solution

May 6, 2024

1 Tema 1 ML - Paunoiu Darius Alexandru

[ ]:
```
import pandas as pd
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt
from IPython.display import display, Latex, HTML

# Assuming df is your DataFrame after loading the CSV
statistics_df = pd.read_csv("date_tema_1_iaut_2024.csv")
pd.set_option("display.max_columns", None)

RANDOM_STATES = [42, 10, 15, 21, 13, 30, 35, 37, 45, 53]
RANDOM_STATE = RANDOM_STATES[0]
SCORERS_NAMES = ["accuracy", "f1", "precision", "recall"]

# List of categorical columns you mentioned
def prelucrate_data(df):
    df["Sedentary_hours_daily"] = (
        df["Sedentary_hours_daily"].str.replace(",", ".").astype(float)
    )
    df["Age"] = df["Age"].str.replace(",", ".").astype(float).astype(int)
    df["Est_avg_calorie_intake"] = df["Est_avg_calorie_intake"].astype(int)
    df["Height"] = df["Height"].str.replace(",", ".").astype(float)
    df["Water_daily"] = df["Water_daily"].str.replace(",", ".").astype(float)
    df["Weight"] = df["Weight"].str.replace(",", ".").astype(float)
    df["Physical_activity_level"] = (
        df["Physical_activity_level"].str.replace(",", ".").astype(float)
    )
    df["Technology_time_use"] = df["Technology_time_use"].astype(object)
    df["Main_meals_daily"] = (
        df["Main_meals_daily"]
        .str.replace(",", ".")
        .astype(float)
        .astype(int)
        .astype(object)
    )
    df["Regular_fiber_diet"] = (
```

```
        df["Regular_fiber_diet"].str.replace(",", ".").astype(float).astype(int)
    )


def bold_extreme_values(df):
    for idx, column in enumerate(df.columns):
        if idx == 0:
            continue  # Skip the first column
        if column.endswith('std'):
            # Apply bold formatting to the minimum value in 'std' columns
            min_val = df[column].min()
            df[column] = df[column].apply(lambda x: f'\\textbf{{{x}}}' if x ==␣
 ↪min_val else x)
        else:
            # Apply bold formatting to the maximum value in other columns
            max_val = df[column].max()
            df[column] = df[column].apply(lambda x: f'\\textbf{{{x}}}' if x ==␣
 ↪max_val else x)
    return df

def format_decimals(df):
    for idx, column in enumerate(df.columns):
        if idx == 0:
            continue  # Skip the first column
        if df[column].dtype.kind in 'fi':  # Checks if the column data type is␣
 ↪float or int
            df[column] = df[column].round(3)
    return df


def pd_to_latex(df: pd.DataFrame):
    # print(dfs[-1].to_latex(
    #     index=False,  # To not include the DataFrame index as a column in the␣
 ↪table
    #     # caption="Comparison of ML Model Performance Metrics",  # The␣
 ↪caption to appear above the table in the LaTeX document
    #     # label="tab:model_comparison",  # A label used for referencing the␣
 ↪table within the LaTeX document
    #     # position="htbp",  # The preferred positions where the table should␣
 ↪be placed in the document ('here', 'top', 'bottom', 'page')
    #     # column_format="|l|l|l|l|",  # The format of the columns:␣
 ↪left-aligned with vertical lines between them
    #     # escape=False,  # Disable escaping LaTeX special characters in the␣
 ↪DataFrame
    #     # float_format="{:0.4f}".format  # Formats floats to two decimal␣
 ↪places
```

```
    #     ))
    df = format_decimals(df)

    df = bold_extreme_values(df)
    # Replace _ with space
    df.columns = df.columns.str.replace("_", " ")
    # Also replace _ with space in the index
    # Replace _ with space for rows
    df = df.map(lambda x: x.replace('_', ' ') if isinstance(x, str) else x)

    latex = df.to_latex(
        float_format="{:0.3f}".format,
        caption="Comparison of ML Model Performance Metrics",
        label="tab:model_comparison",
        escape=False,
    )
    ltx = Latex(latex)
    print(latex)


prelucrate_data(statistics_df)
print(statistics_df.info())

# Splitting the DataFrame into train and test datasets
train_df, test_df = train_test_split(statistics_df, test_size=0.2,␣
 ↪random_state=42)

# Printing the shapes of the train and test datasets
print("Train dataset shape:", train_df.shape)
print("Test dataset shape:", test_df.shape)

statistics_df.tail()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1921 entries, 0 to 1920
Data columns (total 19 columns):
 #   Column                          Non-Null Count  Dtype
---  ------                          --------------  -----
 0   Transportation                  1921 non-null   object
 1   Regular_fiber_diet              1921 non-null   int64
 2   Diagnostic_in_family_history    1921 non-null   object
 3   High_calorie_diet               1921 non-null   object
 4   Sedentary_hours_daily           1921 non-null   float64
 5   Age                             1921 non-null   int64
 6   Alcohol                         1921 non-null   object
 7   Est_avg_calorie_intake          1921 non-null   int64
 8   Main_meals_daily                1921 non-null   object
```

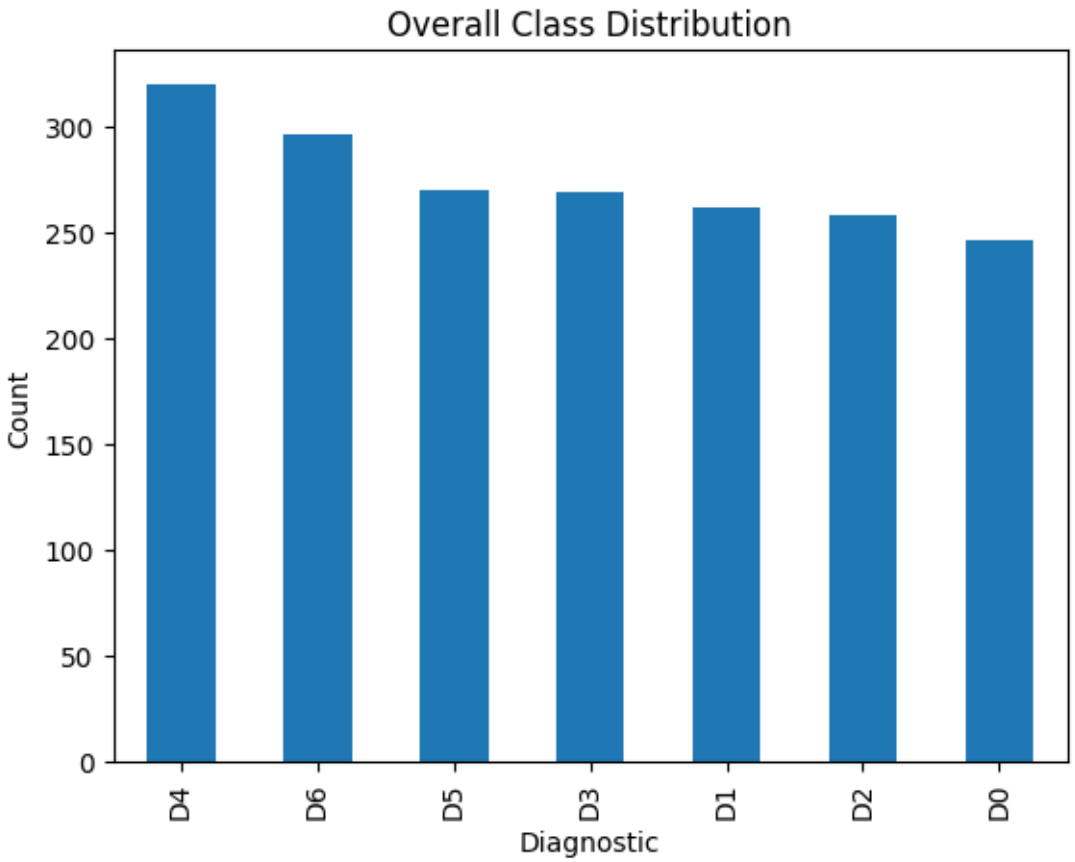
```
 9   Snacks                          1921 non-null   object
 10  Height                          1921 non-null   float64
 11  Smoker                          1921 non-null   object
 12  Water_daily                     1921 non-null   float64
 13  Calorie_monitoring              1921 non-null   object
 14  Weight                          1921 non-null   float64
 15  Physical_activity_level         1921 non-null   float64
 16  Technology_time_use             1921 non-null   object
 17  Gender                          1921 non-null   object
 18  Diagnostic                      1921 non-null   object
dtypes: float64(5), int64(3), object(11)
memory usage: 285.3+ KB
None
Train dataset shape: (1536, 19)
Test dataset shape: (385, 19)
```

[ ]:

	Transportation	Regular_fiber_diet	Diagnostic_in_family_history	High_calorie_diet	Sedentary_hours_daily	Age	Alcohol	Est_avg_calorie_intake	Main_meals_daily	Snacks	Height	Smoker	Water_daily	Calorie_monitoring	Weight	Physical_activity_level	Technology_time_use	Gender	Diagnostic
1916	Public_Transportation	3	yes	yes	3.08	20	Sometimes	2744	3	Sometimes	1.71	no	1.728139	no	131.408528	1.676269	1	Female	D6
1917	Public_Transportation	3	yes	yes	3.00	21	Sometimes	2977	3	Sometimes	1.75	no	2.005130	no	133.742943	1.341390	1	Female	D6
1918	Public_Transportation	3	yes	yes	3.26	22	Sometimes	2422	3	Sometimes	1.75	no	2.054193	no	133.689352	1.414209			
1919	Public_Transportation	3	yes	yes	3.61	24	Sometimes	2372	3	Sometimes	1.74	no	2.852339	no	133.346641	1.139107			
1920	Public_Transportation	3	yes	yes	3.83	23	Sometimes	2336	3	Sometimes	1.74	no	2.863513	no	133.472641	1.026452			

```
1918                    1  Female          D6
1919                    1  Female          D6
1920                    1  Female          D6
```

[ ]:
```
# Class distribution overall
class_counts = statistics_df['Diagnostic'].value_counts()
class_counts.plot(kind='bar')
plt.xlabel('Diagnostic')
plt.ylabel('Count')
plt.title('Overall Class Distribution')
plt.savefig('figs/overall_class_distribution.png', dpi=300)
plt.show()
```



[ ]:
```
train_class_counts = train_df['Diagnostic'].value_counts()
test_class_counts = test_df['Diagnostic'].value_counts()

plt.figure(figsize=(10, 5))
plt.subplot(1, 2, 1)
train_class_counts.plot(kind='bar')
```

```
plt.xlabel('Diagnostic')
plt.ylabel('Count')
plt.title('Train Dataset Class Distribution')

plt.subplot(1, 2, 2)
test_class_counts.plot(kind='bar')
plt.xlabel('Diagnostic')
plt.ylabel('Count')
plt.title('Test Dataset Class Distribution')

plt.tight_layout()
plt.savefig('figs/train_test_class_distribution.png', dpi=300)
plt.show()
```

[ ]:
```
import pandas as pd
import numpy as np
from scipy.stats import tmean, tstd, median_abs_deviation, iqr, tmin, tmax

# Identify numerical columns
numerical_columns = statistics_df.select_dtypes(include=['int64', 'float64']).
  ↪columns

# Initialize a dictionary to store the results
results = {}

# Calculate the required statistics for each numerical column
for col in numerical_columns:
    results[col] = {
```

```
        'Mean': tmean(statistics_df[col]),
        'Standard Deviation': tstd(statistics_df[col]),
        'Mean Absolute Deviation': np.mean(np.abs(statistics_df[col] - np.
↪mean(statistics_df[col]))),
        'Min': tmin(statistics_df[col]),
        'Max': tmax(statistics_df[col]),
        'Difference between Min and Max': tmax(statistics_df[col]) -␣
↪tmin(statistics_df[col]),
        'Median': np.median(statistics_df[col]),  # SciPy does not have a␣
↪median function
        'Median Absolute Deviation': median_abs_deviation(statistics_df[col]),
        'Interquartile Range': iqr(statistics_df[col]),
    }

# Convert the results to a DataFrame
stats_df = pd.DataFrame(results)
display(stats_df.T)
stats_df.columns = stats_df.columns.str.replace('_', ' ')
stats_df = stats_df.T
pd_to_latex(stats_df)
```

	Mean	Standard Deviation
Regular_fiber_diet	3.643415	62.444787
Sedentary_hours_daily	3.693571	21.759835
Age	44.454971	633.322337
Est_avg_calorie_intake	2253.687663	434.075794
Height	3.573488	58.098160
Water_daily	2.010367	0.611034
Weight	205.637344	3225.653536
Physical_activity_level	1.012640	0.855526

	Mean Absolute Deviation	Min	Max
Regular_fiber_diet	2.847847	1.00	2739.00
Sedentary_hours_daily	1.133885	2.21	956.58
Age	40.949876	15.00	19685.00
Est_avg_calorie_intake	375.362344	1500.00	3000.00
Height	3.738525	1.45	1915.00
Water_daily	0.470801	1.00	3.00
Weight	254.647671	-1.00	82628.00
Physical_activity_level	0.702160	0.00	3.00

	Difference between Min and Max	Median
Regular_fiber_diet	2738.00	2.000000
Sedentary_hours_daily	954.37	3.130000
Age	19670.00	22.000000
Est_avg_calorie_intake	1500.00	2253.000000
Height	1913.55	1.700000

```
Water_daily                                    2.00     2.000000
Weight                                     82629.00    80.386078
Physical_activity_level                        3.00     1.000000

                        Median Absolute Deviation  Interquartile Range
Regular_fiber_diet                       0.000000             1.000000
Sedentary_hours_daily                    0.440000             0.870000
Age                                      3.000000             7.000000
Est_avg_calorie_intake                 380.000000           757.000000
Height                                   0.070000             0.140000
Water_daily                              0.444917             0.874479
Weight                                  24.386078            46.205365
Physical_activity_level                  0.815768             1.567523
```

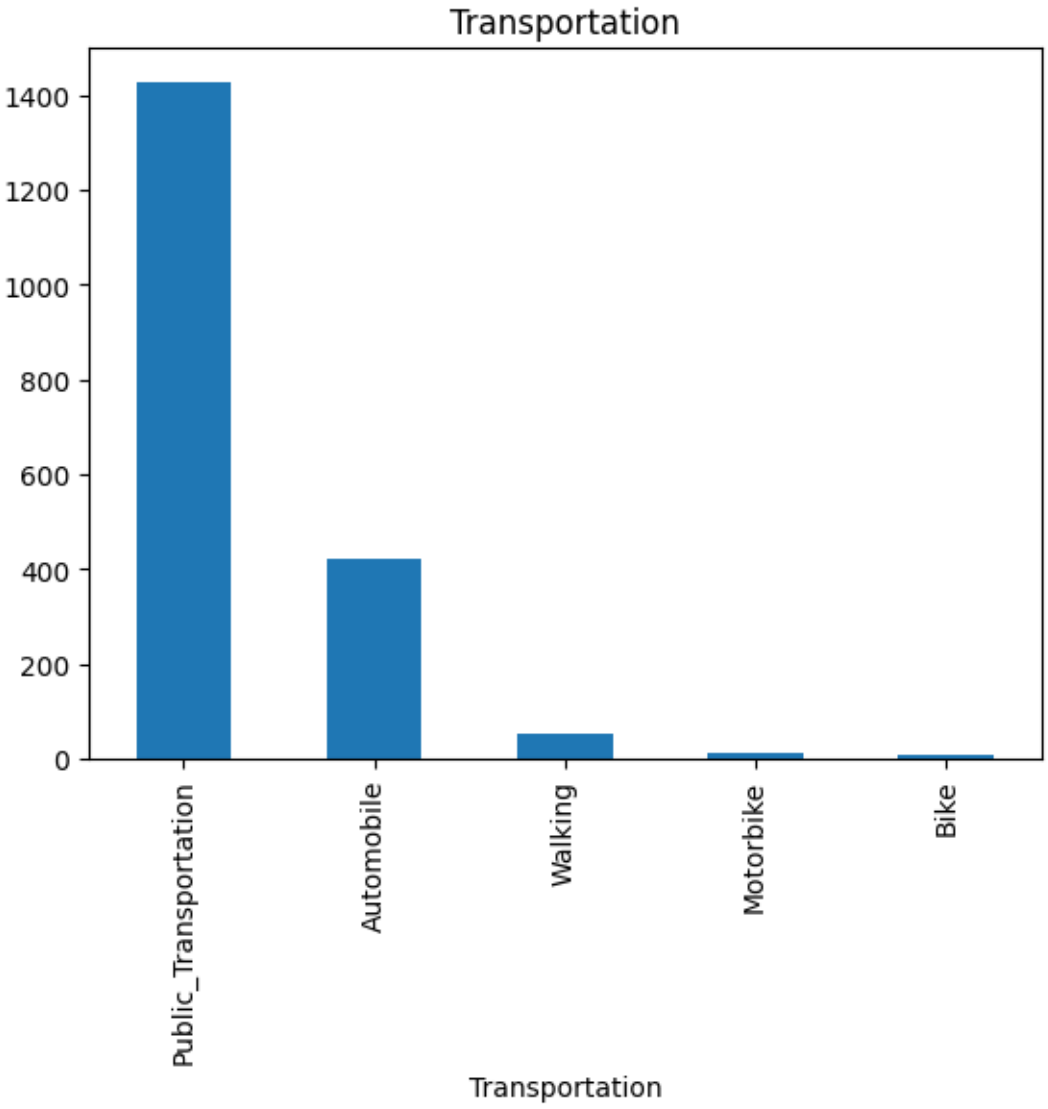
```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lrlllllll}
\toprule
 & Mean & Standard Deviation & Mean Absolute Deviation & Min & Max & Difference
between Min and Max & Median & Median Absolute Deviation & Interquartile Range
\\
\midrule
Regular fiber diet & 3.643 & 62.445 & 2.848 & 1.000 & 2739.000 & 2738.000 &
2.000 & 0.000 & 1.000 \\
Sedentary hours daily & 3.694 & 21.760 & 1.134 & 2.210 & 956.580 & 954.370 &
3.130 & 0.440 & 0.870 \\
Age & 44.455 & 633.322 & 40.950 & 15.000 & 19685.000 & 19670.000 & 22.000 &
3.000 & 7.000 \\
Est avg calorie intake & 2253.688 & 434.076 & \textbf{375.362} & \textbf{1500.0}
& 3000.000 & 1500.000 & \textbf{2253.0} & \textbf{380.0} & \textbf{757.0} \\
Height & 3.573 & 58.098 & 3.739 & 1.450 & 1915.000 & 1913.550 & 1.700 & 0.070 &
0.140 \\
Water daily & 2.010 & 0.611 & 0.471 & 1.000 & 3.000 & 2.000 & 2.000 & 0.445 &
0.874 \\
Weight & 205.637 & \textbf{3225.654} & 254.648 & -1.000 & \textbf{82628.0} &
\textbf{82629.0} & 80.386 & 24.386 & 46.205 \\
Physical activity level & 1.013 & 0.856 & 0.702 & 0.000 & 3.000 & 3.000 & 1.000
& 0.816 & 1.568 \\
\bottomrule
\end{tabular}
\end{table}
```

