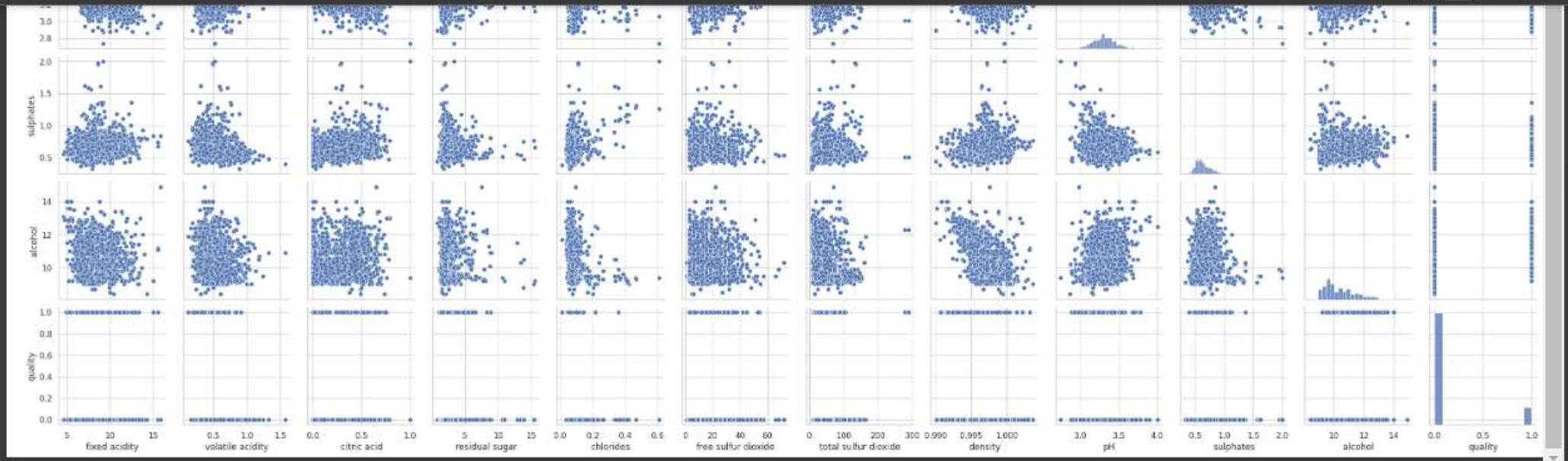
RAM
Disk



1m

```
[26] fig = plt.figure(figsize=(15, 12))
     plt.suptitle('Histograms of Numerical Columns', fontsize=20)
     for i in range(df.shape[1]):
```

8s

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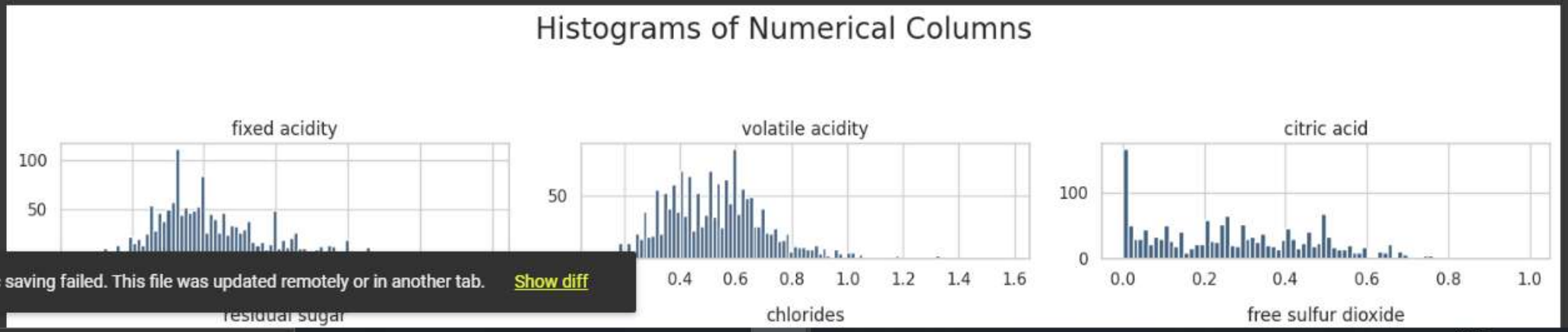
+ Code + Text

RAM Disk

[26]
```
fig = plt.figure(figsize=(15, 12))
plt.suptitle('Histograms of Numerical Columns', fontsize=20)
for i in range(df.shape[1]):
    plt.subplot(6, 3, i + 1)
    f = plt.gca()
    f.set_title(df.columns.values[i])

    vals = np.size(df.iloc[:, i].unique())
    if vals >= 100:
        vals = 100

    plt.hist(df.iloc[:, i], bins=vals, color='#3F5D7D')
plt.tight_layout(rect=[0, 0.03, 1, 0.95])
```



