In [206]:

```python
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import random
from itertools import chain
from tqdm import tqdm
from sklearn.metrics import mean_squared_error
import copy
```

In [207]:

```python
data = pd.read_csv('C:\\Users\\Srikar Reddy\\Downloads\\winequality-whit
```

In [208]:

```python
data.describe()
```

Out[208]:

	fixed acidity	volatile acidity	citric acid	residual sugar	chlorides	free sulfur dioxide	total s di
count	4898.000000	4898.000000	4898.000000	4898.000000	4898.000000	4898.000000	4898.00
mean	6.854788	0.278241	0.334192	6.391415	0.045772	35.308085	138.36
std	0.843868	0.100795	0.121020	5.072058	0.021848	17.007137	42.49
min	3.800000	0.080000	0.000000	0.600000	0.009000	2.000000	9.00
25%	6.300000	0.210000	0.270000	1.700000	0.036000	23.000000	108.00
50%	6.800000	0.260000	0.320000	5.200000	0.043000	34.000000	134.00
75%	7.300000	0.320000	0.390000	9.900000	0.050000	46.000000	167.00
max	14.200000	1.100000	1.660000	65.800000	0.346000	289.000000	440.00

In [209]:

```
corr_matrix = data.corr()
corr_matrix
```

Out[209]:

	fixed acidity	volatile acidity	citric acid	residual sugar	chlorides	free sulfur dioxide	total sulfur dioxide	densit
fixed acidity	1.000000	-0.022697	0.289181	0.089021	0.023086	-0.049396	0.091070	0.26533
volatile acidity	-0.022697	1.000000	-0.149472	0.064286	0.070512	-0.097012	0.089261	0.02711
citric acid	0.289181	-0.149472	1.000000	0.094212	0.114364	0.094077	0.121131	0.14950
residual sugar	0.089021	0.064286	0.094212	1.000000	0.088685	0.299098	0.401439	0.83896
chlorides	0.023086	0.070512	0.114364	0.088685	1.000000	0.101392	0.198910	0.25721
free sulfur dioxide	-0.049396	-0.097012	0.094077	0.299098	0.101392	1.000000	0.615501	0.29421
total sulfur dioxide	0.091070	0.089261	0.121131	0.401439	0.198910	0.615501	1.000000	0.52988
density	0.265331	0.027114	0.149503	0.838966	0.257211	0.294210	0.529881	1.00000
pH	-0.425858	-0.031915	-0.163748	-0.194133	-0.090439	-0.000618	0.002321	-0.09359
sulphates	-0.017143	-0.035728	0.062331	-0.026664	0.016763	0.059217	0.134562	0.07449
alcohol	-0.120881	0.067718	-0.075729	-0.450631	-0.360189	-0.250104	-0.448892	-0.78013
quality	-0.113663	-0.194723	-0.009209	-0.097577	-0.209934	0.008158	-0.174737	-0.30712

This dataset has no misssing values in any columns. So, the empty values are generated in random manner for 4 columns.

In [210]:

```
# droppped the last columns as it is the rating
data_original = data.drop(columns = ['quality'])

```

In [211]:

```
class Features:

    def __init__(self,data):
        self.data = data
        self.features_removed = []

    def feature_removal(self,method, cols):

        print("Selected columns for feature removal are:", cols)
        num_cols = self.data.shape[1]
        data_samples = self.data.shape[0]
        if method == "random":
            if cols == 0 :
                print("None selected")
                return
            random_cols = random.sample(range(num_cols), cols)

            no_samples_to_remove = random.sample(range(data_samples),ran
            for col in random_cols:
                no_samples_to_remove = random.sample(range(data_samples)

                self.data.iloc[:,col].where(self.data.iloc[no_samples_to

            return self.data
        elif method == "selective":
            if len(cols) == 0 :
                print( "None selcted")
                return
            rmv_cols = len(cols)
            # cols are selected here
            for col in cols:
                no_samples_to_remove = random.sample(range(data_samples)
                self.data.iloc[:,col].where(self.data.iloc[no_samples_to
            return self.data


features = Features(data_original)
rem_data = features.feature_removal("random",7)
```

```
Selected columns for feature removal are: 7
```