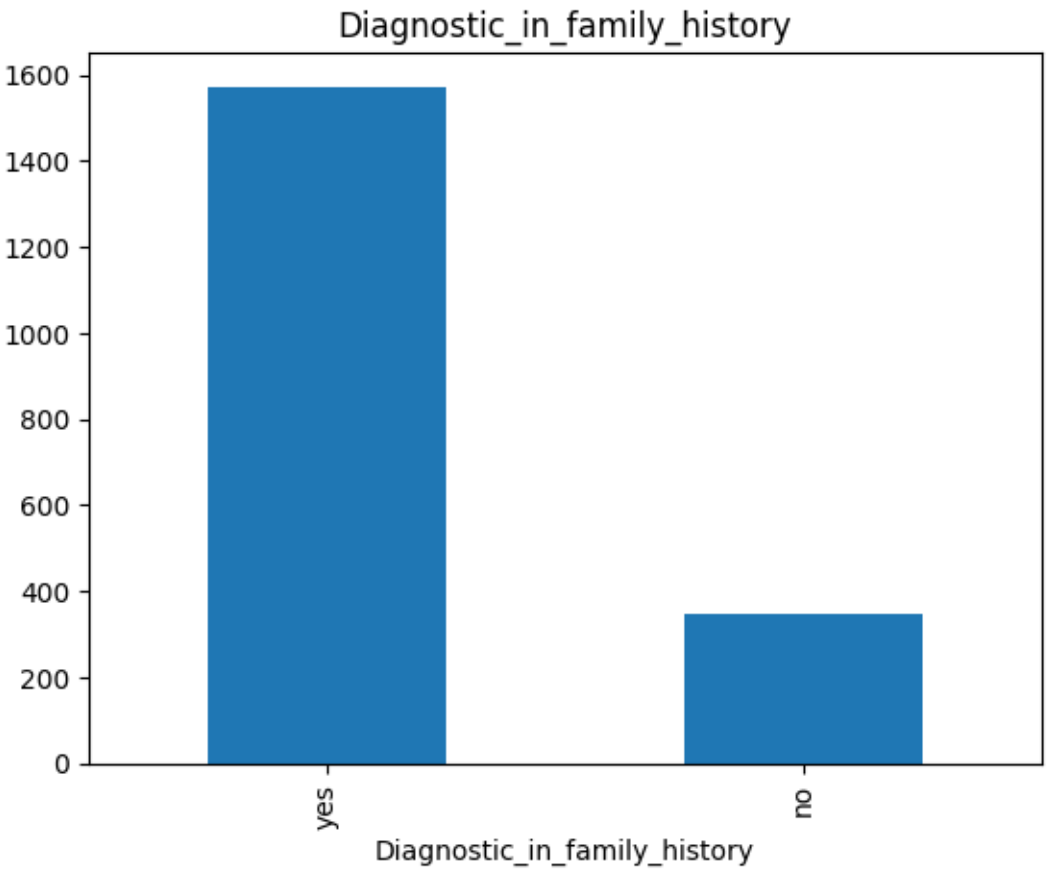
[ ]:
```
import pandas as pd
import matplotlib.pyplot as plt

# Identify discrete, nominal or ordinal columns
```

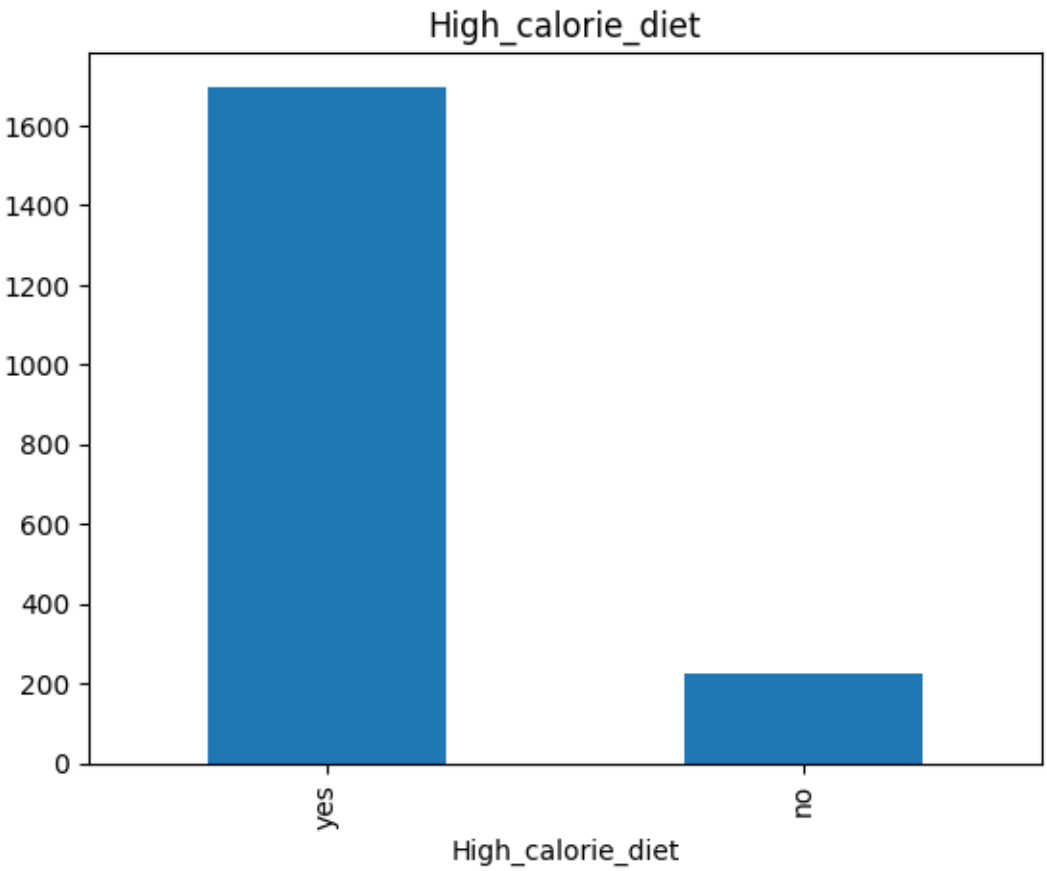
```
categorical_columns = statistics_df.select_dtypes(include=['object',␣
 ↪'category', 'int8']).columns
print(categorical_columns)
# Initialize a dictionary to store the results
results = {}

# Calculate the count of unique values for each column
for col in categorical_columns:
    results[col] = statistics_df[col].nunique()

# Convert the results to a DataFrame
unique_counts_df = pd.DataFrame.from_dict(results, orient='index',␣
 ↪columns=['Unique Count'])

# Display the DataFrame
print(unique_counts_df)

# Plot a histogram for each column
for col in categorical_columns:
    if col == 'Diagnostic':
        continue
    statistics_df[col].value_counts().plot(kind='bar', title=col)
    plt.savefig(f'figs/{col}_histogram.png', dpi=300)
    plt.show()


fig, axs = plt.subplots(2, 5, figsize=(15, 8))

for i, col in enumerate(categorical_columns):
    if col == 'Diagnostic':
        continue
    ax = axs[i // 5, i % 5]
    statistics_df[col].value_counts().plot(kind='bar', title=col, ax=ax)

plt.tight_layout()
plt.savefig('figs/multiplot_histogram.png', dpi=300)
plt.show()
```

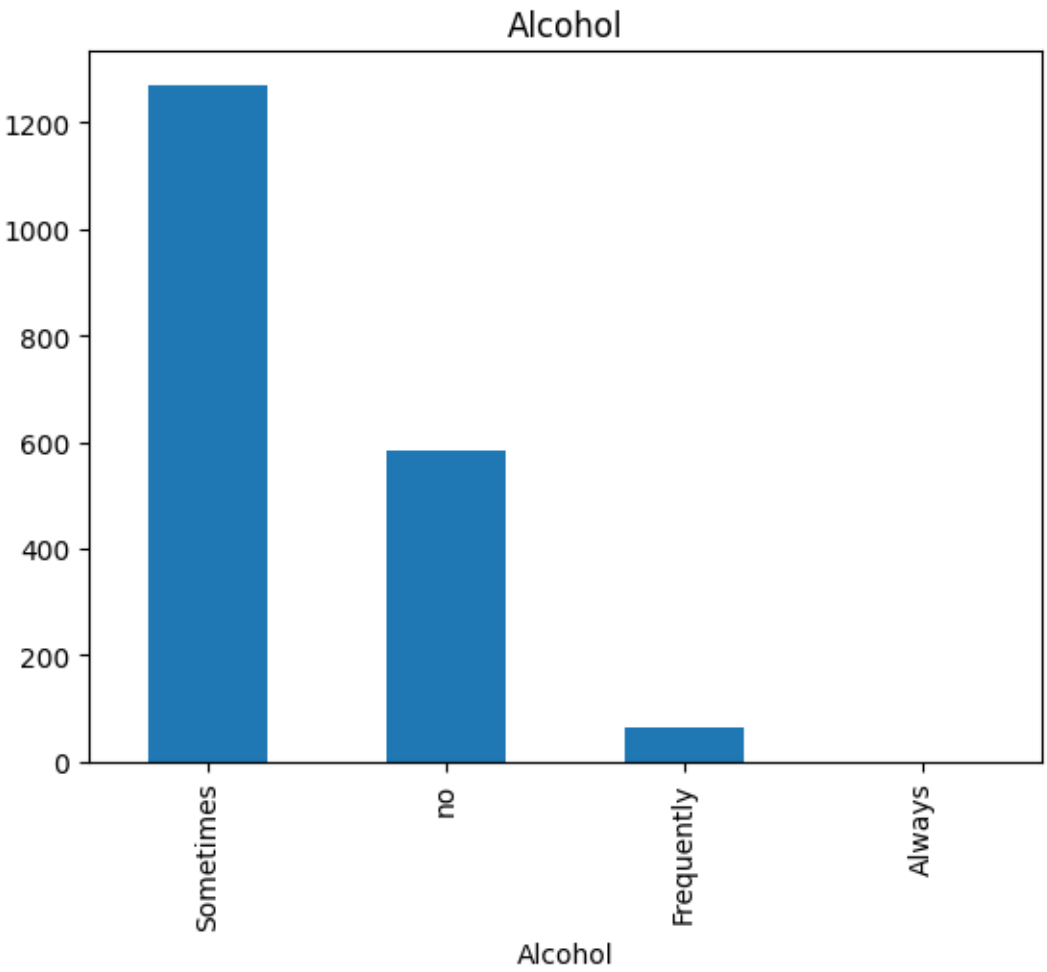
```
Index(['Transportation', 'Diagnostic_in_family_history', 'High_calorie_diet',
       'Alcohol', 'Main_meals_daily', 'Snacks', 'Smoker', 'Calorie_monitoring',
       'Technology_time_use', 'Gender', 'Diagnostic'],
      dtype='object')
                              Unique Count
Transportation                           5
Diagnostic_in_family_history             2
High_calorie_diet                        2
Alcohol                                  4
```

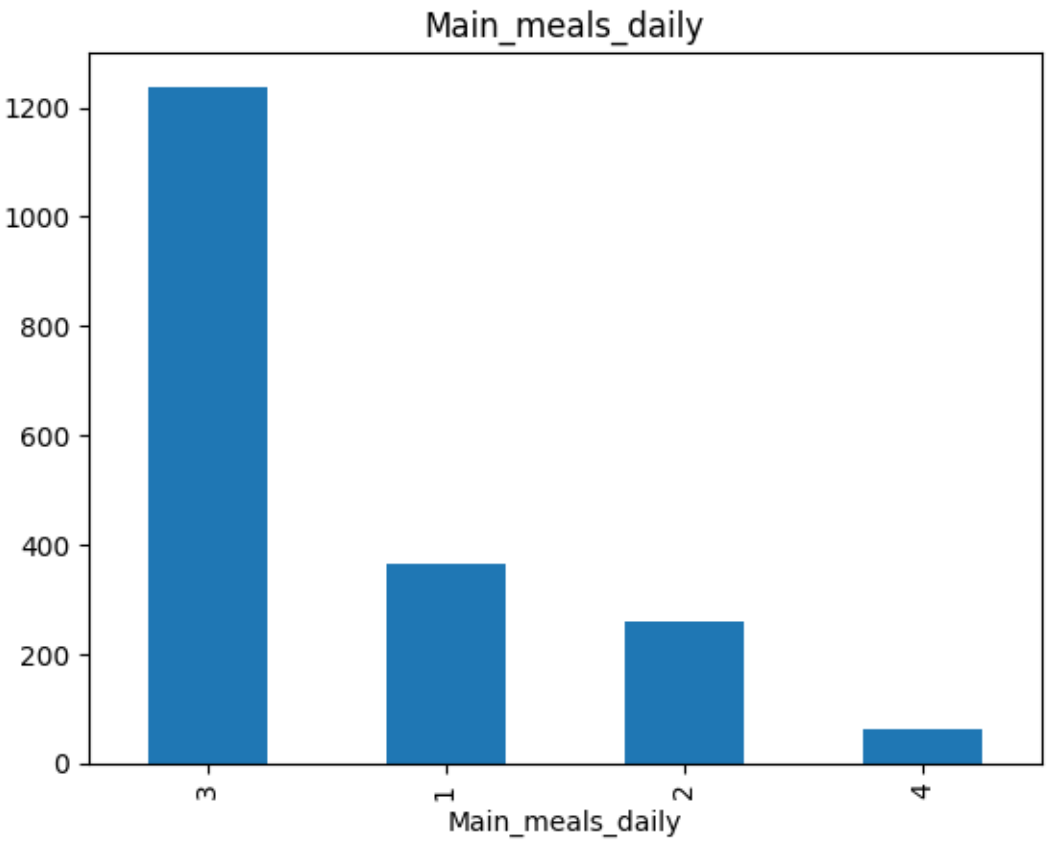
Main_meals_daily	4
Snacks	4
Smoker	2
Calorie_monitoring	2
Technology_time_use	4
Gender	2
Diagnostic	7