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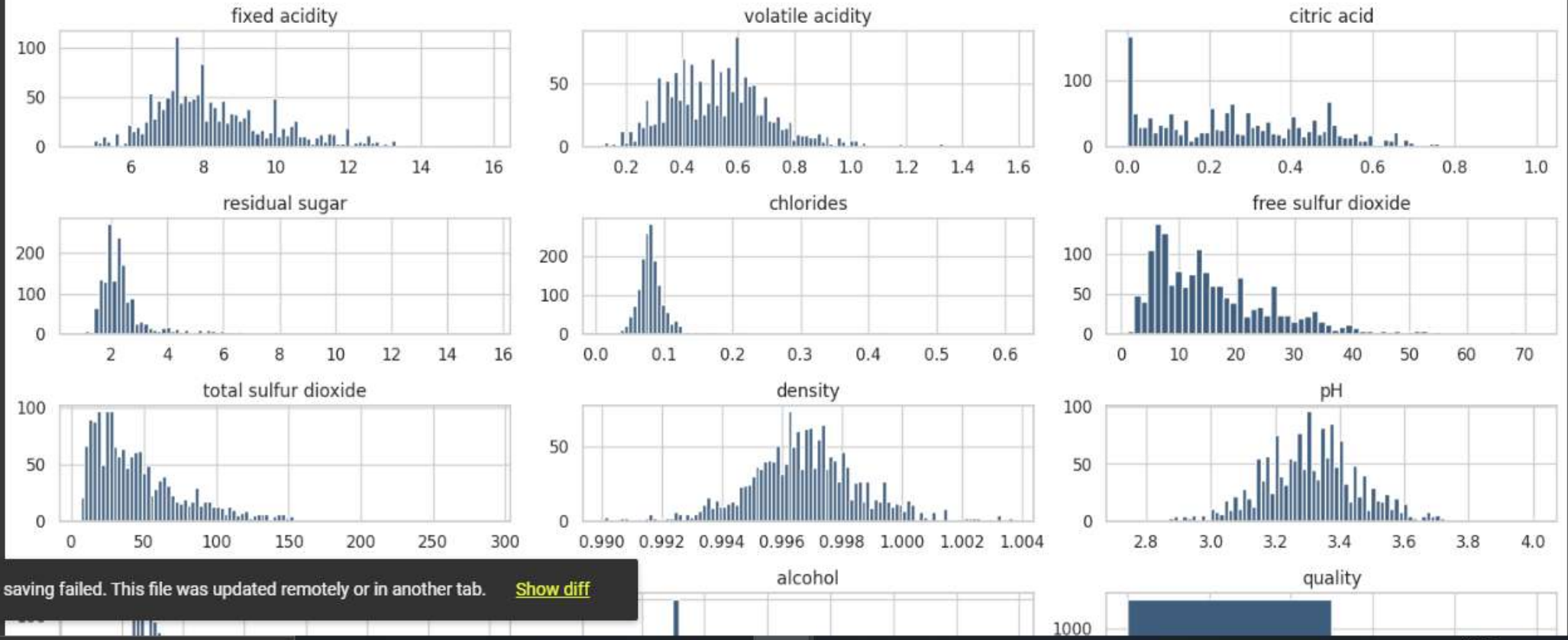
RAM Disk



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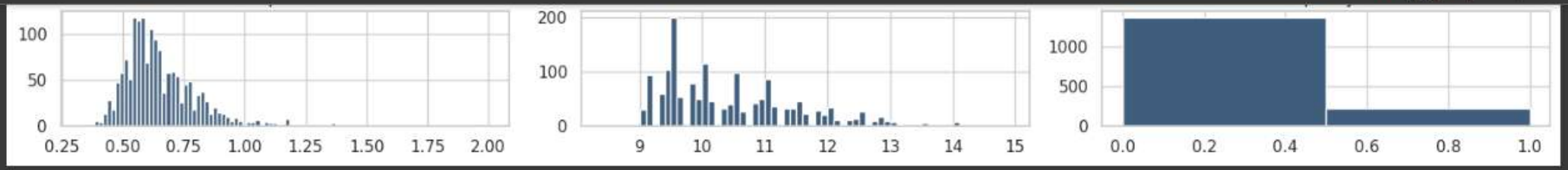
RAM Disk

[26] 8s



[27] 0s
```
df.isna().any()
```

```
fixed acidity           False
volatile acidity        False
citric acid             False
residual sugar          False
chlorides               False
free sulfur dioxide     False
total sulfur dioxide    False
density                 False
pH                      False
sulphates               False
alcohol                 False
quality                 False
dtype: bool
```

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```
ontsize = 15,
```

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+ Code + Text

RAM Disk

[28] 1s
```
df.corrwith(df.quality).plot.bar(
        figsize = (20, 10), title = "Correlation with quality", fontsize = 15,
        rot = 45, grid = True)
```