In [ ]:

```

```

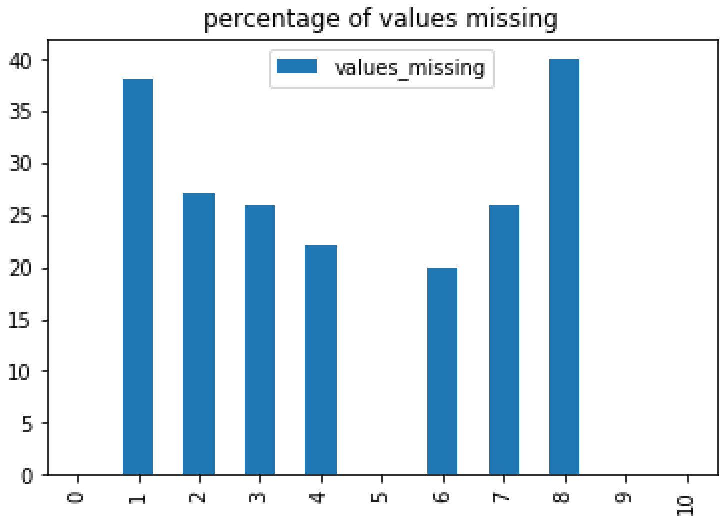
In [212]:

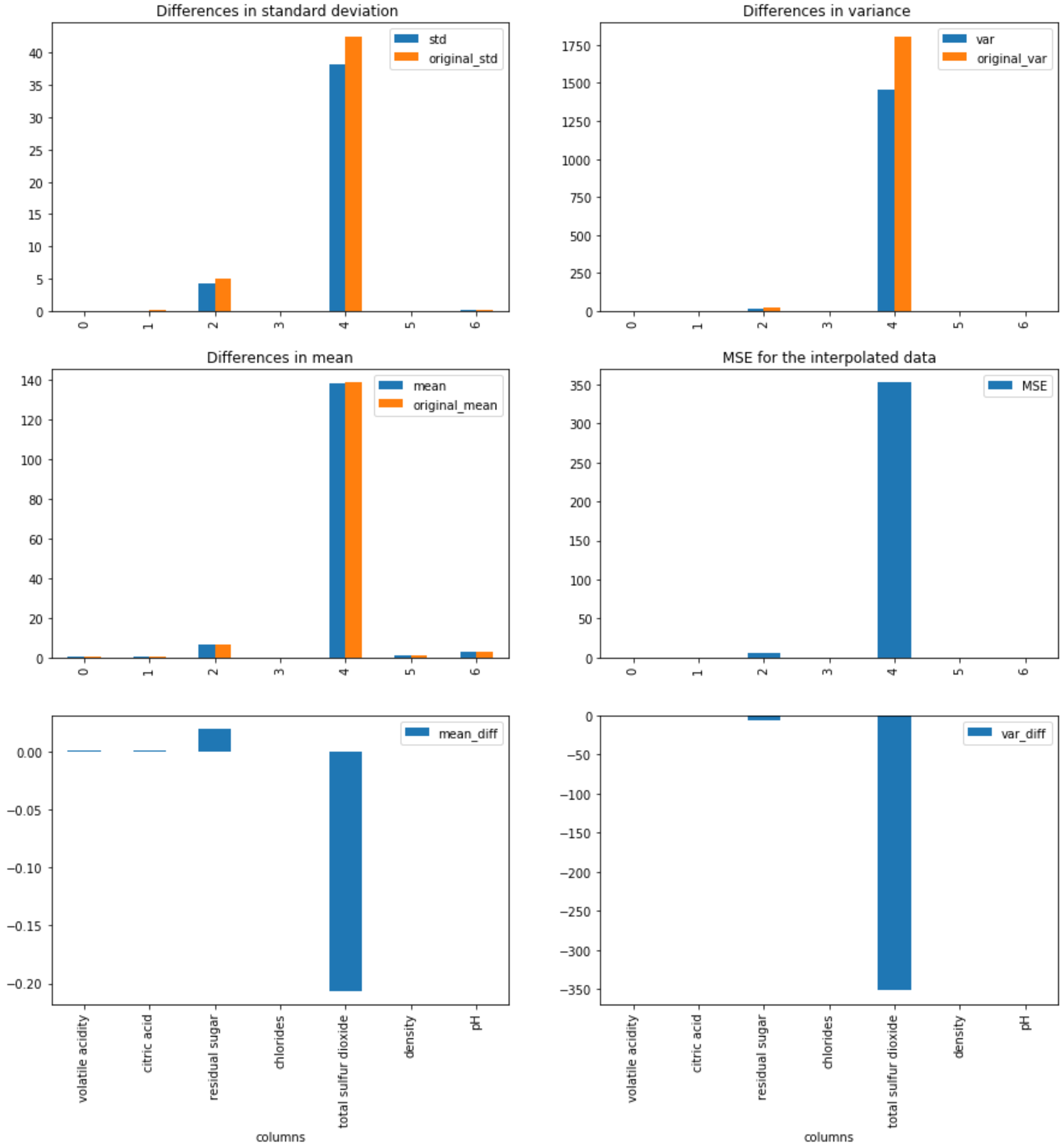
```
class data_methods():

    def __init__(self,data,org_data):
        self.data = data
        self.original_data = org_data
        self.missing_features = []
        self.drop_cols =[]

    def get_missing_features(self):
        no_cols = self.data.shape[1]
        null_columns = []
        info = self.data.isna().any()
        for col in range(0,no_cols):
            if info[col]:
                null_columns.append(col)
        print("Number of columns with null values", len(null_columns))
        print("Columns with null values", null_columns)
        return null_columns

    def plot_graphs(self,plot_data,cols):

        std_cols = []
        mean_cols =[]
        var_cols= []
        for col in cols:
            std_cols.append(np.std(self.original_data[col]))
            mean_cols.append(np.mean(self.original_data[col]))
            var_cols.append(np.var(self.original_data[col]))


        fig, axes = plt.subplots(nrows=3, ncols=2,figsize=(15,15))

        mean_diff = plot_data['mean'] - mean_cols
        plot_data.insert(1,"original_std", std_cols)
        plot_data.insert(3,"original_var", var_cols)
        plot_data.insert(5,"original_mean", mean_cols)
        plot_data.insert(6,"mean_diff",mean_diff)
        plot_data.insert(7,'std_diff', plot_data['std'] - std_cols)
        plot_data.insert(8,'var_diff', plot_data['var'] - var_cols)
        plot_data.insert(9,'columns', self.drop_cols)

        plot_data.plot(  ax = axes[0,0],y =['std','original_std'],kind='
        plot_data.plot(  ax = axes[0,1],y =['var','original_var'],kind='
        plot_data.plot(  ax = axes[1,0],y =['mean','original_mean'],kinc
        plot_data.plot(  ax = axes[1,1],y='MSE',kind='bar',title = 'MSE
        plot_data.plot(  ax = axes[2,0],x ='columns',y = ['mean_diff'],
        plot_data.plot(  ax = axes[2,1],x = 'columns',y='var_diff', kinc


    def plot_perc_of_null_values(self):
        df_null = []
        samples = len(self.data)
        for col in self.data.columns:
#             print(self.data[col].isna().sum())
            df_null.append((self.data[col].isna().sum()/samples)*100)
        df_null = pd.DataFrame(df_null, columns = ['values_missing'])
        df_null.plot(kind='bar', title ='percentage of values missing')

    def error_predict(self, data2,cols):

        std_cols = []
        mean_cols =[]
        var_cols = []
        mse_cols =[]

        for col in cols:
            std_cols.append(np.std(data2[col]))
            mean_cols.append(np.mean(data2[col]))
            var_cols.append(np.var(data2[col]))

            mse_cols.append(mean_squared_error(data2[col], self.original

        plot_data = pd.DataFrame(list(zip(std_cols,var_cols,mean_cols,ms
        self.plot_graphs(plot_data,cols)

    def predict(self,data1, weights):
            return np.dot(data1,weights)


    def mean_naive(self):
        drop_cols= self.get_missing_features()

        data_copy = self.data.copy(deep=True)
        for col in drop_cols:
            mean_of_col = round(data_copy.iloc[:,col].mean(),3)
            data_copy.iloc[:,col].fillna(mean_of_col, inplace = True)


        drop_cols = [ data_copy.columns[i]  for i in drop_cols]
        self.drop_cols = drop_cols
        self.error_predict(data_copy,drop_cols)



    def naive_lin_regression(self): # split data and col name

        missing_features  = self.get_missing_features()

        # create a local temp copy of data