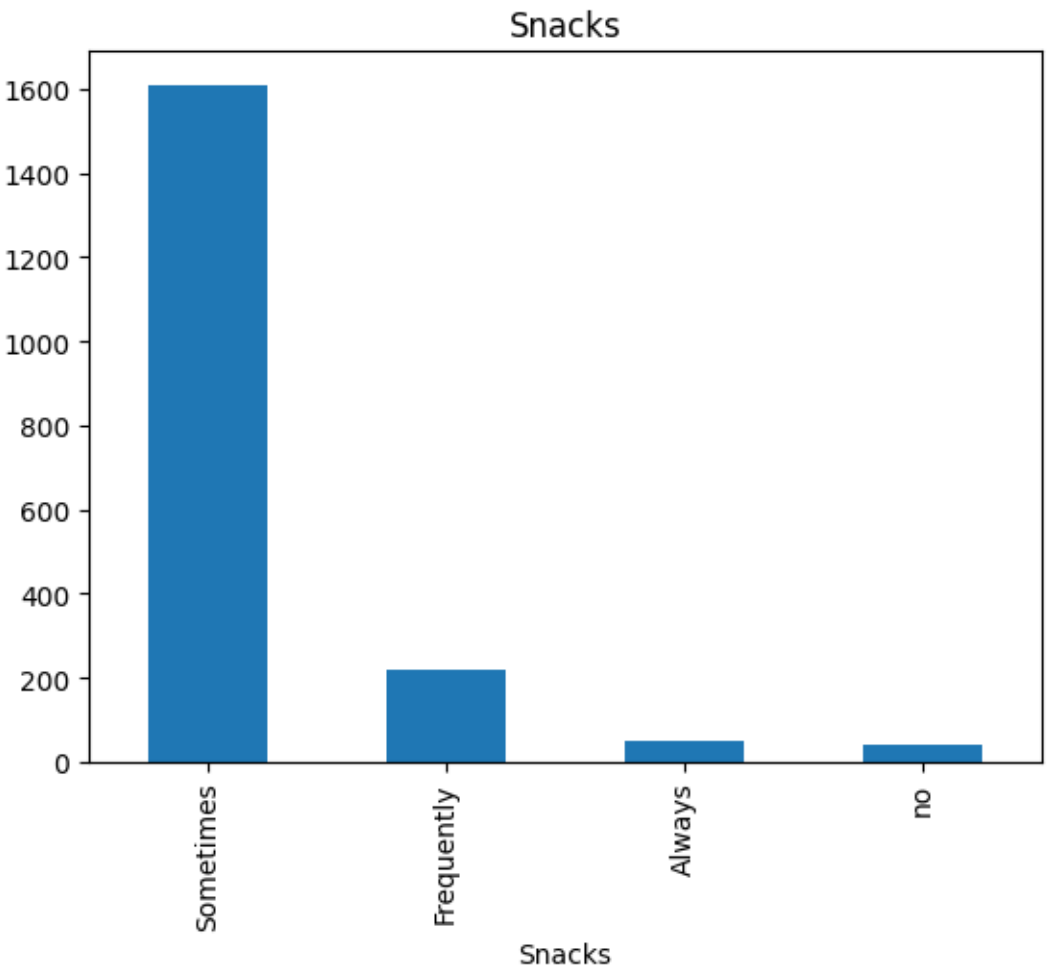


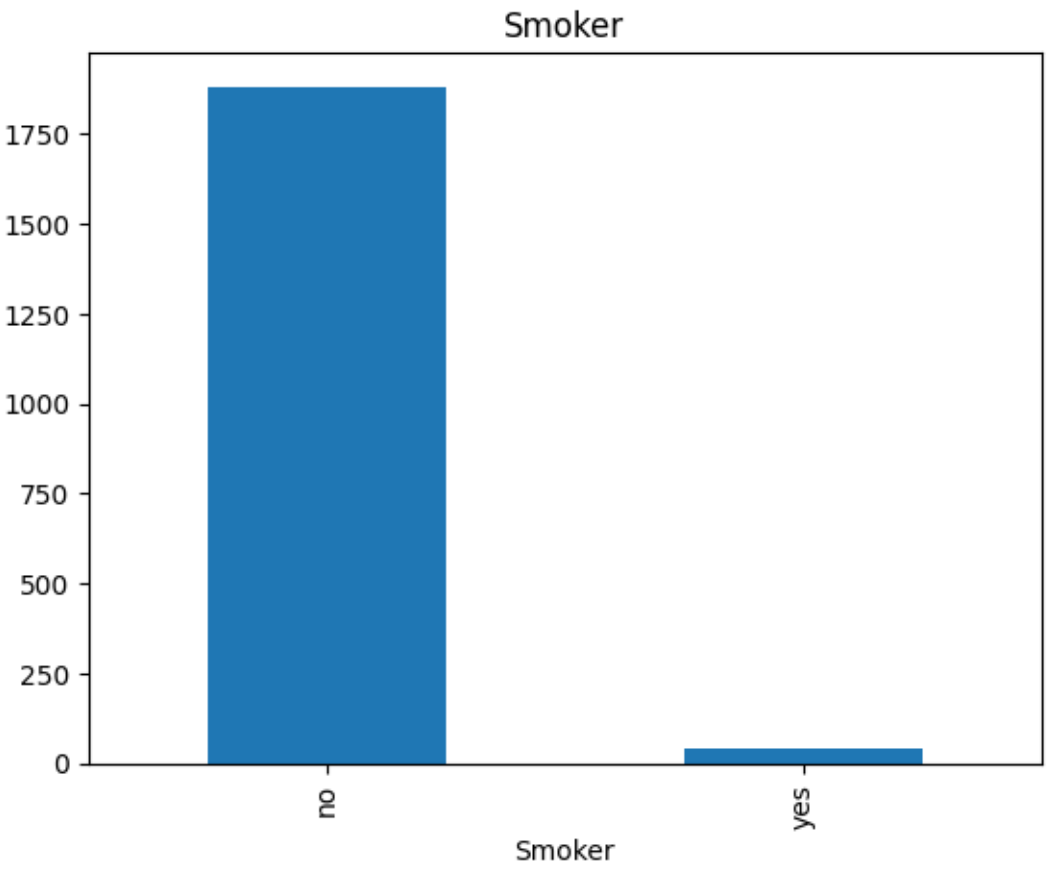

Diagnostic_in_family_history
1600
1400
1200
1000
800
600
400
200
0
yes
no
Diagnostic_in_family_history

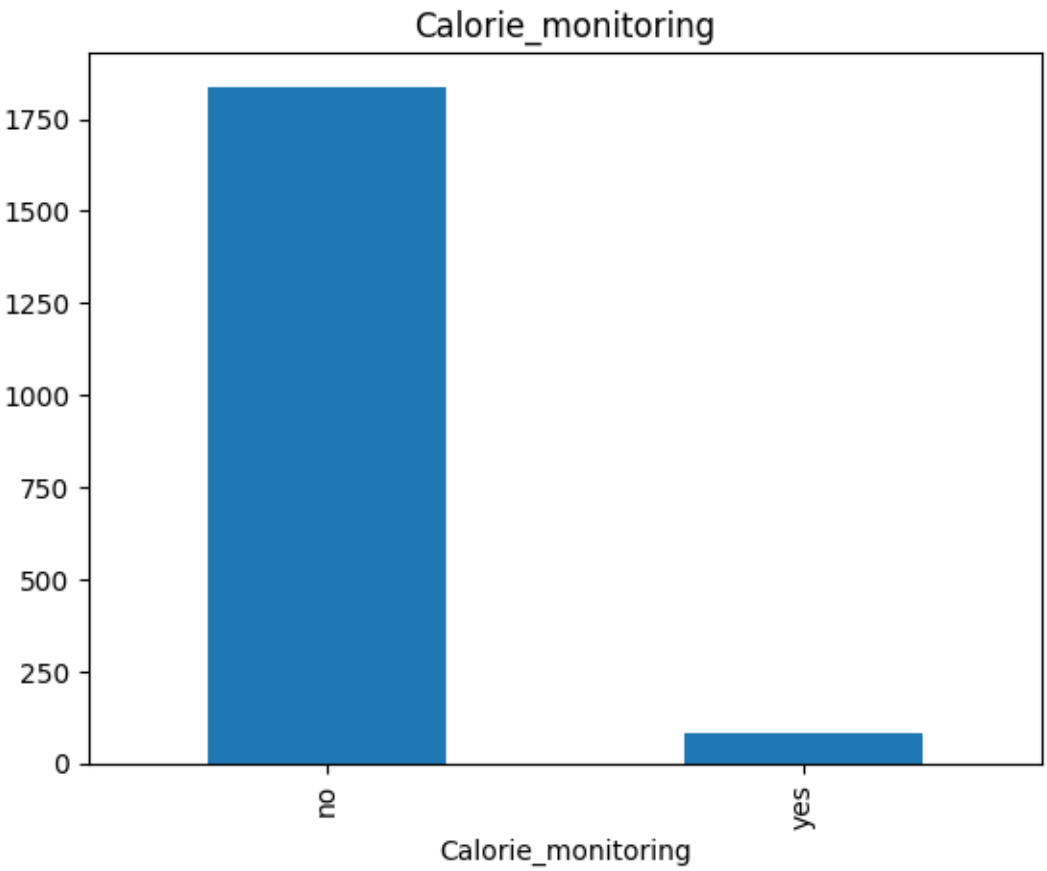

High_calorie_diet
1600
1400
1200
1000
800
600
400
200
0
yes
no
High_calorie_diet

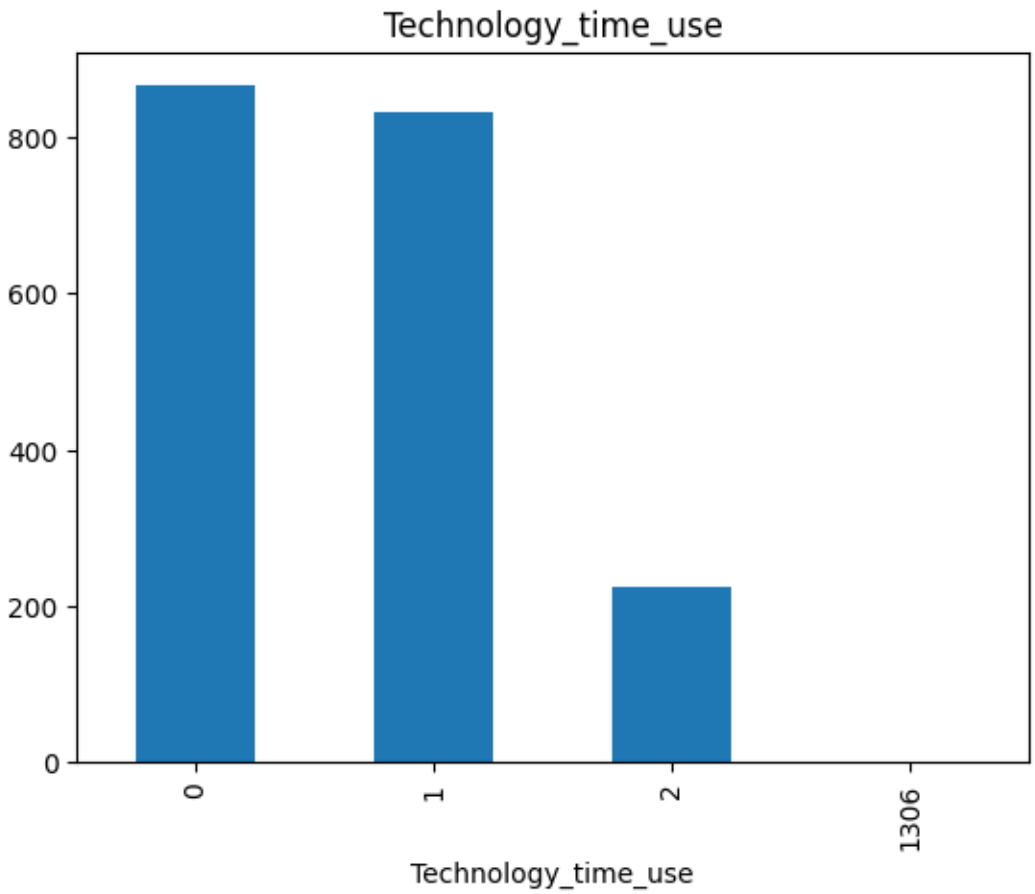

Alcohol
1200
1000
800
600
400
200
0
Sometimes
no
Frequently
Always
Alcohol

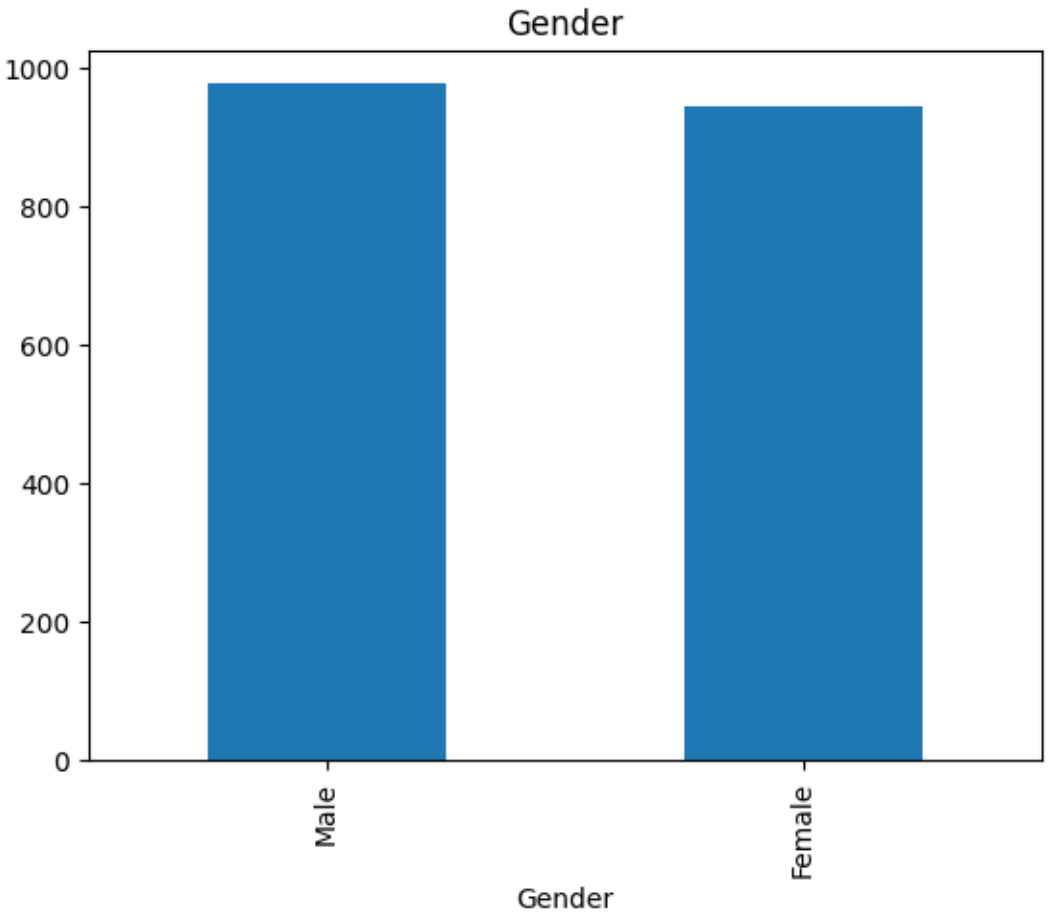

Main_meals_daily
1200
1000
800
600
400
200
0
3
1
2
4
Main_meals_daily

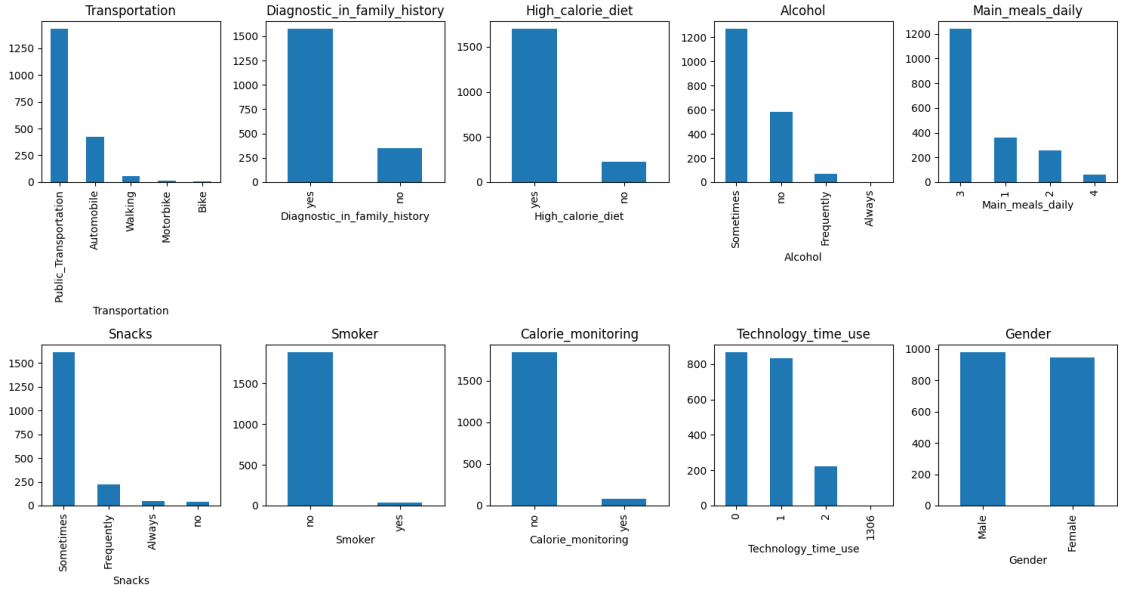

Snacks
1600
1400
1200
1000
800
600
400
200
0
Sometimes
Frequently
Always
no
Snacks


Smoker
1750
1500
1250
1000
750
500
250
0
no
yes
Smoker


Calorie_monitoring
1750
1500
1250
1000
750
500
250
0
no
yes
Calorie_monitoring


Technology_time_use
800
600
400
200
0
0
1
2
1306
Technology_time_use


Gender
1000
800
600
400
200
0
Male
Female
Gender


Transportation
Public_Transportation
Automobile
Walking
Motorbike
Bike
Diagnostic_in_family_history
yes
no
High_calorie_diet
Alcohol
Sometimes
Frequently
Always
Main_meals_daily
Snacks
Smoker
Calorie_monitoring
Technology_time_use
Gender
Male
Female

[ ]:
```
import pandas as pd
from IPython.display import display

for column in statistics_df.columns:
    if statistics_df[column].dtype == 'object':
        statistics_df[column] = statistics_df[column].astype('category').cat.
 ↪codes

cov_attributes = statistics_df.cov()
display(cov_attributes)
variances = cov_attributes.var()

important_attributes = variances.nlargest(10)  # Change 10 to the number of␣
 ↪attributes you want
print(important_attributes)
# Number of columns in the DataFrame
num_cols = cov_attributes.shape[1]

# Split the DataFrame into two halves
cov_attributes_first_half = cov_attributes.iloc[:, :num_cols//2]
cov_attributes_second_half = cov_attributes.iloc[:, num_cols//2:]

display(cov_attributes_first_half)
pd_to_latex(cov_attributes_first_half)


display(cov_attributes_second_half)
pd_to_latex(cov_attributes_second_half)
```