```
<Axes: title={'center': 'Correlation with quality'}>
```

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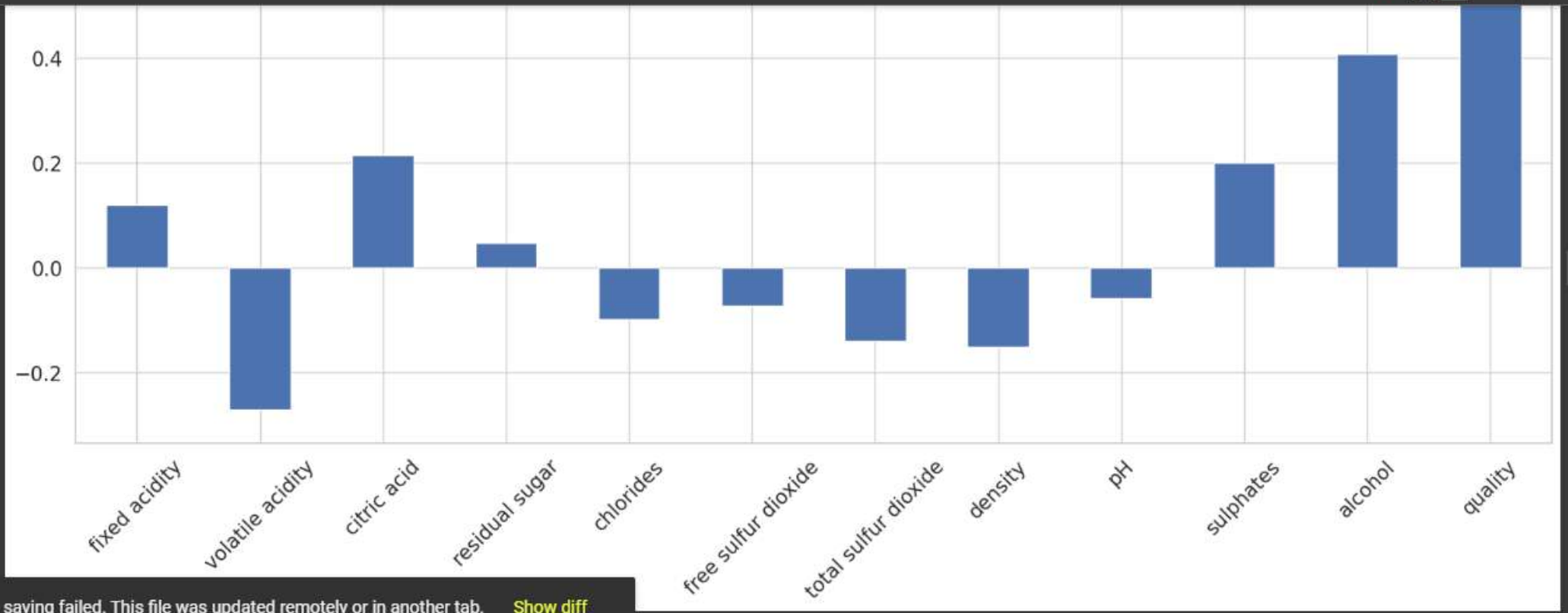
RAM
Disk

[28]
1s



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RAM Disk

[28]

free s... total s...

```
sns.set(style="white")
corr = df.corr()
corr.head()
```

	fixed acidity	volatile acidity	citric acid	residual sugar	chlorides	free sulfur dioxide	total sulfur dioxide	density	pH	sulphates	alcohol	quality
fixed acidity	1.000000	-0.256131	0.671703	0.114777	0.093705	-0.153794	-0.113181	0.668047	-0.682978	0.183006	-0.061668	0.120061
volatile acidity	-0.256131	1.000000	-0.552496	0.001918	0.061298	-0.010504	0.076470	0.022026	0.234937	-0.260987	-0.202288	-0.270712
citric acid	0.671703	-0.552496	1.000000	0.143577	0.203823	-0.060978	0.035533	0.364947	-0.541904	0.312770	0.109903	0.214716
residual sugar	0.114777	0.001918	0.143577	1.000000	0.055610	0.187049	0.203028	0.355283	-0.085652	0.005527	0.042075	0.047779
chlorides	0.093705	0.061298	0.203823	0.055610	1.000000	0.005562	0.047400	0.200632	-0.265026	0.371260	-0.221141	-0.097308

[31]
```
mask = np.zeros_like(corr, dtype=np.bool)
mask[np.triu_indices_from(mask)] = True
```

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RAM Disk

```
mask[np.triu_indices_from(mask)] = True

f, ax = plt.subplots(figsize=(18, 15))

cmap = sns.diverging_palette(220, 10, as_cmap=True)

sns.heatmap(corr, mask=mask, cmap=cmap, vmax=.3, center=0,
            square=True, linewidths=.5, cbar_kws={"shrink": .5})
```

1s