        data_copy = self.data.copy(deep=True)

        number_of_null_values = data_copy.isnull().sum(axis=0)

        columns_to_drop = number_of_null_values.nlargest(len(missing_fea
        drop_data = columns_to_drop
        drop_cols = []
        drop_cols = list(drop_data.index.values)

        copy_of_drop_cols = copy.deepcopy(drop_cols)

        def get_lin_weights(X,Y):

            XTX_inv =  np.linalg.inv(np.dot(X.T,X))
            W_trained = np.dot(XTX_inv.T,(np.dot(X.T,Y)))
            return np.reshape(W_trained, (len(W_trained),-1))



        for col in drop_cols[::-1]:
            copy_of_drop_cols.remove(col)
            complete_data = data_copy[data_copy.columns.drop(copy_of_drc

            testing_data = complete_data[complete_data.isna().any(axis=1
            training_data = complete_data.dropna(how='any',axis=0)
            null_rows = testing_data.index
            testing_data = testing_data.dropna(axis = 1)

            W = get_lin_weights(training_data.drop(col,axis = 1), traini
            predicted_data = self.predict(testing_data, W)
            testing_data[col] = predicted_data

            for i, row in enumerate(null_rows):
                data_copy.loc[row,col] = testing_data.loc[row,col]


        self.error_predict(data_copy,drop_cols)



    def ridge_regression(self,lam):

        missing_features  = self.get_missing_features()

        # create a local temp copy of data
        data_copy = self.data.copy(deep=True)

        number_of_null_values = data_copy.isnull().sum(axis=0)

        columns_to_drop = number_of_null_values.nlargest(len(missing_fea
        drop_data = columns_to_drop
        drop_cols = []
        drop_cols = list(drop_data.index.values)

        copy_of_drop_cols = copy.deepcopy(drop_cols)

        def get_ridge_weights(X,Y,lam):

            lam_inv = lam*np.identity(X.shape[1])
            XTX_inv =  np.linalg.inv(np.dot(X.T,X) + lam_inv)
            W_trained = np.dot(XTX_inv.T,(np.dot(X.T,Y)))
            return np.reshape(W_trained, (len(W_trained),-1))


        for col in drop_cols[::-1]:
            copy_of_drop_cols.remove(col)
            # this has only one col with null values
            complete_data = data_copy[data_copy.columns.drop(copy_of_drc

            testing_data = complete_data[complete_data.isna().any(axis=1
            training_data = complete_data.dropna(how='any',axis=0)
            null_rows = testing_data.index
            testing_data = testing_data.dropna(axis = 1)


            W = get_ridge_weights(training_data.drop(col,axis = 1), trai
            predicted_data = self.predict(testing_data, W)
            testing_data[col] = predicted_data

            for i, row in enumerate(null_rows):
                data_copy.loc[row,col] = testing_data.loc[row,col]
        self.error_predict(data_copy,drop_cols)



    def lasso_regression(self,lam):
        missing_features  = self.get_missing_features()

        # create a local temp copy of data
        data_copy = self.data.copy(deep=True)

        number_of_null_values = data_copy.isnull().sum(axis=0)

        columns_to_drop = number_of_null_values.nlargest(len(missing_fea
        drop_data = columns_to_drop
        drop_cols = []
        drop_cols = list(drop_data.index.values)

        copy_of_drop_cols = copy.deepcopy(drop_cols)

        def get_lasso_weights(X,Y,lam):
            X = np.array(X)
            Y = np.array(Y).reshape((len(Y),1))