	Transportation	Regular_fiber_diet	\
Transportation	1.613173	1.009103	
Regular_fiber_diet	1.009103	3899.351427	
Diagnostic_in_family_history	-0.048862	0.261411	
High_calorie_diet	-0.029535	0.153711	
Sedentary_hours_daily	0.422834	-1.952158	
Age	8.382093	-36.575700	
Alcohol	-0.015630	-0.411274	
Est_avg_calorie_intake	8.080411	-409.969245	
Main_meals_daily	-0.001890	-0.671756	
Snacks	-0.026046	0.175675	
Height	1.200332	-2.841657	
Smoker	-0.001645	-0.026946	
Water_daily	0.040653	-0.227551	
Calorie_monitoring	0.008656	-0.052814	
Weight	82.964571	-145.405515	
Physical_activity_level	0.013698	0.113564	

Technology_time_use	0.146976	-0.986384
Gender	-0.087938	0.603846
Diagnostic	0.031402	2.925678

	Diagnostic_in_family_history	High_calorie_diet	\
Transportation	-0.048862	-0.029535	
Regular_fiber_diet	0.261411	0.153711	
Diagnostic_in_family_history	0.148416	0.024699	
High_calorie_diet	0.024699	0.103063	
Sedentary_hours_daily	0.094913	0.071932	
Age	4.174651	2.496830	
Alcohol	0.006592	-0.014435	
Est_avg_calorie_intake	-6.864424	2.786477	
Main_meals_daily	0.015612	-0.005995	
Snacks	0.031439	0.021901	
Height	0.347992	0.223678	
Smoker	0.000649	-0.002779	
Water_daily	0.036532	0.002342	
Calorie_monitoring	-0.012481	-0.012147	
Weight	27.775319	16.861625	
Physical_activity_level	-0.017956	-0.029297	
Technology_time_use	0.006897	0.013275	
Gender	0.019265	0.010898	
Diagnostic	0.385575	0.154993	

	Sedentary_hours_daily	Age	Alcohol	\
Transportation	0.422834	8.382093	-0.015630	
Regular_fiber_diet	-1.952158	-36.575700	-0.411274	
Diagnostic_in_family_history	0.094913	4.174651	0.006592	
High_calorie_diet	0.071932	2.496830	-0.014435	
Sedentary_hours_daily	473.490415	-12.924928	0.376236	
Age	-12.924928	401097.182477	-5.632406	
Alcohol	0.376236	-5.632406	0.268677	
Est_avg_calorie_intake	273.718418	-84.411467	-0.293501	
Main_meals_daily	-0.735790	9.385148	-0.053053	
Snacks	0.062952	3.126387	-0.011072	
Height	-0.587676	-34.975499	-0.510293	
Smoker	-0.009673	-0.338645	-0.006128	
Water_daily	-0.071017	10.451026	-0.031022	
Calorie_monitoring	-0.023988	-1.008210	-0.000697	
Weight	19.163702	-2773.142041	49.098309	
Physical_activity_level	-0.476095	19.995552	0.036450	
Technology_time_use	1.494694	-4.699622	0.013008	
Gender	-0.252078	10.209111	0.002635	
Diagnostic	-0.637862	-19.515486	-0.154355	

	Est_avg_calorie_intake	Main_meals_daily	\
Transportation	8.080411	-0.001890	

Regular_fiber_diet	-409.969245	-0.671756
Diagnostic_in_family_history	-6.864424	0.015612
High_calorie_diet	2.786477	-0.005995
Sedentary_hours_daily	273.718418	-0.735790
Age	-84.411467	9.385148
Alcohol	-0.293501	-0.053053
Est_avg_calorie_intake	188421.795103	-4.490091
Main_meals_daily	-4.490091	0.692437
Snacks	0.611156	-0.045057
Height	-930.357530	0.915565
Smoker	-2.613285	0.004791
Water_daily	-4.249024	0.038445
Calorie_monitoring	-1.236498	0.002519
Weight	-20457.233307	-21.213213
Physical_activity_level	-1.738810	0.086682
Technology_time_use	3.180425	0.019951
Gender	-5.736378	0.011937
Diagnostic	-32.980618	0.081474

	Snacks	Height	Smoker	Water_daily	\
Transportation	-0.026046	1.200332	-0.001645	0.040653	
Regular_fiber_diet	0.175675	-2.841657	-0.026946	-0.227551	
Diagnostic_in_family_history	0.031439	0.347992	0.000649	0.036532	
High_calorie_diet	0.021901	0.223678	-0.002779	0.002342	
Sedentary_hours_daily	0.062952	-0.587676	-0.009673	-0.071017	
Age	3.126387	-34.975499	-0.338645	10.451026	
Alcohol	-0.011072	-0.510293	-0.006128	-0.031022	
Est_avg_calorie_intake	0.611156	-930.357530	-2.613285	-4.249024	
Main_meals_daily	-0.045057	0.915565	0.004791	0.038445	
Snacks	0.217145	0.269326	-0.004320	0.043916	
Height	0.269326	3375.396169	0.957860	-1.181213	
Smoker	-0.004320	0.957860	0.020400	-0.002802	
Water_daily	0.043916	-1.181213	-0.002802	0.373363	
Calorie_monitoring	-0.010501	-0.083130	0.001704	0.001909	
Weight	21.545168	-182.428303	-2.569740	-28.511896	
Physical_activity_level	-0.010111	-0.237567	0.001530	0.089479	
Technology_time_use	-0.013616	-0.370402	0.000680	0.002872	
Gender	0.021538	0.072980	0.002425	0.034726	
Diagnostic	0.301313	2.670596	-0.001431	0.165964	

	Calorie_monitoring	Weight	\
Transportation	0.008656	8.296457e+01	
Regular_fiber_diet	-0.052814	-1.454055e+02	
Diagnostic_in_family_history	-0.012481	2.777532e+01	
High_calorie_diet	-0.012147	1.686162e+01	
Sedentary_hours_daily	-0.023988	1.916370e+01	
Age	-1.008210	-2.773142e+03	
Alcohol	-0.000697	4.909831e+01	

Est_avg_calorie_intake	-1.236498	-2.045723e+04
Main_meals_daily	0.002519	-2.121321e+01
Snacks	-0.010501	2.154517e+01
Height	-0.083130	-1.824283e+02
Smoker	0.001704	-2.569740e+00
Water_daily	0.001909	-2.851190e+01
Calorie_monitoring	0.041361	-6.559527e+00
Weight	-6.559527	1.040484e+07
Physical_activity_level	0.015701	7.405877e+00
Technology_time_use	-0.001766	3.997895e+01
Gender	-0.008965	-2.128977e+01
Diagnostic	-0.076485	1.139335e+02

	Physical_activity_level	Technology_time_use	\
Transportation	0.013698	0.146976	
Regular_fiber_diet	0.113564	-0.986384	
Diagnostic_in_family_history	-0.017956	0.006897	
High_calorie_diet	-0.029297	0.013275	
Sedentary_hours_daily	-0.476095	1.494694	
Age	19.995552	-4.699622	
Alcohol	0.036450	0.013008	
Est_avg_calorie_intake	-1.738810	3.180425	
Main_meals_daily	0.086682	0.019951	
Snacks	-0.010111	-0.013616	
Height	-0.237567	-0.370402	
Smoker	0.001530	0.000680	
Water_daily	0.089479	0.002872	
Calorie_monitoring	0.015701	-0.001766	
Weight	7.405877	39.978948	
Physical_activity_level	0.731924	0.038979	
Technology_time_use	0.038979	0.458564	
Gender	0.078889	-0.001048	
Diagnostic	-0.335834	-0.113624	

	Gender	Diagnostic
Transportation	-0.087938	0.031402
Regular_fiber_diet	0.603846	2.925678
Diagnostic_in_family_history	0.019265	0.385575
High_calorie_diet	0.010898	0.154993
Sedentary_hours_daily	-0.252078	-0.637862
Age	10.209111	-19.515486
Alcohol	0.002635	-0.154355
Est_avg_calorie_intake	-5.736378	-32.980618
Main_meals_daily	0.011937	0.081474
Snacks	0.021538	0.301313
Height	0.072980	2.670596
Smoker	0.002425	-0.001431
Water_daily	0.034726	0.165964

```
Calorie_monitoring            -0.008965   -0.076485
Weight                       -21.289766  113.933453
Physical_activity_level        0.078889   -0.335834
Technology_time_use           -0.001048   -0.113624
Gender                         0.250056   -0.035916
Diagnostic                    -0.035916    3.935906
```

```
Weight                    5.699370e+12
Age                       8.474530e+09
Est_avg_calorie_intake    1.914368e+09
Regular_fiber_diet        8.233589e+05
Height                    6.684452e+05
Sedentary_hours_daily     1.499751e+04
Diagnostic                7.898953e+02
Transportation            3.587744e+02
Alcohol                   1.304060e+02
Technology_time_use       8.629790e+01
dtype: float64
```

```
                           Transportation  Regular_fiber_diet  \
Transportation                   1.613173            1.009103
Regular_fiber_diet               1.009103         3899.351427
Diagnostic_in_family_history    -0.048862            0.261411
High_calorie_diet               -0.029535            0.153711
Sedentary_hours_daily            0.422834           -1.952158
Age                              8.382093          -36.575700
Alcohol                         -0.015630           -0.411274
Est_avg_calorie_intake           8.080411         -409.969245
Main_meals_daily                -0.001890           -0.671756
Snacks                          -0.026046            0.175675
Height                           1.200332           -2.841657
Smoker                          -0.001645           -0.026946
Water_daily                      0.040653           -0.227551
Calorie_monitoring               0.008656           -0.052814
Weight                          82.964571         -145.405515
Physical_activity_level          0.013698            0.113564
Technology_time_use              0.146976           -0.986384
Gender                          -0.087938            0.603846
Diagnostic                       0.031402            2.925678
```

```
                           Diagnostic_in_family_history  High_calorie_diet  \
Transportation                                -0.048862          -0.029535
Regular_fiber_diet                             0.261411           0.153711
Diagnostic_in_family_history                   0.148416           0.024699
High_calorie_diet                              0.024699           0.103063
Sedentary_hours_daily                          0.094913           0.071932
Age                                            4.174651           2.496830
Alcohol                                        0.006592          -0.014435
Est_avg_calorie_intake                        -6.864424           2.786477
```

Main_meals_daily	0.015612	-0.005995
Snacks	0.031439	0.021901
Height	0.347992	0.223678
Smoker	0.000649	-0.002779
Water_daily	0.036532	0.002342
Calorie_monitoring	-0.012481	-0.012147
Weight	27.775319	16.861625
Physical_activity_level	-0.017956	-0.029297
Technology_time_use	0.006897	0.013275
Gender	0.019265	0.010898
Diagnostic	0.385575	0.154993

	Sedentary_hours_daily	Age	Alcohol	\
Transportation	0.422834	8.382093	-0.015630	
Regular_fiber_diet	-1.952158	-36.575700	-0.411274	
Diagnostic_in_family_history	0.094913	4.174651	0.006592	
High_calorie_diet	0.071932	2.496830	-0.014435	
Sedentary_hours_daily	473.490415	-12.924928	0.376236	
Age	-12.924928	401097.182477	-5.632406	
Alcohol	0.376236	-5.632406	0.268677	
Est_avg_calorie_intake	273.718418	-84.411467	-0.293501	
Main_meals_daily	-0.735790	9.385148	-0.053053	
Snacks	0.062952	3.126387	-0.011072	
Height	-0.587676	-34.975499	-0.510293	
Smoker	-0.009673	-0.338645	-0.006128	
Water_daily	-0.071017	10.451026	-0.031022	
Calorie_monitoring	-0.023988	-1.008210	-0.000697	
Weight	19.163702	-2773.142041	49.098309	
Physical_activity_level	-0.476095	19.995552	0.036450	
Technology_time_use	1.494694	-4.699622	0.013008	
Gender	-0.252078	10.209111	0.002635	
Diagnostic	-0.637862	-19.515486	-0.154355	

	Est_avg_calorie_intake	Main_meals_daily
Transportation	8.080411	-0.001890
Regular_fiber_diet	-409.969245	-0.671756
Diagnostic_in_family_history	-6.864424	0.015612
High_calorie_diet	2.786477	-0.005995
Sedentary_hours_daily	273.718418	-0.735790
Age	-84.411467	9.385148
Alcohol	-0.293501	-0.053053
Est_avg_calorie_intake	188421.795103	-4.490091
Main_meals_daily	-4.490091	0.692437
Snacks	0.611156	-0.045057
Height	-930.357530	0.915565
Smoker	-2.613285	0.004791
Water_daily	-4.249024	0.038445
Calorie_monitoring	-1.236498	0.002519

```
Weight                                -20457.233307        -21.213213
Physical_activity_level                  -1.738810          0.086682
Technology_time_use                       3.180425          0.019951
Gender                                   -5.736378          0.011937
Diagnostic                              -32.980618          0.081474
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lrlllllllll
\toprule
 & Transportation & Regular fiber diet & Diagnostic in family history & High
calorie diet & Sedentary hours daily & Age & Alcohol & Est avg calorie intake &
Main meals daily \\
\midrule
Transportation & 1.613 & 1.009 & -0.049 & -0.030 & 0.423 & 8.382 & -0.016 &
8.080 & -0.002 \\
Regular_fiber_diet & 1.009 & \textbf{3899.351} & 0.261 & 0.154 & -1.952 &
-36.576 & -0.411 & -409.969 & -0.672 \\
Diagnostic_in_family_history & -0.049 & 0.261 & 0.148 & 0.025 & 0.095 & 4.175 &
0.007 & -6.864 & 0.016 \\
High_calorie_diet & -0.030 & 0.154 & 0.025 & 0.103 & 0.072 & 2.497 & -0.014 &
2.786 & -0.006 \\
Sedentary_hours_daily & 0.423 & -1.952 & 0.095 & 0.072 & \textbf{473.49} &
-12.925 & 0.376 & 273.718 & -0.736 \\
Age & 8.382 & -36.576 & 4.175 & 2.497 & -12.925 & \textbf{401097.182} & -5.632 &
-84.411 & \textbf{9.385} \\
Alcohol & -0.016 & -0.411 & 0.007 & -0.014 & 0.376 & -5.632 & 0.269 & -0.294 &
-0.053 \\
Est_avg_calorie_intake & 8.080 & -409.969 & -6.864 & 2.786 & 273.718 & -84.411 &
-0.294 & \textbf{188421.795} & -4.490 \\
Main_meals_daily & -0.002 & -0.672 & 0.016 & -0.006 & -0.736 & 9.385 & -0.053 &
-4.490 & 0.692 \\
Snacks & -0.026 & 0.176 & 0.031 & 0.022 & 0.063 & 3.126 & -0.011 & 0.611 &
-0.045 \\
Height & 1.200 & -2.842 & 0.348 & 0.224 & -0.588 & -34.975 & -0.510 & -930.358 &
0.916 \\
Smoker & -0.002 & -0.027 & 0.001 & -0.003 & -0.010 & -0.339 & -0.006 & -2.613 &
0.005 \\
Water_daily & 0.041 & -0.228 & 0.037 & 0.002 & -0.071 & 10.451 & -0.031 & -4.249
& 0.038 \\
Calorie_monitoring & 0.009 & -0.053 & -0.012 & -0.012 & -0.024 & -1.008 & -0.001
& -1.236 & 0.003 \\
Weight & 82.965 & -145.406 & \textbf{27.775} & \textbf{16.862} & 19.164 &
-2773.142 & \textbf{49.098} & -20457.233 & -21.213 \\
Physical_activity_level & 0.014 & 0.114 & -0.018 & -0.029 & -0.476 & 19.996 &
0.036 & -1.739 & 0.087 \\
Technology_time_use & 0.147 & -0.986 & 0.007 & 0.013 & 1.495 & -4.700 & 0.013 &
```

```
3.180 & 0.020 \\
Gender & -0.088 & 0.604 & 0.019 & 0.011 & -0.252 & 10.209 & 0.003 & -5.736 &
0.012 \\
Diagnostic & 0.031 & 2.926 & 0.386 & 0.155 & -0.638 & -19.515 & -0.154 & -32.981
& 0.081 \\
\bottomrule
\end{tabular}
\end{table}
```

```
/tmp/ipykernel_4702/770483752.py:59: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df[column] = df[column].round(3)
/tmp/ipykernel_4702/770483752.py:51: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df[column] = df[column].apply(lambda x: f'\\textbf{{{x}}}' if x == max_val
else x)
```