```
<Axes: >
```

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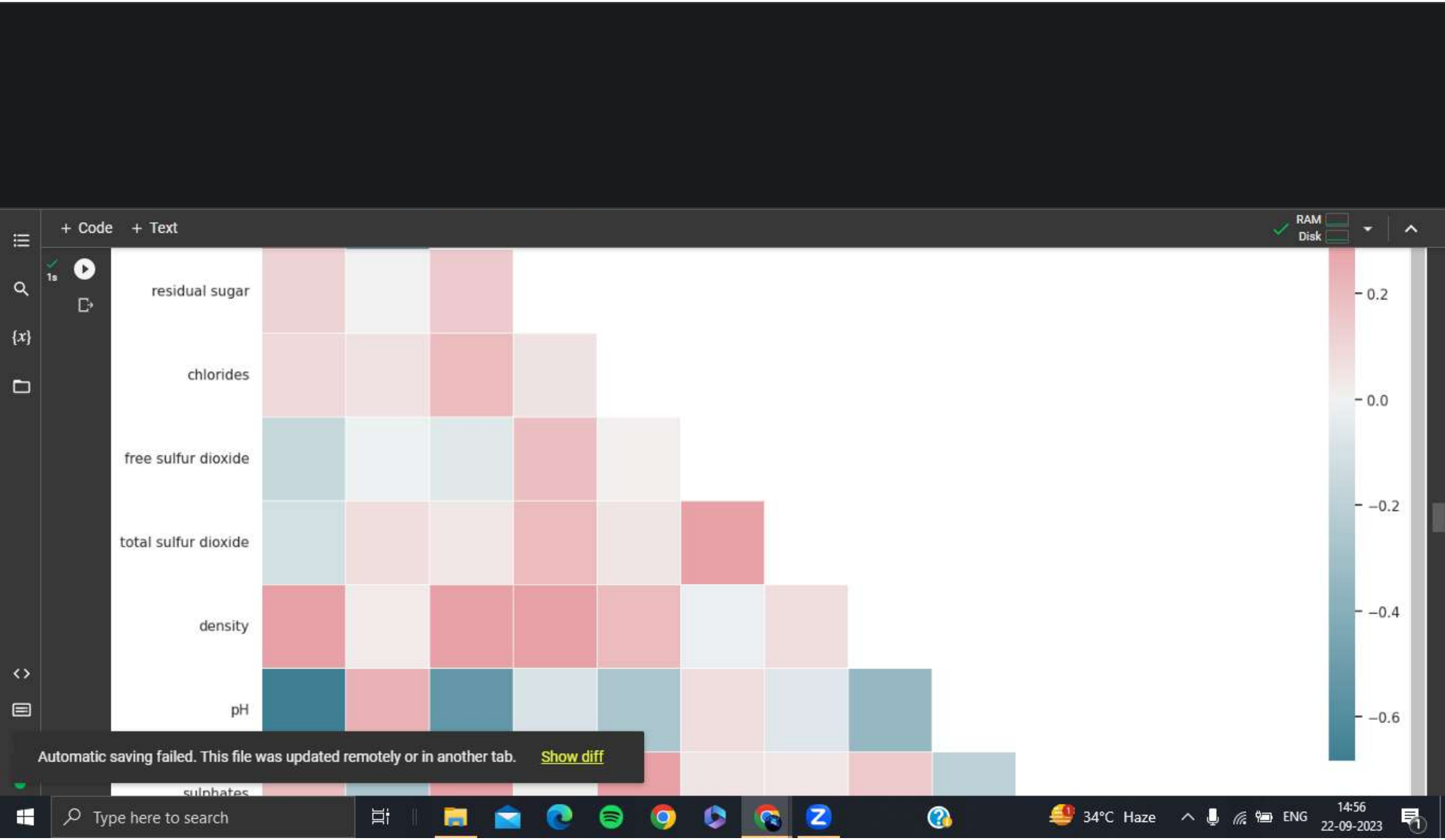
+ Code
+ Text
RAM
Disk
1s
residual sugar
chlorides
free sulfur dioxide
total sulfur dioxide
density
pH
sulphates
0.2
0.0
−0.2
−0.4
−0.6
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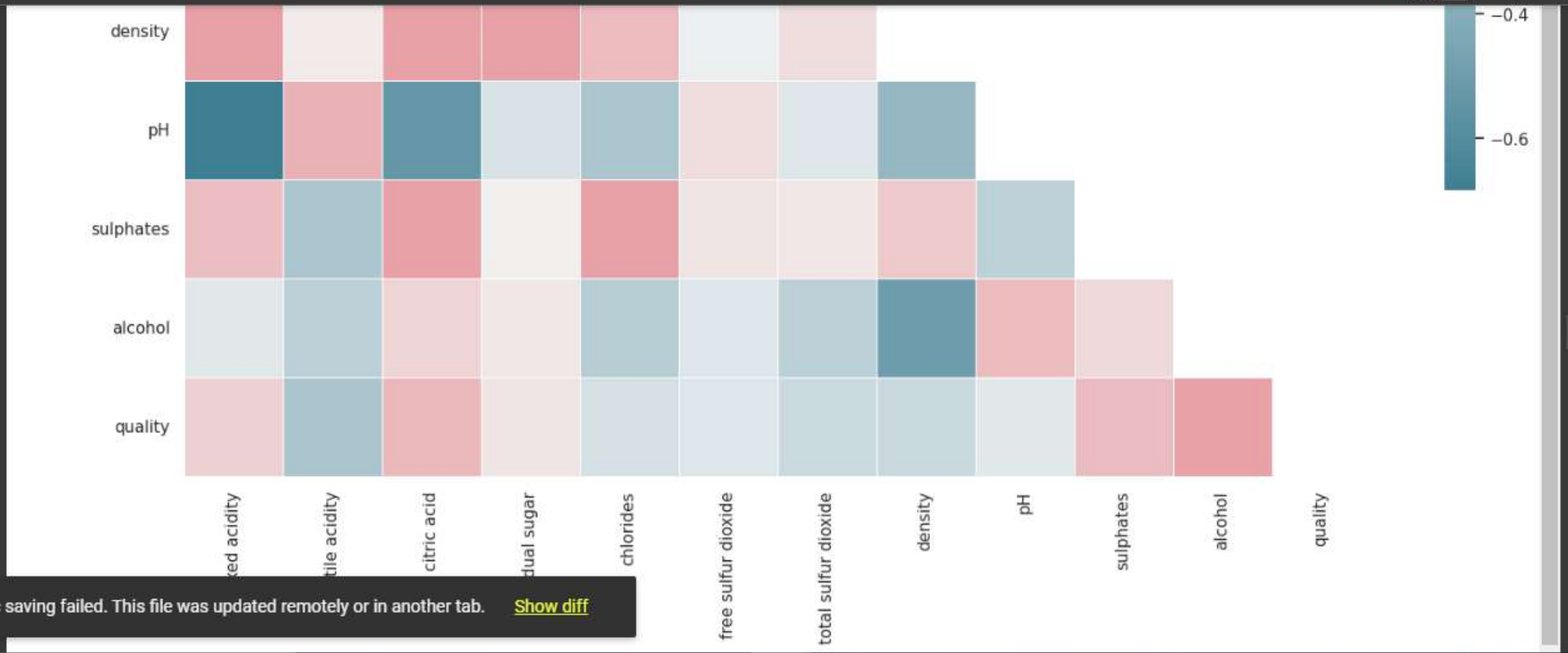

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22-09-2023

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```
[41] X = df.drop('quality',axis=1)
     y=df['quality']
     X.head()
     y.head()
     features_label=df.columns[:11]
```

```
X = df.drop('quality',axis=1)
y=df['quality']
X.head()
```