            samples, features = X.shape
            iterations = 100
            w_lasso = np.zeros(shape = (features,1))
            bias = 1

            def threshold(arg1, lam)-> float:
                if arg1 < 0 and lam < abs(arg1):
                    return arg1- lam
                elif arg1 > 0 and lam < abs(arg1):
                    return arg1 + lam
                else:
                    return 0.0
            for i in range(iterations):
                for j in range(0,features):
                    term = np.dot(X[:,j], Y - np.dot(X,w_lasso))
                    denom = np.dot(X[:,j].T, X[:,j])
                    term_pos = (-term + (lam/2))/denom
                    term_neg = (-term - (lam/2))/denom

                    if w_lasso[j] > term_pos:
                        w_lasso [j] = w_lasso[j] - term_pos
                    elif w_lasso[j] < term_neg:
                        w_lasso [j] = w_lasso[j] - term_neg
                    else:
                        w_lasso[j] = 0
            return w_lasso.flatten()


        for col in drop_cols[::-1]:
            copy_of_drop_cols.remove(col)
            # this has only one col with null values
            complete_data = data_copy[data_copy.columns.drop(copy_of_drc

            testing_data = complete_data[complete_data.isna().any(axis=1
            training_data = complete_data.dropna(how='any',axis=0)
            null_rows = testing_data.index
            testing_data = testing_data.dropna(axis = 1)


            W = get_lasso_weights(training_data.drop(col,axis = 1), trai
            predicted_data = self.predict(testing_data, W)
            testing_data[col] = predicted_data

            for i, row in enumerate(null_rows):
                data_copy.loc[row,col] = testing_data.loc[row,col]

        self.error_predict(data_copy,drop_cols)


    def knn(self,k):
        missing_features  = self.get_missing_features()

        # create a local temp copy of data
        data_copy = self.data.copy(deep=True)

        number_of_null_values = data_copy.isnull().sum(axis=0)

        columns_to_drop = number_of_null_values.nlargest(len(missing_fea
        drop_data = columns_to_drop
        drop_cols = []
        drop_cols = list(drop_data.index.values)

        copy_of_drop_cols = copy.deepcopy(drop_cols)


        for col in tqdm(drop_cols[::-1]):

            copy_of_drop_cols.remove(col)
            complete_data = data_copy[data_copy.columns.drop(copy_of_drc

            testing_data = complete_data[complete_data.isna().any(axis=1
            training_data = complete_data.dropna(how='any',axis=0)
            null_rows = testing_data.index

            training_data = np.array(training_data)
            sample_dim = training_data.shape
            for row in testing_data.index:

                test_row = np.array(testing_data.loc[row,:])
                neighbours = np.zeros(sample_dim[0])
                for i,train_row in enumerate(training_data):
                    neighbours[i] = ((np.array(train_row) - np.array(tes
                neighbour_df = pd.DataFrame(neighbours)
                neighbour_df =  neighbour_df[0].sort_values()[0:k]

                break
                testing_data.loc[row,col] = np.mean(np.array(neighbour_d

            for i, row in enumerate(null_rows):
                data_copy.loc[row,col] = testing_data.loc[row,col]

        self.error_predict(data_copy,drop_cols)