	Snacks	Height	Smoker	Water_daily	\
Transportation	-0.026046	1.200332	-0.001645	0.040653	
Regular_fiber_diet	0.175675	-2.841657	-0.026946	-0.227551	
Diagnostic_in_family_history	0.031439	0.347992	0.000649	0.036532	
High_calorie_diet	0.021901	0.223678	-0.002779	0.002342	
Sedentary_hours_daily	0.062952	-0.587676	-0.009673	-0.071017	
Age	3.126387	-34.975499	-0.338645	10.451026	
Alcohol	-0.011072	-0.510293	-0.006128	-0.031022	
Est_avg_calorie_intake	0.611156	-930.357530	-2.613285	-4.249024	
Main_meals_daily	-0.045057	0.915565	0.004791	0.038445	
Snacks	0.217145	0.269326	-0.004320	0.043916	
Height	0.269326	3375.396169	0.957860	-1.181213	
Smoker	-0.004320	0.957860	0.020400	-0.002802	
Water_daily	0.043916	-1.181213	-0.002802	0.373363	
Calorie_monitoring	-0.010501	-0.083130	0.001704	0.001909	
Weight	21.545168	-182.428303	-2.569740	-28.511896	
Physical_activity_level	-0.010111	-0.237567	0.001530	0.089479	
Technology_time_use	-0.013616	-0.370402	0.000680	0.002872	
Gender	0.021538	0.072980	0.002425	0.034726	
Diagnostic	0.301313	2.670596	-0.001431	0.165964	

	Calorie_monitoring	Weight	\
Transportation	0.008656	8.296457e+01	

```
Regular_fiber_diet                  -0.052814 -1.454055e+02
Diagnostic_in_family_history        -0.012481  2.777532e+01
High_calorie_diet                   -0.012147  1.686162e+01
Sedentary_hours_daily               -0.023988  1.916370e+01
Age                                 -1.008210 -2.773142e+03
Alcohol                             -0.000697  4.909831e+01
Est_avg_calorie_intake              -1.236498 -2.045723e+04
Main_meals_daily                     0.002519 -2.121321e+01
Snacks                              -0.010501  2.154517e+01
Height                              -0.083130 -1.824283e+02
Smoker                               0.001704 -2.569740e+00
Water_daily                          0.001909 -2.851190e+01
Calorie_monitoring                   0.041361 -6.559527e+00
Weight                              -6.559527  1.040484e+07
Physical_activity_level              0.015701  7.405877e+00
Technology_time_use                 -0.001766  3.997895e+01
Gender                              -0.008965 -2.128977e+01
Diagnostic                          -0.076485  1.139335e+02

                            Physical_activity_level  Technology_time_use  \
Transportation                             0.013698             0.146976
Regular_fiber_diet                         0.113564            -0.986384
Diagnostic_in_family_history              -0.017956             0.006897
High_calorie_diet                         -0.029297             0.013275
Sedentary_hours_daily                     -0.476095             1.494694
Age                                       19.995552            -4.699622
Alcohol                                    0.036450             0.013008
Est_avg_calorie_intake                    -1.738810             3.180425
Main_meals_daily                           0.086682             0.019951
Snacks                                    -0.010111            -0.013616
Height                                    -0.237567            -0.370402
Smoker                                     0.001530             0.000680
Water_daily                                0.089479             0.002872
Calorie_monitoring                         0.015701            -0.001766
Weight                                     7.405877            39.978948
Physical_activity_level                    0.731924             0.038979
Technology_time_use                        0.038979             0.458564
Gender                                     0.078889            -0.001048
Diagnostic                                -0.335834            -0.113624

                              Gender  Diagnostic
Transportation             -0.087938    0.031402
Regular_fiber_diet          0.603846    2.925678
Diagnostic_in_family_history  0.019265    0.385575
High_calorie_diet           0.010898    0.154993
Sedentary_hours_daily      -0.252078   -0.637862
Age                        10.209111  -19.515486
Alcohol                     0.002635   -0.154355
```

```
Est_avg_calorie_intake        -5.736378  -32.980618
Main_meals_daily               0.011937    0.081474
Snacks                         0.021538    0.301313
Height                         0.072980    2.670596
Smoker                         0.002425   -0.001431
Water_daily                    0.034726    0.165964
Calorie_monitoring            -0.008965   -0.076485
Weight                       -21.289766  113.933453
Physical_activity_level        0.078889   -0.335834
Technology_time_use           -0.001048   -0.113624
Gender                         0.250056   -0.035916
Diagnostic                    -0.035916    3.935906
```

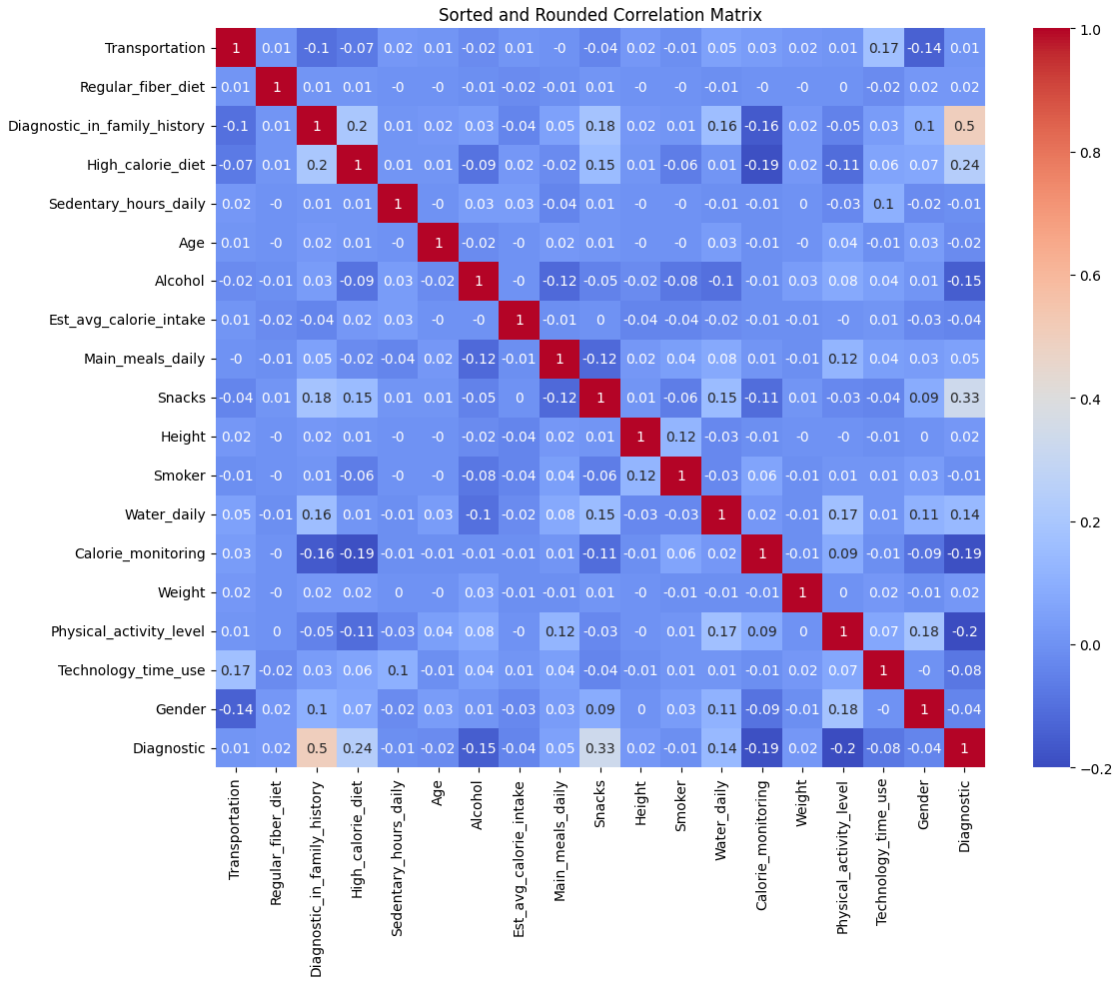
```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lrlllllllll}
\toprule
 & Snacks & Height & Smoker & Water daily & Calorie monitoring & Weight &
Physical activity level & Technology time use & Gender & Diagnostic \\
\midrule
Transportation & -0.026 & 1.200 & -0.002 & 0.041 & 0.009 & 82.965 & 0.014 &
0.147 & -0.088 & 0.031 \\
Regular_fiber_diet & 0.176 & -2.842 & -0.027 & -0.228 & -0.053 & -145.406 &
0.114 & -0.986 & 0.604 & 2.926 \\
Diagnostic_in_family_history & 0.031 & 0.348 & 0.001 & 0.037 & -0.012 & 27.775 &
-0.018 & 0.007 & 0.019 & 0.386 \\
High_calorie_diet & 0.022 & 0.224 & -0.003 & 0.002 & -0.012 & 16.862 & -0.029 &
0.013 & 0.011 & 0.155 \\
Sedentary_hours_daily & 0.063 & -0.588 & -0.010 & -0.071 & -0.024 & 19.164 &
-0.476 & 1.495 & -0.252 & -0.638 \\
Age & 3.126 & -34.975 & -0.339 & \textbf{10.451} & -1.008 & -2773.142 &
\textbf{19.996} & -4.700 & \textbf{10.209} & -19.515 \\
Alcohol & -0.011 & -0.510 & -0.006 & -0.031 & -0.001 & 49.098 & 0.036 & 0.013 &
0.003 & -0.154 \\
Est_avg_calorie_intake & 0.611 & -930.358 & -2.613 & -4.249 & -1.236 &
-20457.233 & -1.739 & 3.180 & -5.736 & -32.981 \\
Main_meals_daily & -0.045 & 0.916 & 0.005 & 0.038 & 0.003 & -21.213 & 0.087 &
0.020 & 0.012 & 0.081 \\
Snacks & 0.217 & 0.269 & -0.004 & 0.044 & -0.011 & 21.545 & -0.010 & -0.014 &
0.022 & 0.301 \\
Height & 0.269 & \textbf{3375.396} & \textbf{0.958} & -1.181 & -0.083 & -182.428
& -0.238 & -0.370 & 0.073 & 2.671 \\
Smoker & -0.004 & 0.958 & 0.020 & -0.003 & 0.002 & -2.570 & 0.002 & 0.001 &
0.002 & -0.001 \\
Water_daily & 0.044 & -1.181 & -0.003 & 0.373 & 0.002 & -28.512 & 0.089 & 0.003
& 0.035 & 0.166 \\
Calorie_monitoring & -0.011 & -0.083 & 0.002 & 0.002 & \textbf{0.041} & -6.560 &
```

```
0.016 & -0.002 & -0.009 & -0.076 \\
Weight & 21.545 & -182.428 & -2.570 & -28.512 & -6.560 & \textbf{10404840.733} &
7.406 & \textbf{39.979} & -21.290 & \textbf{113.933} \\
Physical_activity_level & -0.010 & -0.238 & 0.002 & 0.089 & 0.016 & 7.406 &
0.732 & 0.039 & 0.079 & -0.336 \\
Technology_time_use & -0.014 & -0.370 & 0.001 & 0.003 & -0.002 & 39.979 & 0.039
& 0.459 & -0.001 & -0.114 \\
Gender & 0.022 & 0.073 & 0.002 & 0.035 & -0.009 & -21.290 & 0.079 & -0.001 &
0.250 & -0.036 \\
Diagnostic & 0.301 & 2.671 & -0.001 & 0.166 & -0.076 & 113.933 & -0.336 & -0.114
& -0.036 & 3.936 \\
\bottomrule
\end{tabular}
\end{table}
```

```
/tmp/ipykernel_4702/770483752.py:59: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df[column] = df[column].round(3)
/tmp/ipykernel_4702/770483752.py:51: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df[column] = df[column].apply(lambda x: f'\\textbf{{{x}}}' if x == max_val
else x)
```

[ ]:
```python
import seaborn as sns
correlation_matrix = statistics_df.corr()

# Round the values to a maximum of 3 decimals
rounded_corr_matrix = correlation_matrix.round(2)

# Create a heatmap of the sorted and rounded correlation matrix
plt.figure(figsize=(12, 10))
sns.heatmap(rounded_corr_matrix, annot=True, cmap='coolwarm')

# Set the title of the heatmap
plt.title('Sorted and Rounded Correlation Matrix')

# Display the heatmap
plt.tight_layout()
plt.savefig(f"figs/correlation_matrix.png", dpi=300)
```

```
plt.show()
```



[ ]:
```
import ast
from sklearn.base import ClassifierMixin
from sklearn.discriminant_analysis import StandardScaler
from sklearn.experimental import enable_iterative_imputer
from sklearn.impute import IterativeImputer
from sklearn.model_selection import train_test_split
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import (
    accuracy_score,
    classification_report,
    confusion_matrix,
    f1_score,
    make_scorer,
    precision_score,
```

```
    recall_score,
)
from sklearn.preprocessing import (
    LabelEncoder,
    Normalizer,
    QuantileTransformer,
    RobustScaler,
)
from sklearn.feature_selection import (
    SelectPercentile,
    VarianceThreshold,
    chi2,
    f_classif,
)
from sklearn.model_selection import GridSearchCV

from matplotlib.backends.backend_pdf import PdfPages


def prepare_dataset():
    df = pd.read_csv("date_tema_1_iaut_2024.csv")
    prelucrate_data(df)
    # Replace -1 with NaN in the 'Weight' column
    df["Weight"] = df["Weight"].replace(-1, np.nan)
    # df['Age'] = df['Age'].mask(df['Age'] >= 100)
    # Initialize the IterativeImputer
    imputer = IterativeImputer()

    # Perform the imputation on the 'Weight' column
    numerical_columns = df.select_dtypes(include=["int64", "float64"]).columns
    df = df.replace(-1, np.nan)
    df[numerical_columns] = imputer.fit_transform(df[numerical_columns])

    # Convert categorical columns to numerical
    le = LabelEncoder()
    for col in df.columns:
        df[col] = le.fit_transform(df[col])

    X = df.drop("Diagnostic", axis=1)
    y = df["Diagnostic"]

    # Create a VarianceThreshold object
    selector = VarianceThreshold(threshold=0.1)

    # Fit and transform the selector to the data
    features_before = X.columns
    X = pd.DataFrame(
```

```
        selector.fit_transform(X), columns=X.columns[selector.get_support()]
    )
    print(f"Features removed: {set(features_before) - set(X.columns)}")

    # Create a SelectPercentile object
    selector = SelectPercentile(f_classif, percentile=90)

    # Fit and transform the selector to the data
    features_before = X.columns
    X = pd.DataFrame(
        selector.fit_transform(X, y), columns=X.columns[selector.get_support()]
    )
    print(f"Features removed: {set(features_before) - set(X.columns)}")

    # Quantile transformer
    transformer = QuantileTransformer()
    X = transformer.fit_transform(X, y)

    # Standardize the features
    scaler = RobustScaler()
    X = scaler.fit_transform(X, y)
    return X, y


def find_best_params(classifier, param_grid, X, y, random_state=42):

    # Create train test
    X_train, X_test, y_train, y_test = train_test_split(
        X, y, test_size=0.2, random_state=random_state
    )

    # Convert the custom scorer into a scorer that can be used with GridSearchCV

    scorers = {
        "accuracy": make_scorer(accuracy_score),
        "precision": make_scorer(precision_score, average="weighted"),
        "recall": make_scorer(recall_score, average="weighted"),
        "f1": make_scorer(f1_score, average="weighted"),
    }

    def accuracy_score_specific_class(y_true, y_pred, *, class_label):
        return accuracy_score(y_true == class_label, y_pred == class_label)

    def f1_score_specific_class(y_true, y_pred, *, class_label):
        return f1_score(y_true, y_pred, labels=[class_label], average=None)[0]

    def precision_score_specific_class(y_true, y_pred, *, class_label):
```

```
        return precision_score(y_true, y_pred, labels=[class_label],␣
↪average=None)[0]

    def recall_score_specific_class(y_true, y_pred, *, class_label):
        return recall_score(y_true, y_pred, labels=[class_label],␣
↪average=None)[0]

    for class_label in np.unique(y):
        scorers[f"accuracy_D{class_label}"] = make_scorer(
            accuracy_score_specific_class,
            class_label=class_label,
        )

    for class_label in np.unique(y):
        scorers[f"f1_D{class_label}"] = make_scorer(
            f1_score_specific_class,
            class_label=class_label,
        )

    for class_label in np.unique(y):
        scorers[f"precision_D{class_label}"] = make_scorer(
            precision_score_specific_class,
            class_label=class_label,
        )
    for class_label in np.unique(y):
        scorers[f"recall_D{class_label}"] = make_scorer(
            recall_score_specific_class,
            class_label=class_label,
        )

    # Initialize a GridSearchCV
    grid_search = GridSearchCV(
        estimator=classifier,
        param_grid=param_grid,
        cv=5,
        scoring=scorers,
        refit="f1",
        n_jobs=4,
    )
    # Fit the GridSearchCV to the training data
    grid_search.fit(X_train, y_train)

    # Print the best parameters
    print("Best parameters found: ", grid_search.best_params_)

    return grid_search, grid_search.best_params_
```

```python
def evaluate_my_model(
    model: ClassifierMixin, grid_search: GridSearchCV, X, y, random_state=42
):
    print(f"Model: {model.__class__.__name__}")
    # Create a DataFrame from cv_results_
    df = pd.DataFrame(grid_search.cv_results_)

    columns = [
        "params",
        "mean_test_accuracy",
        "std_test_accuracy",
        "mean_test_precision",
        "std_test_precision",
        "mean_test_recall",
        "std_test_recall",
        "mean_test_f1",
        "std_test_f1",
    ]
    for scr in SCORERS_NAMES:
        for class_label in np.unique(y):
            columns.append(f"mean_test_{scr}_D{class_label}")
            columns.append(f"std_test_{scr}_D{class_label}")
    # Select the columns of interest
    print(df.columns)
    df = df[columns]

    # Rename the columns
    df["params"] = df["params"].apply(lambda x: x.values())
    df["params"] = df["params"].apply(lambda x: list(x))
    df['params'] = df['params'].apply(lambda x: f"{','.join(map(str, x))}")

    rename_params_to = ",".join([x for x in grid_search.best_params_])
    df = df.rename(columns={"params": rename_params_to})

    # Highlight the row with the best parameters

    dfs = []
    for class_label in np.unique(y):
        cols = [rename_params_to]
        for scr in SCORERS_NAMES:
            cols.append(f"mean_test_{scr}_D{class_label}")
            cols.append(f"std_test_{scr}_D{class_label}")
        dfs.append(df[cols])
        renamed_cols = [rename_params_to]
```

```
        for scr in SCORERS_NAMES:
            renamed_cols.append(f"{scr}_D{class_label}")
            renamed_cols.append(f"{scr}_D{class_label}_std")
        dfs[-1].columns = renamed_cols

    X_train, X_test, y_train, y_test = train_test_split(
        X, y, test_size=0.2, random_state=random_state
    )
    model.fit(X_train, y_train)
    y_pred = model.predict(X_test)
    accuracy = accuracy_score(y_test, y_pred)
    f1 = f1_score(y_test, y_pred, average="weighted")
    precision = precision_score(y_test, y_pred, average="weighted")
    recall = recall_score(y_test, y_pred, average="weighted")
    print(
        classification_report(
            y_test, y_pred, target_names=["D0", "D1", "D2", "D3", "D4", "D5",␣
↪"D6"]
        )
    )

    # Confusion matrix
    def plot_confusion_matrix(cm, classes, model: RandomForestClassifier):
        df_cm = pd.DataFrame(cm, index=classes, columns=classes)
        plt.figure(figsize=(10, 7))
        sns.heatmap(df_cm, annot=True, fmt="d", cmap="Blues")
        plt.title("Confusion Matrix")
        plt.ylabel("True label")
        plt.xlabel("Predicted label")
        plt.savefig(f"figs/confusion_matrix_{model.__class__.__name__}.png",␣
↪dpi=300)
        plt.show()

    cm = confusion_matrix(y_test, y_pred)
    plot_confusion_matrix(cm, ["D0", "D1", "D2", "D3", "D4", "D5", "D6"], model)

    return accuracy, f1, precision, recall, dfs
```