	fixed acidity	volatile acidity	citric acid	residual sugar	chlorides	free sulfur dioxide	total sulfur dioxide	density	pH	sulphates	alcohol
0	7.4	0.70	0.00	1.9	0.076	11.0	34.0	0.9978	3.51	0.56	9.4
1	7.8	0.88	0.00	2.6	0.098	25.0	67.0	0.9968	3.20	0.68	9.8
2	7.8	0.76	0.04	2.3	0.092	15.0	54.0	0.9970	3.26	0.65	9.8
3	11.2	0.28	0.56	1.9	0.075	17.0	60.0	0.9980	3.16	0.58	9.8
4	7.4	0.70	0.00	1.9	0.076	11.0	34.0	0.9978	3.51	0.56	9.4

```
[35] y.head()
```

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[35] y.head()

```
0    0
1    0
2    0
3    0
4    0
Name: quality, dtype: int64
```

[39] features_label=df.columns[:11]

```
from sklearn.ensemble import RandomForestClassifier
classifier = RandomForestClassifier(n_estimators = 200, criterion = 'entropy', random_state = 0)
classifier.fit(X, y)
importances = classifier.feature_importances_
indices = np. argsort(importances)[::-1]
for i in range(X.shape[1]):
    print ("%2d) %-*s %f" % (i + 1, 30, features_label[i],importances[indices[i]]))
```

```
 1) fixed acidity                 0.178690
 2) volatile acidity              0.128748
 3) citric acid                   0.106496
 4) residual sugar                0.095718
```