```

In [213]:

```
data_final = pd.read_csv('C:\\Users\\Srikar Reddy\\Downloads\\winequalit
feature1 = data_methods(rem_data,data_final)


feature1.plot_perc_of_null_values()
feature1.mean_naive()

# print(feature1.drop_cols)
feature1.naive_lin_regression()
feature1.ridge_regression(2)

feature1.lasso_regression(0.1)
# feature1.knn(10)
```

```
Number of columns with null values 7
Columns with null values [1, 2, 3, 4, 6, 7, 8]
Number of columns with null values 7
Columns with null values [1, 2, 3, 4, 6, 7, 8]
Number of columns with null values 7
Columns with null values [1, 2, 3, 4, 6, 7, 8]
Number of columns with null values 7
Columns with null values [1, 2, 3, 4, 6, 7, 8]
```



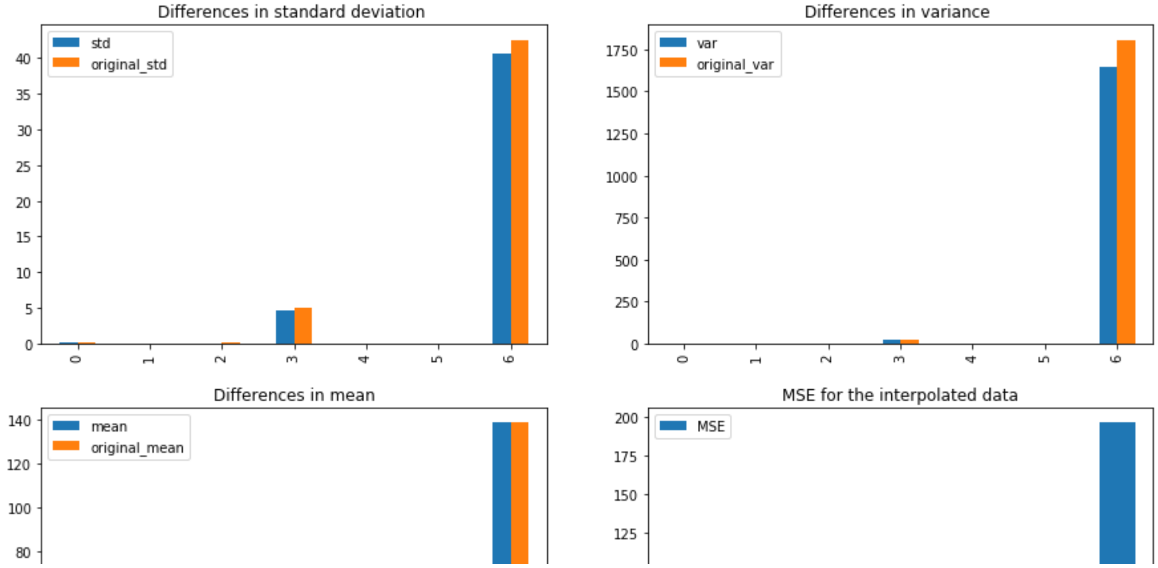


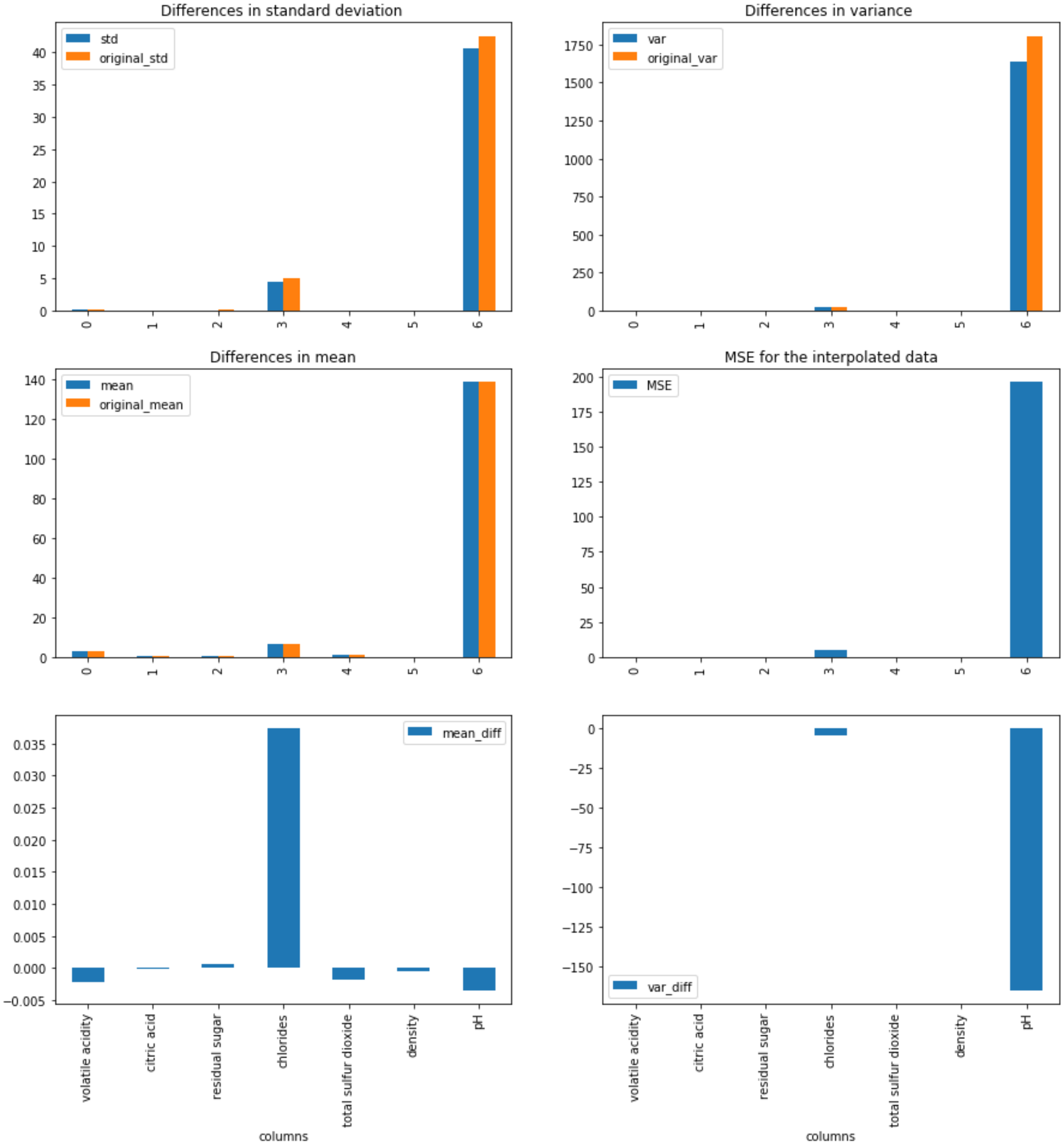
Differences in standard deviation

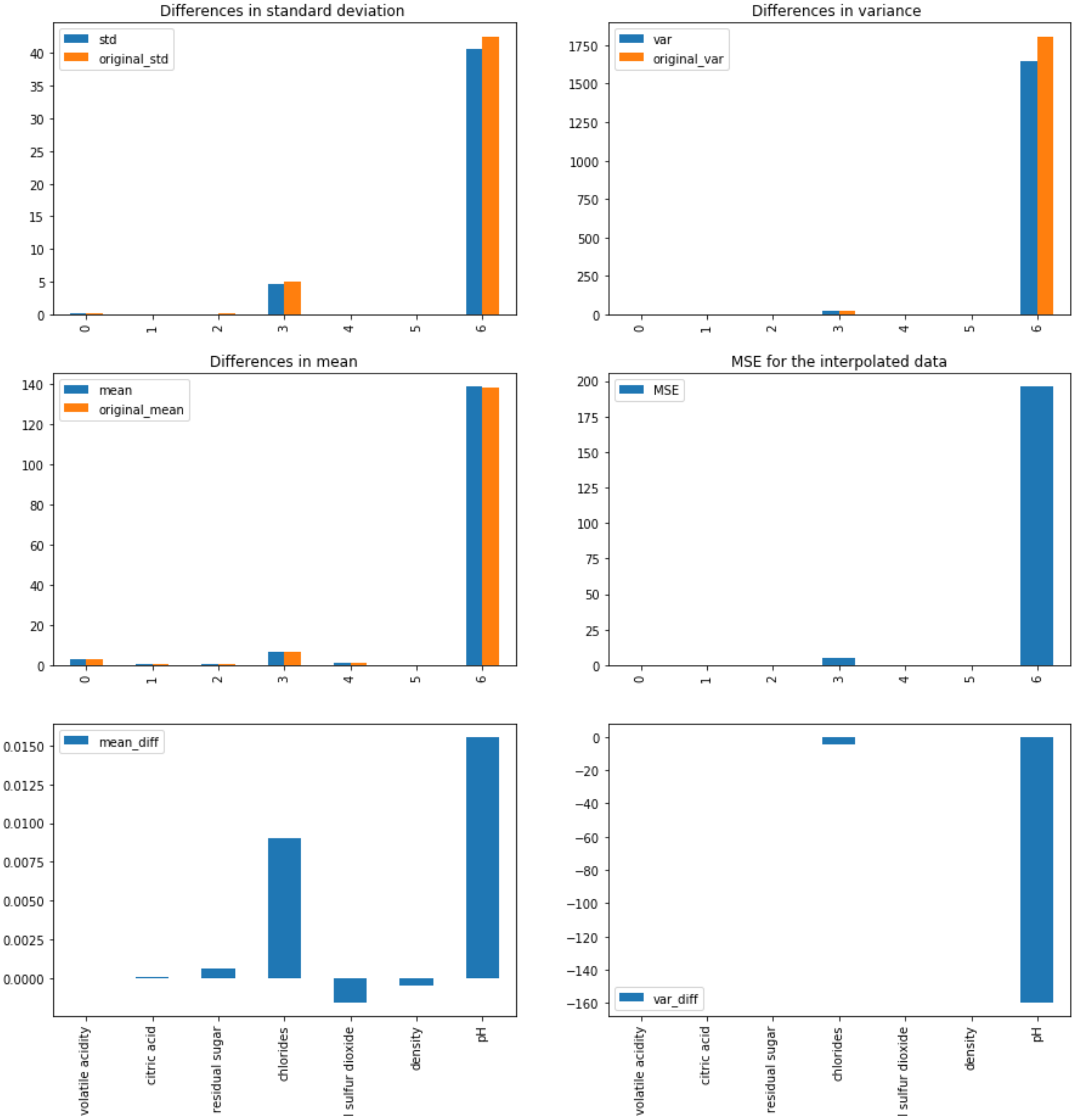
Differences in variance

Differences in mean

MSE for the interpolated data


Differences in standard deviation
std
original_std
0
5
10
15
20
25
30
35
40
0
1
2
3
4
5
6
Differences in variance
var
original_var
0
250
500
750
1000
1250
1500
1750
0
1
2
3
4
5
6
Differences in mean
mean
original_mean
80
100
120
140
MSE for the interpolated data
MSE
125
150
175
200


Differences in standard deviation
std
original_std
0
5
10
15
20
25
30
35
40
0
1
2
3
4
5
6
Differences in variance
var
original_var
0
250
500
750
1000
1250
1500
1750
0
1
2
3
4
5
6
Differences in mean
mean
original_mean
0
20
40
60
80
100
120
140
0
1
2
3
4
5
6
MSE for the interpolated data
MSE
0
25
50
75
100
125
150
175
200
0
1
2
3
4
5
6
mean_diff
−0.005
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
volatile acidity
citric acid
residual sugar
chlorides
total sulfur dioxide
density
pH
columns
var_diff
0
−25
−50
−75
−100
−125
−150
volatile acidity
citric acid
residual sugar
chlorides
total sulfur dioxide
density
pH
columns