[ ]:
```
# Initialize a RandomForestClassifier
clf = RandomForestClassifier(random_state=42)


# Define the parameter grid
param_grid = {
    'n_estimators': [100, 150, 200],
    'max_depth': [15, 20, 25],
    'max_samples': [0.5, 0.7, 1.0],
```

```
}
X, y = prepare_dataset()
grid_search, best_params = find_best_params(clf, param_grid, X, y, RANDOM_STATE)
```

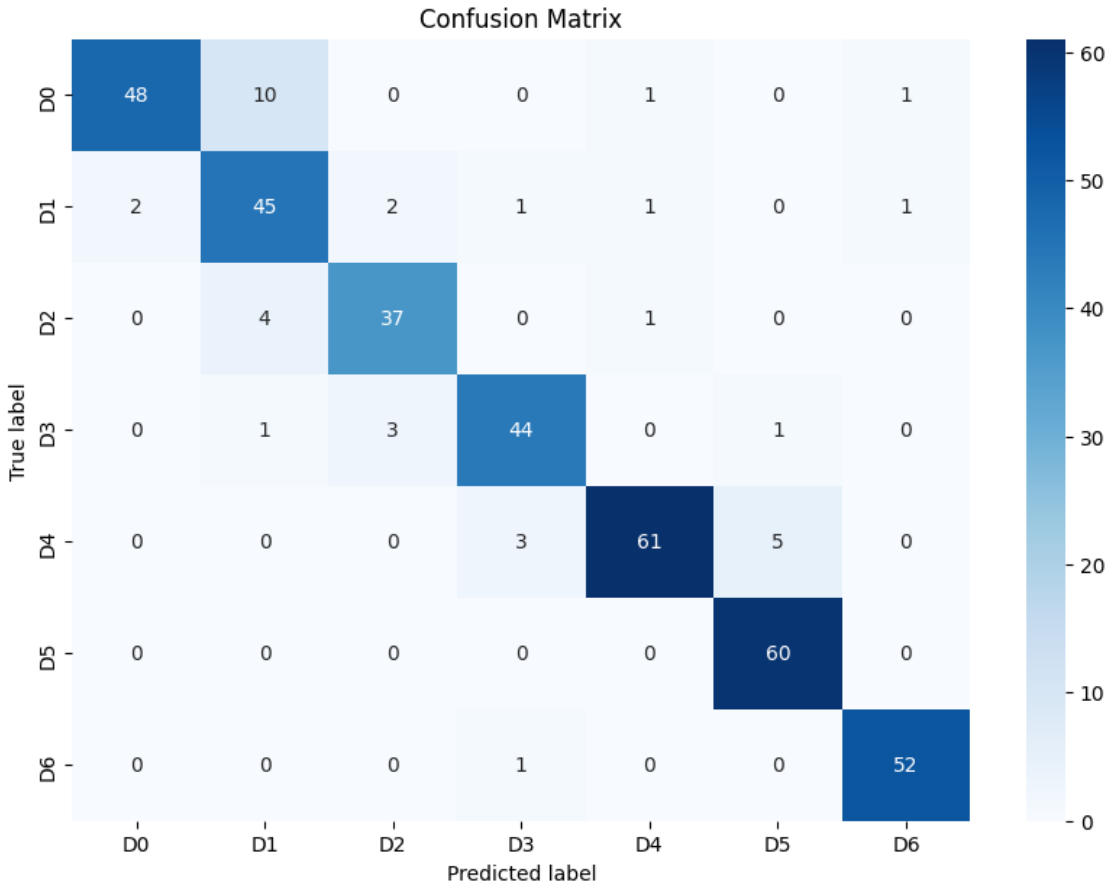
```
Features removed: {'Smoker', 'Calorie_monitoring'}
Features removed: {'Sedentary_hours_daily', 'Est_avg_calorie_intake'}
Best parameters found:  {'max_depth': 20, 'max_samples': 1.0, 'n_estimators':
200}
```

[ ]:
```
best_clf = RandomForestClassifier(**best_params, random_state=RANDOM_STATE)
accuracy, f1, precision, recall, dfs = evaluate_my_model(best_clf, grid_search,␣
 ↪X, y, RANDOM_STATE)
```

```
Model: RandomForestClassifier
Index(['mean_fit_time', 'std_fit_time', 'mean_score_time', 'std_score_time',
       'param_max_depth', 'param_max_samples', 'param_n_estimators', 'params',
       'split0_test_accuracy', 'split1_test_accuracy',
       …
       'std_test_recall_D5', 'rank_test_recall_D5', 'split0_test_recall_D6',
       'split1_test_recall_D6', 'split2_test_recall_D6',
       'split3_test_recall_D6', 'split4_test_recall_D6', 'mean_test_recall_D6',
       'std_test_recall_D6', 'rank_test_recall_D6'],
      dtype='object', length=264)
              precision    recall  f1-score   support

           D0       0.96      0.80      0.87        60
           D1       0.75      0.87      0.80        52
           D2       0.88      0.88      0.88        42
           D3       0.90      0.90      0.90        49
           D4       0.95      0.88      0.92        69
           D5       0.91      1.00      0.95        60
           D6       0.96      0.98      0.97        53

    accuracy                           0.90       385
   macro avg       0.90      0.90      0.90       385
weighted avg       0.91      0.90      0.90       385
```



[ ]:
```
print(f"Accuracy: {accuracy}")
print(f"F1 Score: {f1}")
print(f"Precision: {precision}")
print(f"Recall: {recall}")
print(grid_search.best_index_)
for df in dfs:
    # Replace the dictionary values with list
    display(df)
    pd_to_latex(df)
```

```
Accuracy: 0.9012987012987013
F1 Score: 0.9015570378350735
Precision: 0.9063587443701079
Recall: 0.9012987012987013
17
```

	max_depth,max_samples,n_estimators	accuracy_D0	accuracy_D0_std	f1_D0	\
0	15,0.5,100	0.986332	0.005958	0.942906	
1	15,0.5,150	0.988286	0.004396	0.950829	
2	15,0.5,200	0.988286	0.004396	0.950829	

3	15,0.7,100	0.989587	0.003782	0.956010
4	15,0.7,150	0.988284	0.003896	0.950828
5	15,0.7,200	0.987633	0.005597	0.948015
6	15,1.0,100	0.985680	0.003892	0.939781
7	15,1.0,150	0.985680	0.004862	0.939924
8	15,1.0,200	0.987635	0.004300	0.947937
9	20,0.5,100	0.984378	0.005595	0.934391
10	20,0.5,150	0.988286	0.004396	0.950829
11	20,0.5,200	0.987635	0.004300	0.947937
12	20,0.7,100	0.988936	0.003305	0.953115
13	20,0.7,150	0.988936	0.003305	0.953115
14	20,0.7,200	0.988936	0.004864	0.953193
15	20,1.0,100	0.987633	0.003179	0.948164
16	20,1.0,150	0.986332	0.005197	0.942816
17	20,1.0,200	0.986983	0.005435	0.945342
18	25,0.5,100	0.984378	0.005595	0.934391
19	25,0.5,150	0.988286	0.004396	0.950829
20	25,0.5,200	0.987635	0.004300	0.947937
21	25,0.7,100	0.988936	0.003305	0.953115
22	25,0.7,150	0.988936	0.003305	0.953115
23	25,0.7,200	0.988936	0.004864	0.953193
24	25,1.0,100	0.987633	0.003179	0.948164
25	25,1.0,150	0.986332	0.005197	0.942816
26	25,1.0,200	0.986983	0.005435	0.945342

	f1_D0_std	precision_D0	precision_D0_std	recall_D0	recall_D0_std
0	0.024680	0.956148	0.027508	0.930299	0.026794
1	0.018329	0.966658	0.011118	0.935704	0.026679
2	0.018329	0.966658	0.011118	0.935704	0.026679
3	0.016082	0.977610	0.011209	0.935704	0.026679
4	0.016454	0.967093	0.020149	0.935704	0.026679
5	0.023308	0.966800	0.026333	0.930299	0.026794
6	0.016627	0.955814	0.012786	0.924893	0.030949
7	0.020499	0.956361	0.026697	0.924893	0.030949
8	0.017964	0.966499	0.011042	0.930299	0.026794
9	0.023470	0.949991	0.020784	0.919488	0.029105
10	0.018329	0.966658	0.011118	0.935704	0.026679
11	0.017964	0.966499	0.011042	0.930299	0.026794
12	0.014081	0.977610	0.011209	0.930299	0.026794
13	0.014081	0.977610	0.011209	0.930299	0.026794
14	0.020446	0.977619	0.020832	0.930299	0.026794
15	0.013607	0.961537	0.012799	0.935704	0.026679
16	0.021905	0.956520	0.026788	0.930299	0.031782
17	0.022986	0.961378	0.022069	0.930299	0.031782
18	0.023470	0.949991	0.020784	0.919488	0.029105
19	0.018329	0.966658	0.011118	0.935704	0.026679
20	0.017964	0.966499	0.011042	0.930299	0.026794
21	0.014081	0.977610	0.011209	0.930299	0.026794

```
22   0.014081      0.977610          0.011209   0.930299       0.026794
23   0.020446      0.977619          0.020832   0.930299       0.026794
24   0.013607      0.961537          0.012799   0.935704       0.026679
25   0.021905      0.956520          0.026788   0.930299       0.031782
26   0.022986      0.961378          0.022069   0.930299       0.031782
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & max depth,max samples,n estimators & accuracy D0 & accuracy D0 std & f1 D0 &
f1 D0 std & precision D0 & precision D0 std & recall D0 & recall D0 std \\
\midrule
0 & 15,0.5,100 & 0.986 & 0.006 & 0.943 & 0.025 & 0.956 & 0.028 & 0.930 &
\textbf{0.027} \\
1 & 15,0.5,150 & 0.988 & 0.004 & 0.951 & 0.018 & 0.967 & \textbf{0.011} &
\textbf{0.936} & \textbf{0.027} \\
2 & 15,0.5,200 & 0.988 & 0.004 & 0.951 & 0.018 & 0.967 & \textbf{0.011} &
\textbf{0.936} & \textbf{0.027} \\
3 & 15,0.7,100 & \textbf{0.99} & 0.004 & \textbf{0.956} & 0.016 & \textbf{0.978}
& \textbf{0.011} & \textbf{0.936} & \textbf{0.027} \\
4 & 15,0.7,150 & 0.988 & 0.004 & 0.951 & 0.016 & 0.967 & 0.020 & \textbf{0.936}
& \textbf{0.027} \\
5 & 15,0.7,200 & 0.988 & 0.006 & 0.948 & 0.023 & 0.967 & 0.026 & 0.930 &
\textbf{0.027} \\
6 & 15,1.0,100 & 0.986 & 0.004 & 0.940 & 0.017 & 0.956 & 0.013 & 0.925 & 0.031
\\
7 & 15,1.0,150 & 0.986 & 0.005 & 0.940 & 0.020 & 0.956 & 0.027 & 0.925 & 0.031
\\
8 & 15,1.0,200 & 0.988 & 0.004 & 0.948 & 0.018 & 0.966 & \textbf{0.011} & 0.930
& \textbf{0.027} \\
9 & 20,0.5,100 & 0.984 & 0.006 & 0.934 & 0.023 & 0.950 & 0.021 & 0.919 & 0.029
\\
10 & 20,0.5,150 & 0.988 & 0.004 & 0.951 & 0.018 & 0.967 & \textbf{0.011} &
\textbf{0.936} & \textbf{0.027} \\
11 & 20,0.5,200 & 0.988 & 0.004 & 0.948 & 0.018 & 0.966 & \textbf{0.011} & 0.930
& \textbf{0.027} \\
12 & 20,0.7,100 & 0.989 & \textbf{0.003} & 0.953 & \textbf{0.014} &
\textbf{0.978} & \textbf{0.011} & 0.930 & \textbf{0.027} \\
13 & 20,0.7,150 & 0.989 & \textbf{0.003} & 0.953 & \textbf{0.014} &
\textbf{0.978} & \textbf{0.011} & 0.930 & \textbf{0.027} \\
14 & 20,0.7,200 & 0.989 & 0.005 & 0.953 & 0.020 & \textbf{0.978} & 0.021 & 0.930
& \textbf{0.027} \\
15 & 20,1.0,100 & 0.988 & \textbf{0.003} & 0.948 & \textbf{0.014} & 0.962 &
0.013 & \textbf{0.936} & \textbf{0.027} \\
16 & 20,1.0,150 & 0.986 & 0.005 & 0.943 & 0.022 & 0.957 & 0.027 & 0.930 & 0.032
\\
```

```
17 & 20,1.0,200 & 0.987 & 0.005 & 0.945 & 0.023 & 0.961 & 0.022 & 0.930 & 0.032
\\
18 & 25,0.5,100 & 0.984 & 0.006 & 0.934 & 0.023 & 0.950 & 0.021 & 0.919 & 0.029
\\
19 & 25,0.5,150 & 0.988 & 0.004 & 0.951 & 0.018 & 0.967 & \textbf{0.011} &
\textbf{0.936} & \textbf{0.027} \\
20 & 25,0.5,200 & 0.988 & 0.004 & 0.948 & 0.018 & 0.966 & \textbf{0.011} & 0.930
& \textbf{0.027} \\
21 & 25,0.7,100 & 0.989 & \textbf{0.003} & 0.953 & \textbf{0.014} &
\textbf{0.978} & \textbf{0.011} & 0.930 & \textbf{0.027} \\
22 & 25,0.7,150 & 0.989 & \textbf{0.003} & 0.953 & \textbf{0.014} &
\textbf{0.978} & \textbf{0.011} & 0.930 & \textbf{0.027} \\
23 & 25,0.7,200 & 0.989 & 0.005 & 0.953 & 0.020 & \textbf{0.978} & 0.021 & 0.930
& \textbf{0.027} \\
24 & 25,1.0,100 & 0.988 & \textbf{0.003} & 0.948 & \textbf{0.014} & 0.962 &
0.013 & \textbf{0.936} & \textbf{0.027} \\
25 & 25,1.0,150 & 0.986 & 0.005 & 0.943 & 0.022 & 0.957 & 0.027 & 0.930 & 0.032
\\
26 & 25,1.0,200 & 0.987 & 0.005 & 0.945 & 0.023 & 0.961 & 0.022 & 0.930 & 0.032
\\
\bottomrule
\end{tabular}
\end{table}
```

	max_depth,max_samples,n_estimators	accuracy_D1	accuracy_D1_std	f1_D1	\
0	15,0.5,100	0.946612	0.010438	0.811017	
1	15,0.5,150	0.947910	0.013529	0.816577	
2	15,0.5,200	0.947912	0.009900	0.817270	
3	15,0.7,100	0.953118	0.011963	0.837372	
4	15,0.7,150	0.951170	0.009224	0.830069	
5	15,0.7,200	0.947914	0.009674	0.820037	
6	15,1.0,100	0.944004	0.010207	0.802799	
7	15,1.0,150	0.945306	0.009778	0.807396	
8	15,1.0,200	0.947910	0.014292	0.818414	
9	20,0.5,100	0.945306	0.012105	0.808230	
10	20,0.5,150	0.948562	0.012104	0.819874	
11	20,0.5,200	0.949211	0.012656	0.821790	
12	20,0.7,100	0.950516	0.013270	0.829916	
13	20,0.7,150	0.949869	0.009355	0.826726	
14	20,0.7,200	0.947265	0.010385	0.816613	
15	20,1.0,100	0.945304	0.010617	0.809319	
16	20,1.0,150	0.948562	0.012786	0.820204	
17	20,1.0,200	0.950516	0.012273	0.827870	
18	25,0.5,100	0.945306	0.012105	0.808230	
19	25,0.5,150	0.948562	0.012104	0.819874	
20	25,0.5,200	0.949211	0.012656	0.821790	
21	25,0.7,100	0.950516	0.013270	0.829916	