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8) density 0.070104

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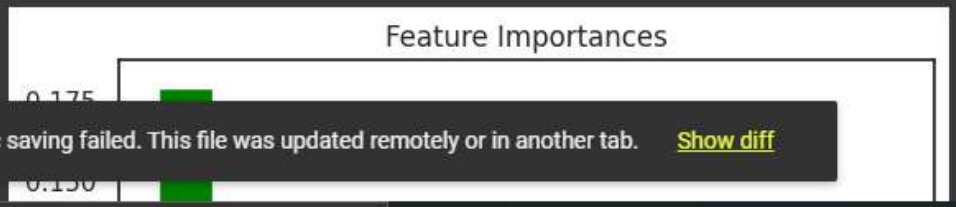
```
[40] for i in range(X.shape[1]):
         print ("%2d) %-*s %f" % (i + 1, 30, features_label[i],importances[indices[i]]))
```

```
 1) fixed acidity                 0.178690
 2) volatile acidity              0.128748
 3) citric acid                   0.106496
 4) residual sugar                0.095718
 5) chlorides                     0.089280
 6) free sulfur dioxide           0.083482
 7) total sulfur dioxide          0.070669
 8) density                       0.070104
 9) pH                            0.060459
10) sulphates                     0.060048
11) alcohol                       0.056307
```

```
plt.title('Feature Importances')
plt.bar(range(X.shape[1]),importances[indices], color="green", align="center")
plt.xticks(range(X.shape[1]),features_label, rotation=90)
plt.xlim([-1, X.shape[1]])
plt.show()
```



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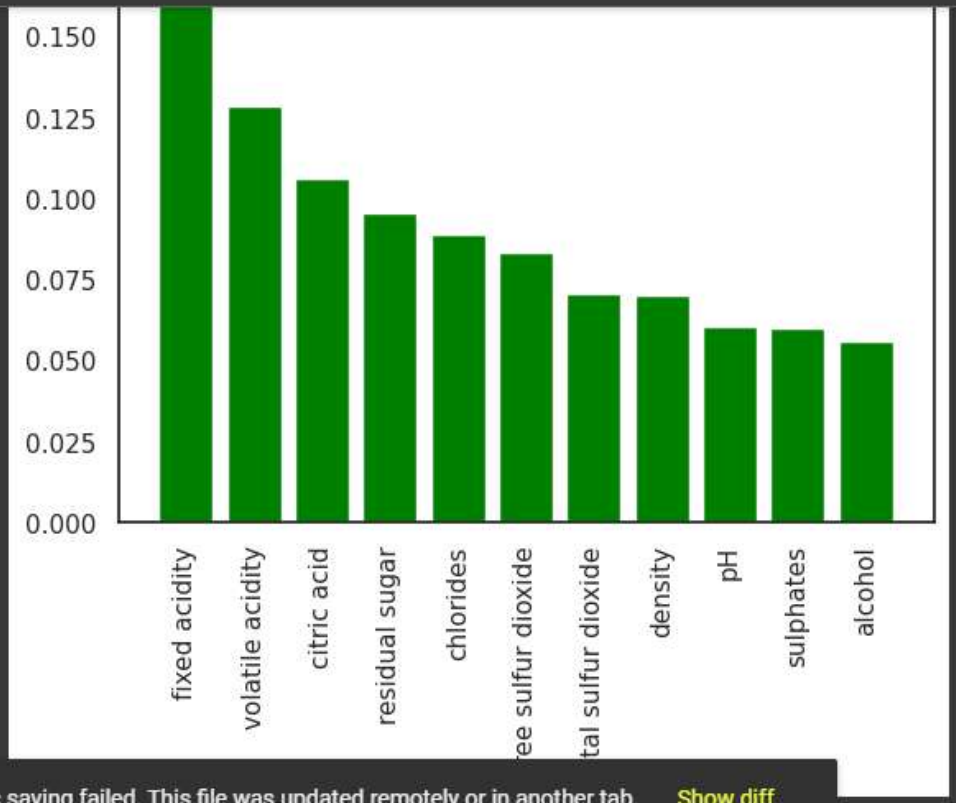

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ENG

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22-09-2023

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RAM Disk

[43]
```
from sklearn.model_selection  import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.20, random_state = 5)
```

```
from sklearn.preprocessing import StandardScaler
sc = StandardScaler()
X_train2 = pd.DataFrame(sc.fit_transform(X_train))
X_test2 = pd.DataFrame(sc.transform(X_test))
X_train2.columns = X_train.columns.values
X_test2.columns = X_test.columns.values
X_train2.index = X_train.index.values
X_test2.index = X_test.index.values
X_train = X_train2
X_test = X_test2
```

[45]
```
from sklearn.decomposition import PCA
pca = PCA(n_components = 4)
X_train = pca.fit_transform(X_train)
X_test = pca.transform(X_test)
explained_variance = pca.explained_variance_ratio_
print(pd.DataFrame(explained_variance))
```

```
          0
```

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[45]
```
print(pd.DataFrame(explained_variance))
```

```
          0
0  0.281687
1  0.171462
2  0.143245
3  0.114765
```

```
from sklearn.linear_model import LogisticRegression
classifier = LogisticRegression(random_state = 0, penalty = 'l2')
classifier.fit(X_train, y_train)

y_pred = classifier.predict(X_test)
from sklearn.metrics import confusion_matrix, accuracy_score, f1_score, precision_score, recall_score
acc = accuracy_score(y_test, y_pred)
prec = precision_score(y_test, y_pred)
rec = recall_score(y_test, y_pred)
f1 = f1_score(y_test, y_pred)
results = pd.DataFrame([['Logistic Regression', acc, prec, rec, f1]],
              columns = ['Model', 'Accuracy', 'Precision', 'Recall', 'F1 Score'])
print(results)
```

```
                Model  Accuracy  Precision   Recall  F1 Score
0  Logistic Regression   0.86875        0.6  0.26087  0.363636
```