Generation of synthetic data

In [214]:

```

df = pd.read_csv('C:\\Users\\Srikar Reddy\\Downloads\\winequality-white.

# Determine the mean and standard deviation of the columns
mean_fixed_acidity = df.iloc[:, 0].mean()
mean_volatile_acidity = df.iloc[:, 1].mean()
mean_citric_acid = df.iloc[:, 2].mean()
mean_residual_sugar = df.iloc[:, 3].mean()
mean_chlorides = df.iloc[:, 4].mean()
mean_free_sulfur_dioxide = df.iloc[:, 5].mean()
mean_total_sulfur_dioxide = df.iloc[:, 6].mean()
mean_density = df.iloc[:, 7].mean()
mean_pH = df.iloc[:, 8].mean()
mean_sulphates = df.iloc[:, 9].mean()
mean_alcohol = df.iloc[:, 10].mean()

sd_fixed_acidity = df.iloc[:, 0].std()
sd_volatile_acidity = df.iloc[:, 1].std()
sd_citric_acid = df.iloc[:, 2].std()
sd_residual_sugar = df.iloc[:, 3].std()
sd_chlorides = df.iloc[:, 4].std()
sd_free_sulfur_dioxide = df.iloc[:, 5].std()
sd_total_sulfur_dioxide = df.iloc[:, 6].std()
sd_density = df.iloc[:, 7].std()
sd_pH = df.iloc[:, 8].std()
sd_sulphates = df.iloc[:, 9].std()
sd_alcohol = df.iloc[:, 10].std()

# Use Normal distribution to generate new data with 1000 rows


fixed_acidity = np.random.normal(mean_fixed_acidity, sd_fixed_acidity, 1
volatile_acidity = np.random.normal(mean_volatile_acidity, sd_volatile_a
citric_acid = np.random.normal(mean_citric_acid, sd_citric_acid, 1000).t
residual_sugar = np.random.normal(mean_residual_sugar, sd_residual_sugar
chlorides = np.random.normal(mean_chlorides, sd_chlorides, 1000).tolist(
free_sulfur_dioxide = np.random.normal(mean_free_sulfur_dioxide, sd_free
total_sulfur_dioxide = np.random.normal(mean_total_sulfur_dioxide, sd_to
density = np.random.normal(mean_density, sd_density, 1000).tolist()
pH = np.random.normal(mean_pH, sd_pH, 1000).tolist()
sulphates = np.random.normal(mean_sulphates, sd_sulphates, 1000).tolist(
alcohol = np.random.normal(mean_alcohol, sd_alcohol, 1000).tolist()

generated_data = [fixed_acidity, volatile_acidity, citric_acid, residual
                  total_sulfur_dioxide, density, pH, sulphates, alcohol]
# print(generated_data)
generated_data = zip(*generated_data)

new_data = pd.DataFrame(generated_data, columns=("fixed_acidity", "volat
                                                 "residual_sugar", "chlo
                                                 "total_sulfur_dioxide",

print(new_data)

```

```
     fixed_acidity  volatile_acidity  citric_acid  residual_sugar  chloride
s  \
0         5.438443          0.441439     0.391584        5.700246   0.08483
1
1         6.480482          0.248256     0.478533       10.875139   0.04041
3
2         5.904033          0.356718     0.256335       10.418443   0.05497
9
3         6.550473          0.199234     0.279990        5.236445   0.07913
9
4         6.523641          0.353398     0.294530        2.307736   0.05333
9
..             ...               ...          ...             ...
...
995       8.379449          0.381907     0.414494        0.106521   0.05401
2
996       7.591703          0.324668     0.451202        7.344098   0.07193
5
997       7.640908          0.349288     0.290834       13.160833   0.05679
8
998       6.397226          0.329351     0.413944        3.797984   0.04811
3
999       6.316188          0.274489     0.297229        1.731183   0.04251
8

     free_sulfur_dioxide  total_sulfur_dioxide   density        pH  sulphat
es  \
0              15.809703            137.391780  0.994096  3.132742   0.4606
27
1              43.027189            146.653691  0.996669  3.205016   0.4575
65
2              -3.170294            149.524068  0.997333  3.268303   0.5055
67
3              37.974501            170.949869  0.993274  2.964196   0.3353
62
4              68.115477            128.471350  0.992335  3.378678   0.5681
18
..                   ...                   ...       ...       ...
...
995            41.149299             50.032004  0.992444  3.112493   0.3581
28
996            43.777707            161.714481  0.995227  2.714061   0.8219
47
997            20.167316            179.982528  0.989047  3.358432   0.7175
82
998            18.709801            150.725285  0.994989  3.202310   0.3806
47
999            17.688918            204.154485  0.995012  3.194400   0.5401
66

       alcohol
0     9.774789
1     9.178506
2    10.125796
3    11.083581
4     9.890099
..         ...
995   9.717740
996   9.995019
```

```
997  10.273444
998  10.775828
999   9.997577

[1000 rows x 11 columns]
```

In [ ]:

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