22	25,0.7,150	0.949869	0.009355	0.826726	
23	25,0.7,200	0.947265	0.010385	0.816613	
24	25,1.0,100	0.945304	0.010617	0.809319	
25	25,1.0,150	0.947912	0.012376	0.817383	
26	25,1.0,200	0.949865	0.011599	0.825181	

	f1_D1_std	precision_D1	precision_D1_std	recall_D1	recall_D1_std
0	0.036335	0.787797	0.043941	0.838095	0.050843
1	0.042993	0.796178	0.067382	0.842857	0.051287
2	0.028478	0.792554	0.054060	0.847619	0.038686
3	0.035078	0.804340	0.056464	0.876190	0.031587
4	0.025221	0.798339	0.049404	0.866667	0.011664
5	0.031609	0.778704	0.036531	0.866667	0.032297
6	0.028210	0.783173	0.061889	0.828571	0.038095
7	0.026090	0.788547	0.063815	0.833333	0.042592
8	0.044698	0.790600	0.067889	0.852381	0.046168
9	0.036992	0.782401	0.055415	0.838095	0.031587
10	0.038934	0.791922	0.055606	0.852381	0.040963
11	0.040862	0.796191	0.059077	0.852381	0.046168
12	0.039492	0.790239	0.057117	0.876190	0.031587
13	0.028218	0.787525	0.041750	0.871429	0.024281
14	0.033136	0.781321	0.043061	0.857143	0.039841
15	0.030100	0.780460	0.056221	0.842857	0.011664
16	0.033353	0.799402	0.072130	0.847619	0.024281
17	0.034691	0.799089	0.062145	0.861905	0.017817
18	0.036992	0.782401	0.055415	0.838095	0.031587
19	0.038934	0.791922	0.055606	0.852381	0.040963
20	0.040862	0.796191	0.059077	0.852381	0.046168
21	0.039492	0.790239	0.057117	0.876190	0.031587
22	0.028218	0.787525	0.041750	0.871429	0.024281
23	0.033136	0.781321	0.043061	0.857143	0.039841
24	0.030100	0.780460	0.056221	0.842857	0.011664
25	0.031836	0.798670	0.071593	0.842857	0.028571
26	0.031665	0.798425	0.061500	0.857143	0.015058

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\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & max depth,max samples,n estimators & accuracy D1 & accuracy D1 std & f1 D1 &
f1 D1 std & precision D1 & precision D1 std & recall D1 & recall D1 std \\
\midrule
0 & 15,0.5,100 & 0.947 & 0.010 & 0.811 & 0.036 & 0.788 & 0.044 & 0.838 & 0.051
\\
1 & 15,0.5,150 & 0.948 & 0.014 & 0.817 & 0.043 & 0.796 & 0.067 & 0.843 & 0.051
\\
2 & 15,0.5,200 & 0.948 & 0.010 & 0.817 & 0.028 & 0.793 & 0.054 & 0.848 & 0.039
```

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\\
3 & 15,0.7,100 & \textbf{0.953} & 0.012 & \textbf{0.837} & 0.035 &
\textbf{0.804} & 0.056 & \textbf{0.876} & 0.032 \\
4 & 15,0.7,150 & 0.951 & \textbf{0.009} & 0.830 & \textbf{0.025} & 0.798 & 0.049
& 0.867 & \textbf{0.012} \\
5 & 15,0.7,200 & 0.948 & 0.010 & 0.820 & 0.032 & 0.779 & \textbf{0.037} & 0.867
& 0.032 \\
6 & 15,1.0,100 & 0.944 & 0.010 & 0.803 & 0.028 & 0.783 & 0.062 & 0.829 & 0.038
\\
7 & 15,1.0,150 & 0.945 & 0.010 & 0.807 & 0.026 & 0.789 & 0.064 & 0.833 & 0.043
\\
8 & 15,1.0,200 & 0.948 & 0.014 & 0.818 & 0.045 & 0.791 & 0.068 & 0.852 & 0.046
\\
9 & 20,0.5,100 & 0.945 & 0.012 & 0.808 & 0.037 & 0.782 & 0.055 & 0.838 & 0.032
\\
10 & 20,0.5,150 & 0.949 & 0.012 & 0.820 & 0.039 & 0.792 & 0.056 & 0.852 & 0.041
\\
11 & 20,0.5,200 & 0.949 & 0.013 & 0.822 & 0.041 & 0.796 & 0.059 & 0.852 & 0.046
\\
12 & 20,0.7,100 & 0.951 & 0.013 & 0.830 & 0.039 & 0.790 & 0.057 & \textbf{0.876}
& 0.032 \\
13 & 20,0.7,150 & 0.950 & \textbf{0.009} & 0.827 & 0.028 & 0.788 & 0.042 & 0.871
& 0.024 \\
14 & 20,0.7,200 & 0.947 & 0.010 & 0.817 & 0.033 & 0.781 & 0.043 & 0.857 & 0.040
\\
15 & 20,1.0,100 & 0.945 & 0.011 & 0.809 & 0.030 & 0.780 & 0.056 & 0.843 &
\textbf{0.012} \\
16 & 20,1.0,150 & 0.949 & 0.013 & 0.820 & 0.033 & 0.799 & 0.072 & 0.848 & 0.024
\\
17 & 20,1.0,200 & 0.951 & 0.012 & 0.828 & 0.035 & 0.799 & 0.062 & 0.862 & 0.018
\\
18 & 25,0.5,100 & 0.945 & 0.012 & 0.808 & 0.037 & 0.782 & 0.055 & 0.838 & 0.032
\\
19 & 25,0.5,150 & 0.949 & 0.012 & 0.820 & 0.039 & 0.792 & 0.056 & 0.852 & 0.041
\\
20 & 25,0.5,200 & 0.949 & 0.013 & 0.822 & 0.041 & 0.796 & 0.059 & 0.852 & 0.046
\\
21 & 25,0.7,100 & 0.951 & 0.013 & 0.830 & 0.039 & 0.790 & 0.057 & \textbf{0.876}
& 0.032 \\
22 & 25,0.7,150 & 0.950 & \textbf{0.009} & 0.827 & 0.028 & 0.788 & 0.042 & 0.871
& 0.024 \\
23 & 25,0.7,200 & 0.947 & 0.010 & 0.817 & 0.033 & 0.781 & 0.043 & 0.857 & 0.040
\\
24 & 25,1.0,100 & 0.945 & 0.011 & 0.809 & 0.030 & 0.780 & 0.056 & 0.843 &
\textbf{0.012} \\
25 & 25,1.0,150 & 0.948 & 0.012 & 0.817 & 0.032 & 0.799 & 0.072 & 0.843 & 0.029
\\
26 & 25,1.0,200 & 0.950 & 0.012 & 0.825 & 0.032 & 0.798 & 0.061 & 0.857 & 0.015
```

\\
\bottomrule
\end{tabular}
\end{table}

	max_depth,max_samples,n_estimators	accuracy_D2	accuracy_D2_std	f1_D2	\
0	15,0.5,100	0.957680	0.013826	0.844849	
1	15,0.5,150	0.960933	0.011107	0.855393	
2	15,0.5,200	0.958985	0.011760	0.847969	
3	15,0.7,100	0.963539	0.011913	0.865544	
4	15,0.7,150	0.964844	0.010782	0.868305	
5	15,0.7,200	0.962240	0.011393	0.860066	
6	15,1.0,100	0.965496	0.009791	0.872546	
7	15,1.0,150	0.965496	0.009347	0.873499	
8	15,1.0,200	0.962892	0.009570	0.863580	
9	20,0.5,100	0.959637	0.011758	0.850017	
10	20,0.5,150	0.960937	0.012188	0.853621	
11	20,0.5,200	0.960284	0.011552	0.853174	
12	20,0.7,100	0.962892	0.012795	0.860887	
13	20,0.7,150	0.961591	0.013247	0.855967	
14	20,0.7,200	0.958987	0.014054	0.847344	
15	20,1.0,100	0.964193	0.008494	0.869169	
16	20,1.0,150	0.962238	0.009126	0.861836	
17	20,1.0,200	0.964846	0.010373	0.871716	
18	25,0.5,100	0.959637	0.011758	0.850017	
19	25,0.5,150	0.960937	0.012188	0.853621	
20	25,0.5,200	0.960284	0.011552	0.853174	
21	25,0.7,100	0.962892	0.012795	0.860887	
22	25,0.7,150	0.961591	0.013247	0.855967	
23	25,0.7,200	0.958987	0.014054	0.847344	
24	25,1.0,100	0.964193	0.008494	0.869169	
25	25,1.0,150	0.962238	0.009126	0.861836	
26	25,1.0,200	0.964846	0.010373	0.871716	

	f1_D2_std	precision_D2	precision_D2_std	recall_D2	recall_D2_std
0	0.054237	0.863083	0.031450	0.828647	0.075963
1	0.044324	0.886325	0.030629	0.828647	0.066876
2	0.047744	0.875896	0.018517	0.823996	0.076009
3	0.046566	0.892213	0.037796	0.842495	0.068226
4	0.042879	0.909163	0.028328	0.833298	0.068107
5	0.044538	0.891558	0.032994	0.833298	0.069677
6	0.038536	0.900840	0.017677	0.847252	0.059829
7	0.035419	0.897041	0.019814	0.851903	0.052032
8	0.037905	0.887194	0.015179	0.842600	0.061315
9	0.047330	0.880696	0.024608	0.823890	0.076179
10	0.048211	0.893592	0.028384	0.819345	0.074328
11	0.045364	0.881499	0.028819	0.828647	0.070036

12	0.051768	0.898322	0.026519	0.828541	0.077548
13	0.053498	0.892845	0.024959	0.823890	0.078968
14	0.055259	0.879286	0.035168	0.819345	0.077183
15	0.032883	0.890033	0.026312	0.851797	0.060038
16	0.034748	0.884769	0.033438	0.842706	0.060991
17	0.037836	0.893987	0.037776	0.851903	0.052032
18	0.047330	0.880696	0.024608	0.823890	0.076179
19	0.048211	0.893592	0.028384	0.819345	0.074328
20	0.045364	0.881499	0.028819	0.828647	0.070036
21	0.051768	0.898322	0.026519	0.828541	0.077548
22	0.053498	0.892845	0.024959	0.823890	0.078968
23	0.055259	0.879286	0.035168	0.819345	0.077183
24	0.032883	0.890033	0.026312	0.851797	0.060038
25	0.034748	0.884769	0.033438	0.842706	0.060991
26	0.037836	0.893987	0.037776	0.851903	0.052032