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```
classifier = SVC(random_state = 0, kernel = 'rbf')
```

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[48]

```
                  Model  Accuracy  Precision   Recall  F1 Score
0  Logistic Regression   0.86875        0.6  0.26087  0.363636
```

```
from sklearn.svm import SVC
classifier = SVC(random_state = 0, kernel = 'rbf')
classifier.fit(X_train, y_train)

y_pred = classifier.predict(X_test)
acc = accuracy_score(y_test, y_pred)
prec = precision_score(y_test, y_pred)
rec = recall_score(y_test, y_pred)
f1 = f1_score(y_test, y_pred)

model_results = pd.DataFrame([['SVM (RBF)', acc, prec, rec, f1]],
               columns = ['Model', 'Accuracy', 'Precision', 'Recall', 'F1 Score'])

results = results.append(model_results, ignore_index = True)
print(results)
```

```
                  Model  Accuracy  Precision    Recall  F1 Score
0  Logistic Regression   0.86875   0.600000  0.260870  0.363636
1            SVM (RBF)   0.87500   0.714286  0.217391  0.333333
2            SVM (RBF)   0.87500   0.714286  0.217391  0.333333
```

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```
classifier = RandomForestClassifier(random_state = 0, n_estimators = 100,
```

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[51]
```
from sklearn.ensemble import RandomForestClassifier
classifier = RandomForestClassifier(random_state = 0, n_estimators = 100,
                                    criterion = 'entropy')
classifier.fit(X_train, y_train)

# Predicting Test Set
y_pred = classifier.predict(X_test)
acc = accuracy_score(y_test, y_pred)
prec = precision_score(y_test, y_pred)
rec = recall_score(y_test, y_pred)
f1 = f1_score(y_test, y_pred)

model_results = pd.DataFrame([['Random Forest (n=100)', acc, prec, rec, f1]],
               columns = ['Model', 'Accuracy', 'Precision', 'Recall', 'F1 Score'])

results = results.append(model_results, ignore_index = True)
print(results)
```

	Model	Accuracy	Precision	Recall	F1 Score
0	Logistic Regression	0.868750	0.600000	0.260870	0.363636
1	SVM (RBF)	0.875000	0.714286	0.217391	0.333333
2	SVM (RBF)	0.875000	0.714286	0.217391	0.333333
3	Random Forest (n=100)	0.903125	0.741935	0.500000	0.597403

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```
y = y_train,
```

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[52] 4s
```
from sklearn.model_selection import cross_val_score
accuracies = cross_val_score(estimator = classifier, X= X_train, y = y_train,
                             cv = 10)
print("Random Forest Classifier Accuracy: %0.2f (+/- %0.2f)"  % (accuracies.mean(), accuracies.std() * 2))
```

```
Random Forest Classifier Accuracy: 0.89 (+/- 0.04)
```

1m
```
parameters = {"max_depth": [3, None],

              'min_samples_split': [2, 5, 10],
              'min_samples_leaf': [1, 5, 10],
              "bootstrap": [True, False],
              "criterion": ["entropy"]}

from sklearn.model_selection import GridSearchCV
grid_search = GridSearchCV(estimator = classifier,
                           param_grid = parameters,
                           scoring = "accuracy",
                           cv = 10,
                           n_jobs = -1)

t0 = time.time()
grid_search = grid_search.fit(X_train, y_train)
```

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```
rf_best_accuracy = grid_search.best_score
```

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1m

```
from sklearn.model_selection import GridSearchCV
grid_search = GridSearchCV(estimator = classifier,
                           param_grid = parameters,
                           scoring = "accuracy",
                           cv = 10,
                           n_jobs = -1)

t0 = time.time()
grid_search = grid_search.fit(X_train, y_train)
t1 = time.time()
print("Took %0.2f seconds" % (t1 - t0))

rf_best_accuracy = grid_search.best_score_
rf_best_parameters = grid_search.best_params_
rf_best_accuracy, rf_best_parameters
```

```
Took 100.39 seconds
(0.8991510826771654,
 {'bootstrap': False,
  'criterion': 'entropy',
  'max_depth': None,
  'min_samples_leaf': 1,
  'min_samples_split': 2})
```

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```
parameters = {"max_depth": [None],

              'min_samples_split': [8, 10, 12],
              'min_samples_leaf': [1, 2, 3],
              "bootstrap": [True],
              "criterion": ["entropy"]}

from sklearn.model_selection import GridSearchCV
grid_search = GridSearchCV(estimator = classifier,
                           param_grid = parameters,
                           scoring = "accuracy",
                           cv = 10,
                           n_jobs = -1)

t0 = time.time()
grid_search = grid_search.fit(X_train, y_train)
t1 = time.time()
print("Took %0.2f seconds" % (t1 - t0))

rf_best_accuracy = grid_search.best_score_
rf_best_parameters = grid_search.best_params_
rf_best_accuracy, rf_best_parameters
```

30s

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```
{'bootstrap': True,
```

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30s [56] Took 30.56 seconds
(0.8881951279527559,
{'bootstrap': True,
'criterion': 'entropy',
'max_depth': None,
'min_samples_leaf': 1,
'min_samples_split': 8})

1m [57]
```
parameters = {"max_depth": [3, None],

              'min_samples_split': [2, 5, 10],
              'min_samples_leaf': [1, 5, 10],
              "bootstrap": [True, False],
              "criterion": ["gini"]}
from sklearn.model_selection import GridSearchCV
grid_search = GridSearchCV(estimator = classifier,
                           param_grid = parameters,
                           scoring = "accuracy",
                           cv = 10,
                           n_jobs = -1)

t0 = time.time()
grid_search = grid_search.fit(X_train, y_train)
```

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```
rf_best_accuracy = grid_search.best_score
```

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```
                           param_grid = parameters,
                           scoring = "accuracy",
                           cv = 10,
                           n_jobs = -1)

    t0 = time.time()
    grid_search = grid_search.fit(X_train, y_train)
    t1 = time.time()
    print("Took %0.2f seconds" % (t1 - t0))

    rf_best_accuracy = grid_search.best_score_
    rf_best_parameters = grid_search.best_params_
    rf_best_accuracy, rf_best_parameters
```

```
Took 87.44 seconds
(0.8983698326771654,
 {'bootstrap': True,
  'criterion': 'gini',
  'max_depth': None,
  'min_samples_leaf': 1,
  'min_samples_split': 2})
```

```
[58] parameters = {"max_depth": [None],
```

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[58] 23s

```
parameters = {"max_depth": [None],
              'min_samples_split': [2, 3, 4],
              'min_samples_leaf': [8, 10, 12],
              "bootstrap": [True],
              "criterion": ["gini"]}

from sklearn.model_selection import GridSearchCV
grid_search = GridSearchCV(estimator = classifier,
                           param_grid = parameters,
                           scoring = "accuracy",
                           cv = 10,
                           n_jobs = -1)

t0 = time.time()
grid_search = grid_search.fit(X_train, y_train)
t1 = time.time()
print("Took %0.2f seconds" % (t1 - t0))

rf_best_accuracy = grid_search.best_score_
rf_best_parameters = grid_search.best_params_
rf_best_accuracy, rf_best_parameters
```

```
Took 23.19 seconds
(0.8810280762270528
```

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```
 'max_depth': None,
```

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```
[58] rf_best_accuracy, rf_best_parameters
```

23s

```
Took 23.19 seconds
(0.8819389763779528,
 {'bootstrap': True,
  'criterion': 'gini',
  'max_depth': None,
  'min_samples_leaf': 8,
  'min_samples_split': 2})
```

```
rf_best_accuracy, rf_best_parameters
```

0s

```
(0.8819389763779528,
 {'bootstrap': True,
  'criterion': 'gini',
  'max_depth': None,
  'min_samples_leaf': 8,
  'min_samples_split': 2})
```

```
[60] y_pred = grid_search.predict(X_test)
     acc = accuracy_score(y_test, y_pred)
     prec = precision_score(y_test, y_pred)
     rec = recall_score(y_test, y_pred)
     f1 = f1_score(y_test, y_pred)
```

0s

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```
)', acc, prec, rec, f1]],
columns = ['Model', 'Accuracy', 'Precision', 'Recall', 'F1 Score'])
```

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```
y_pred = grid_search.predict(X_test)
acc = accuracy_score(y_test, y_pred)
prec = precision_score(y_test, y_pred)
rec = recall_score(y_test, y_pred)
f1 = f1_score(y_test, y_pred)

model_results = pd.DataFrame([['Random Forest (n=100, GSx2 + Gini)', acc, prec, rec, f1]],
               columns = ['Model', 'Accuracy', 'Precision', 'Recall', 'F1 Score'])

results = results.append(model_results, ignore_index = True)
results
```

	Model	Accuracy	Precision	Recall	F1 Score
0	Logistic Regression	0.868750	0.600000	0.260870	0.363636
1	SVM (RBF)	0.875000	0.714286	0.217391	0.333333
2	SVM (RBF)	0.875000	0.714286	0.217391	0.333333
3	Random Forest (n=100)	0.903125	0.741935	0.500000	0.597403
4	Random Forest (n=100, GSx2 + Gini)	0.881250	0.700000	0.304348	0.424242

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