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & max depth,max samples,n estimators & accuracy D2 & accuracy D2 std & f1 D2 &
f1 D2 std & precision D2 & precision D2 std & recall D2 & recall D2 std \\
\midrule
0 & 15,0.5,100 & 0.958 & 0.014 & 0.845 & 0.054 & 0.863 & 0.031 & 0.829 & 0.076
\\
1 & 15,0.5,150 & 0.961 & 0.011 & 0.855 & 0.044 & 0.886 & 0.031 & 0.829 & 0.067
\\
2 & 15,0.5,200 & 0.959 & 0.012 & 0.848 & 0.048 & 0.876 & 0.019 & 0.824 & 0.076
\\
3 & 15,0.7,100 & 0.964 & 0.012 & 0.866 & 0.047 & 0.892 & 0.038 & 0.842 & 0.068
\\
4 & 15,0.7,150 & \textbf{0.965} & 0.011 & 0.868 & 0.043 & \textbf{0.909} & 0.028
& 0.833 & 0.068 \\
5 & 15,0.7,200 & 0.962 & 0.011 & 0.860 & 0.045 & 0.892 & 0.033 & 0.833 & 0.070
\\
6 & 15,1.0,100 & \textbf{0.965} & 0.010 & \textbf{0.873} & 0.039 & 0.901 & 0.018
& 0.847 & 0.060 \\
7 & 15,1.0,150 & \textbf{0.965} & 0.009 & \textbf{0.873} & 0.035 & 0.897 & 0.020
& \textbf{0.852} & \textbf{0.052} \\
8 & 15,1.0,200 & 0.963 & 0.010 & 0.864 & 0.038 & 0.887 & \textbf{0.015} & 0.843
& 0.061 \\
9 & 20,0.5,100 & 0.960 & 0.012 & 0.850 & 0.047 & 0.881 & 0.025 & 0.824 & 0.076
\\
10 & 20,0.5,150 & 0.961 & 0.012 & 0.854 & 0.048 & 0.894 & 0.028 & 0.819 & 0.074
\\
11 & 20,0.5,200 & 0.960 & 0.012 & 0.853 & 0.045 & 0.881 & 0.029 & 0.829 & 0.070
\\
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12 & 20,0.7,100 & 0.963 & 0.013 & 0.861 & 0.052 & 0.898 & 0.027 & 0.829 & 0.078
\\
13 & 20,0.7,150 & 0.962 & 0.013 & 0.856 & 0.053 & 0.893 & 0.025 & 0.824 & 0.079
\\
14 & 20,0.7,200 & 0.959 & 0.014 & 0.847 & 0.055 & 0.879 & 0.035 & 0.819 & 0.077
\\
15 & 20,1.0,100 & 0.964 & \textbf{0.008} & 0.869 & \textbf{0.033} & 0.890 &
0.026 & \textbf{0.852} & 0.060 \\
16 & 20,1.0,150 & 0.962 & 0.009 & 0.862 & 0.035 & 0.885 & 0.033 & 0.843 & 0.061
\\
17 & 20,1.0,200 & \textbf{0.965} & 0.010 & 0.872 & 0.038 & 0.894 & 0.038 &
\textbf{0.852} & \textbf{0.052} \\
18 & 25,0.5,100 & 0.960 & 0.012 & 0.850 & 0.047 & 0.881 & 0.025 & 0.824 & 0.076
\\
19 & 25,0.5,150 & 0.961 & 0.012 & 0.854 & 0.048 & 0.894 & 0.028 & 0.819 & 0.074
\\
20 & 25,0.5,200 & 0.960 & 0.012 & 0.853 & 0.045 & 0.881 & 0.029 & 0.829 & 0.070
\\
21 & 25,0.7,100 & 0.963 & 0.013 & 0.861 & 0.052 & 0.898 & 0.027 & 0.829 & 0.078
\\
22 & 25,0.7,150 & 0.962 & 0.013 & 0.856 & 0.053 & 0.893 & 0.025 & 0.824 & 0.079
\\
23 & 25,0.7,200 & 0.959 & 0.014 & 0.847 & 0.055 & 0.879 & 0.035 & 0.819 & 0.077
\\
24 & 25,1.0,100 & 0.964 & \textbf{0.008} & 0.869 & \textbf{0.033} & 0.890 &
0.026 & \textbf{0.852} & 0.060 \\
25 & 25,1.0,150 & 0.962 & 0.009 & 0.862 & 0.035 & 0.885 & 0.033 & 0.843 & 0.061
\\
26 & 25,1.0,200 & \textbf{0.965} & 0.010 & 0.872 & 0.038 & 0.894 & 0.038 &
\textbf{0.852} & \textbf{0.052} \\
\bottomrule
\end{tabular}
\end{table}
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```
   max_depth,max_samples,n_estimators  accuracy_D3  accuracy_D3_std     f1_D3  \
0                           15,0.5,100     0.963548         0.005556  0.867626
1                           15,0.5,150     0.963545         0.004754  0.868264
2                           15,0.5,200     0.964195         0.007125  0.869969
3                           15,0.7,100     0.962894         0.006018  0.866236
4                           15,0.7,150     0.964846         0.005587  0.874270
5                           15,0.7,200     0.966801         0.004287  0.879728
6                           15,1.0,100     0.970705         0.005815  0.894863
7                           15,1.0,150     0.971357         0.003777  0.896984
8                           15,1.0,200     0.970707         0.005423  0.895183
9                           20,0.5,100     0.963543         0.005593  0.868253
10                          20,0.5,150     0.964195         0.007698  0.871371
11                          20,0.5,200     0.966145         0.006046  0.877760
```

12	20,0.7,100	0.964848	0.006614	0.874253
13	20,0.7,150	0.964846	0.004767	0.873595
14	20,0.7,200	0.964195	0.005813	0.871217
15	20,1.0,100	0.970701	0.005057	0.893953
16	20,1.0,150	0.970703	0.005451	0.895157
17	20,1.0,200	0.970705	0.006169	0.895184
18	25,0.5,100	0.963543	0.005593	0.868253
19	25,0.5,150	0.964195	0.007698	0.871371
20	25,0.5,200	0.966145	0.006046	0.877760
21	25,0.7,100	0.964848	0.006614	0.874253
22	25,0.7,150	0.964846	0.004767	0.873595
23	25,0.7,200	0.964195	0.005813	0.871217
24	25,1.0,100	0.970701	0.005057	0.893953
25	25,1.0,150	0.971352	0.005612	0.897665
26	25,1.0,200	0.971355	0.005969	0.897687

	f1_D3_std	precision_D3	precision_D3_std	recall_D3	recall_D3_std
0	0.017521	0.908344	0.042483	0.831818	0.018182
1	0.013858	0.905727	0.048353	0.836364	0.026504
2	0.022412	0.913704	0.052288	0.831818	0.011134
3	0.019693	0.901036	0.051285	0.836364	0.026504
4	0.016888	0.902840	0.052155	0.850000	0.023177
5	0.012742	0.919950	0.048478	0.845455	0.026504
6	0.019890	0.925801	0.046511	0.868182	0.030151
7	0.010829	0.930538	0.044230	0.868182	0.026504
8	0.015667	0.926667	0.052281	0.868182	0.017008
9	0.018036	0.904173	0.041857	0.836364	0.017008
10	0.023721	0.907418	0.061244	0.840909	0.020328
11	0.019121	0.914322	0.044466	0.845455	0.017008
12	0.021932	0.902171	0.050824	0.850000	0.023177
13	0.014242	0.906866	0.051172	0.845455	0.026504
14	0.016413	0.907280	0.057880	0.840909	0.020328
15	0.014751	0.935864	0.053248	0.859091	0.033402
16	0.015121	0.927414	0.053042	0.868182	0.026504
17	0.018670	0.926325	0.050744	0.868182	0.017008
18	0.018036	0.904173	0.041857	0.836364	0.017008
19	0.023721	0.907418	0.061244	0.840909	0.020328
20	0.019121	0.914322	0.044466	0.845455	0.017008
21	0.021932	0.902171	0.050824	0.850000	0.023177
22	0.014242	0.906866	0.051172	0.845455	0.026504
23	0.016413	0.907280	0.057880	0.840909	0.020328
24	0.014751	0.935864	0.053248	0.859091	0.033402
25	0.016150	0.927837	0.052886	0.872727	0.030829
26	0.018152	0.926830	0.050355	0.872727	0.023177

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
```

```
\begin{tabular}{lllllllllll}
\toprule
 & max depth,max samples,n estimators & accuracy D3 & accuracy D3 std & f1 D3 &
f1 D3 std & precision D3 & precision D3 std & recall D3 & recall D3 std \\
\midrule
0 & 15,0.5,100 & 0.964 & 0.006 & 0.868 & 0.018 & 0.908 & \textbf{0.042} & 0.832
& 0.018 \\
1 & 15,0.5,150 & 0.964 & 0.005 & 0.868 & 0.014 & 0.906 & 0.048 & 0.836 & 0.027
\\
2 & 15,0.5,200 & 0.964 & 0.007 & 0.870 & 0.022 & 0.914 & 0.052 & 0.832 &
\textbf{0.011} \\
3 & 15,0.7,100 & 0.963 & 0.006 & 0.866 & 0.020 & 0.901 & 0.051 & 0.836 & 0.027
\\
4 & 15,0.7,150 & 0.965 & 0.006 & 0.874 & 0.017 & 0.903 & 0.052 & 0.850 & 0.023
\\
5 & 15,0.7,200 & 0.967 & \textbf{0.004} & 0.880 & 0.013 & 0.920 & 0.048 & 0.845
& 0.027 \\
6 & 15,1.0,100 & \textbf{0.971} & 0.006 & 0.895 & 0.020 & 0.926 & 0.047 & 0.868
& 0.030 \\
7 & 15,1.0,150 & \textbf{0.971} & \textbf{0.004} & 0.897 & \textbf{0.011} &
0.931 & 0.044 & 0.868 & 0.027 \\
8 & 15,1.0,200 & \textbf{0.971} & 0.005 & 0.895 & 0.016 & 0.927 & 0.052 & 0.868
& 0.017 \\
9 & 20,0.5,100 & 0.964 & 0.006 & 0.868 & 0.018 & 0.904 & \textbf{0.042} & 0.836
& 0.017 \\
10 & 20,0.5,150 & 0.964 & 0.008 & 0.871 & 0.024 & 0.907 & 0.061 & 0.841 & 0.020
\\
11 & 20,0.5,200 & 0.966 & 0.006 & 0.878 & 0.019 & 0.914 & 0.044 & 0.845 & 0.017
\\
12 & 20,0.7,100 & 0.965 & 0.007 & 0.874 & 0.022 & 0.902 & 0.051 & 0.850 & 0.023
\\
13 & 20,0.7,150 & 0.965 & 0.005 & 0.874 & 0.014 & 0.907 & 0.051 & 0.845 & 0.027
\\
14 & 20,0.7,200 & 0.964 & 0.006 & 0.871 & 0.016 & 0.907 & 0.058 & 0.841 & 0.020
\\
15 & 20,1.0,100 & \textbf{0.971} & 0.005 & 0.894 & 0.015 & \textbf{0.936} &
0.053 & 0.859 & 0.033 \\
16 & 20,1.0,150 & \textbf{0.971} & 0.005 & 0.895 & 0.015 & 0.927 & 0.053 & 0.868
& 0.027 \\
17 & 20,1.0,200 & \textbf{0.971} & 0.006 & 0.895 & 0.019 & 0.926 & 0.051 & 0.868
& 0.017 \\
18 & 25,0.5,100 & 0.964 & 0.006 & 0.868 & 0.018 & 0.904 & \textbf{0.042} & 0.836
& 0.017 \\
19 & 25,0.5,150 & 0.964 & 0.008 & 0.871 & 0.024 & 0.907 & 0.061 & 0.841 & 0.020
\\
20 & 25,0.5,200 & 0.966 & 0.006 & 0.878 & 0.019 & 0.914 & 0.044 & 0.845 & 0.017
\\
21 & 25,0.7,100 & 0.965 & 0.007 & 0.874 & 0.022 & 0.902 & 0.051 & 0.850 & 0.023
```

```
\\
22 & 25,0.7,150 & 0.965 & 0.005 & 0.874 & 0.014 & 0.907 & 0.051 & 0.845 & 0.027
\\
23 & 25,0.7,200 & 0.964 & 0.006 & 0.871 & 0.016 & 0.907 & 0.058 & 0.841 & 0.020
\\
24 & 25,1.0,100 & \textbf{0.971} & 0.005 & 0.894 & 0.015 & \textbf{0.936} &
0.053 & 0.859 & 0.033 \\
25 & 25,1.0,150 & \textbf{0.971} & 0.006 & \textbf{0.898} & 0.016 & 0.928 &
0.053 & \textbf{0.873} & 0.031 \\
26 & 25,1.0,200 & \textbf{0.971} & 0.006 & \textbf{0.898} & 0.018 & 0.927 &
0.050 & \textbf{0.873} & 0.023 \\
\bottomrule
\end{tabular}
\end{table}
```

	max_depth,max_samples,n_estimators	accuracy_D4	accuracy_D4_std	f1_D4	\
0	15,0.5,100	0.975259	0.014065	0.925087	
1	15,0.5,150	0.975913	0.013444	0.927174	
2	15,0.5,200	0.975908	0.013607	0.927395	
3	15,0.7,100	0.974612	0.012926	0.922065	
4	15,0.7,150	0.976564	0.014180	0.928554	
5	15,0.7,200	0.975913	0.015902	0.925949	
6	15,1.0,100	0.979168	0.011393	0.936586	
7	15,1.0,150	0.978521	0.011383	0.934892	
8	15,1.0,200	0.980469	0.012361	0.940072	
9	20,0.5,100	0.975913	0.015497	0.927737	
10	20,0.5,150	0.975915	0.013280	0.927170	
11	20,0.5,200	0.976564	0.011166	0.928653	
12	20,0.7,100	0.974608	0.015336	0.922332	
13	20,0.7,150	0.975259	0.017312	0.924832	
14	20,0.7,200	0.975259	0.017312	0.924832	
15	20,1.0,100	0.979817	0.010784	0.937932	
16	20,1.0,150	0.980469	0.009880	0.939946	
17	20,1.0,200	0.981120	0.011726	0.942080	
18	25,0.5,100	0.975913	0.015497	0.927737	
19	25,0.5,150	0.975915	0.013280	0.927170	
20	25,0.5,200	0.976564	0.011166	0.928653	
21	25,0.7,100	0.974608	0.015336	0.922332	
22	25,0.7,150	0.975911	0.016559	0.927089	
23	25,0.7,200	0.975259	0.017312	0.924832	
24	25,1.0,100	0.980469	0.009880	0.939746	
25	25,1.0,150	0.981120	0.010175	0.941922	
26	25,1.0,200	0.981770	0.011764	0.943944	

	f1_D4_std	precision_D4	precision_D4_std	recall_D4	recall_D4_std
0	0.041195	0.927242	0.061148	0.924314	0.029358
1	0.039824	0.922871	0.051656	0.932314	0.034769

2	0.039731	0.923570	0.056915	0.932235	0.027203
3	0.039601	0.929067	0.049704	0.916235	0.040933
4	0.042985	0.929546	0.051122	0.928235	0.041254
5	0.049066	0.932932	0.056300	0.920235	0.052246
6	0.034792	0.933008	0.036576	0.940235	0.033470
7	0.034223	0.930082	0.040824	0.940235	0.033470
8	0.037867	0.944069	0.040627	0.936235	0.036689
9	0.045074	0.924176	0.064044	0.932314	0.026997
10	0.039343	0.922796	0.050351	0.932314	0.034769
11	0.033280	0.929527	0.044509	0.928314	0.027044
12	0.046411	0.929692	0.061518	0.916235	0.040933
13	0.052218	0.926427	0.065170	0.924235	0.046387
14	0.052218	0.926427	0.065170	0.924235	0.046387
15	0.033444	0.939742	0.028872	0.936235	0.038809
16	0.030275	0.944058	0.031781	0.936235	0.034440
17	0.035674	0.948627	0.044444	0.936235	0.034440
18	0.045074	0.924176	0.064044	0.932314	0.026997
19	0.039343	0.922796	0.050351	0.932314	0.034769
20	0.033280	0.929527	0.044509	0.928314	0.027044
21	0.046411	0.929692	0.061518	0.916235	0.040933
22	0.049541	0.926976	0.064618	0.928235	0.041254
23	0.052218	0.926427	0.065170	0.924235	0.046387
24	0.030882	0.943484	0.024020	0.936235	0.038809
25	0.031077	0.948314	0.037114	0.936235	0.034440
26	0.035821	0.952392	0.044450	0.936235	0.034440

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & max depth,max samples,n estimators & accuracy D4 & accuracy D4 std & f1 D4 &
f1 D4 std & precision D4 & precision D4 std & recall D4 & recall D4 std \\
\midrule
0 & 15,0.5,100 & 0.975 & 0.014 & 0.925 & 0.041 & 0.927 & 0.061 & 0.924 & 0.029
\\
1 & 15,0.5,150 & 0.976 & 0.013 & 0.927 & 0.040 & 0.923 & 0.052 & 0.932 & 0.035
\\
2 & 15,0.5,200 & 0.976 & 0.014 & 0.927 & 0.040 & 0.924 & 0.057 & 0.932 &
\textbf{0.027} \\
3 & 15,0.7,100 & 0.975 & 0.013 & 0.922 & 0.040 & 0.929 & 0.050 & 0.916 & 0.041
\\
4 & 15,0.7,150 & 0.977 & 0.014 & 0.929 & 0.043 & 0.930 & 0.051 & 0.928 & 0.041
\\
5 & 15,0.7,200 & 0.976 & 0.016 & 0.926 & 0.049 & 0.933 & 0.056 & 0.920 & 0.052
\\
6 & 15,1.0,100 & 0.979 & 0.011 & 0.937 & 0.035 & 0.933 & 0.037 & \textbf{0.94} &
0.033 \\
```

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7 & 15,1.0,150 & 0.979 & 0.011 & 0.935 & 0.034 & 0.930 & 0.041 & \textbf{0.94} &
0.033 \\
8 & 15,1.0,200 & 0.980 & 0.012 & 0.940 & 0.038 & 0.944 & 0.041 & 0.936 & 0.037
\\
9 & 20,0.5,100 & 0.976 & 0.015 & 0.928 & 0.045 & 0.924 & 0.064 & 0.932 &
\textbf{0.027} \\
10 & 20,0.5,150 & 0.976 & 0.013 & 0.927 & 0.039 & 0.923 & 0.050 & 0.932 & 0.035
\\
11 & 20,0.5,200 & 0.977 & 0.011 & 0.929 & 0.033 & 0.930 & 0.045 & 0.928 &
\textbf{0.027} \\
12 & 20,0.7,100 & 0.975 & 0.015 & 0.922 & 0.046 & 0.930 & 0.062 & 0.916 & 0.041
\\
13 & 20,0.7,150 & 0.975 & 0.017 & 0.925 & 0.052 & 0.926 & 0.065 & 0.924 & 0.046
\\
14 & 20,0.7,200 & 0.975 & 0.017 & 0.925 & 0.052 & 0.926 & 0.065 & 0.924 & 0.046
\\
15 & 20,1.0,100 & 0.980 & 0.011 & 0.938 & 0.033 & 0.940 & 0.029 & 0.936 & 0.039
\\
16 & 20,1.0,150 & 0.980 & \textbf{0.01} & 0.940 & \textbf{0.03} & 0.944 & 0.032
& 0.936 & 0.034 \\
17 & 20,1.0,200 & 0.981 & 0.012 & 0.942 & 0.036 & 0.949 & 0.044 & 0.936 & 0.034
\\
18 & 25,0.5,100 & 0.976 & 0.015 & 0.928 & 0.045 & 0.924 & 0.064 & 0.932 &
\textbf{0.027} \\
19 & 25,0.5,150 & 0.976 & 0.013 & 0.927 & 0.039 & 0.923 & 0.050 & 0.932 & 0.035
\\
20 & 25,0.5,200 & 0.977 & 0.011 & 0.929 & 0.033 & 0.930 & 0.045 & 0.928 &
\textbf{0.027} \\
21 & 25,0.7,100 & 0.975 & 0.015 & 0.922 & 0.046 & 0.930 & 0.062 & 0.916 & 0.041
\\
22 & 25,0.7,150 & 0.976 & 0.017 & 0.927 & 0.050 & 0.927 & 0.065 & 0.928 & 0.041
\\
23 & 25,0.7,200 & 0.975 & 0.017 & 0.925 & 0.052 & 0.926 & 0.065 & 0.924 & 0.046
\\
24 & 25,1.0,100 & 0.980 & \textbf{0.01} & 0.940 & 0.031 & 0.943 & \textbf{0.024}
& 0.936 & 0.039 \\
25 & 25,1.0,150 & 0.981 & \textbf{0.01} & 0.942 & 0.031 & 0.948 & 0.037 & 0.936
& 0.034 \\
26 & 25,1.0,200 & \textbf{0.982} & 0.012 & \textbf{0.944} & 0.036 &
\textbf{0.952} & 0.044 & 0.936 & 0.034 \\
\bottomrule
\end{tabular}
\end{table}
```

```
   max_depth,max_samples,n_estimators  accuracy_D5  accuracy_D5_std     f1_D5  \
0                          15,0.5,100     0.984380         0.007527  0.944916
1                          15,0.5,150     0.985031         0.006690  0.947428
```

2	15,0.5,200	0.984380	0.007527	0.944916
3	15,0.7,100	0.984380	0.010372	0.945233
4	15,0.7,150	0.984380	0.010372	0.945233
5	15,0.7,200	0.984380	0.010372	0.945233
6	15,1.0,100	0.985029	0.008387	0.947119
7	15,1.0,150	0.986332	0.007808	0.951449
8	15,1.0,200	0.987635	0.007242	0.956207
9	20,0.5,100	0.985683	0.006999	0.949244
10	20,0.5,150	0.985031	0.006690	0.947428
11	20,0.5,200	0.985031	0.006690	0.947428
12	20,0.7,100	0.984380	0.008825	0.945025
13	20,0.7,150	0.984380	0.010372	0.945233
14	20,0.7,200	0.983728	0.009870	0.942987
15	20,1.0,100	0.985680	0.007304	0.949204
16	20,1.0,150	0.986983	0.006821	0.953962
17	20,1.0,200	0.987635	0.005956	0.956101
18	25,0.5,100	0.985683	0.006999	0.949244
19	25,0.5,150	0.985031	0.006690	0.947428
20	25,0.5,200	0.985031	0.006690	0.947428
21	25,0.7,100	0.984380	0.008825	0.945025
22	25,0.7,150	0.985031	0.009338	0.947270
23	25,0.7,200	0.983728	0.009870	0.942987
24	25,1.0,100	0.986332	0.006304	0.951717
25	25,1.0,150	0.986332	0.006304	0.951717
26	25,1.0,200	0.986983	0.005435	0.953855

	f1_D5_std	precision_D5	precision_D5_std	recall_D5	recall_D5_std
0	0.026420	0.916254	0.036650	0.976190	0.026082
1	0.023078	0.916759	0.036250	0.980952	0.017817
2	0.026420	0.916254	0.036650	0.976190	0.026082
3	0.035774	0.916847	0.048907	0.976190	0.026082
4	0.035774	0.916847	0.048907	0.976190	0.026082
5	0.035774	0.916847	0.048907	0.976190	0.026082
6	0.029371	0.920166	0.037896	0.976190	0.026082
7	0.027615	0.928347	0.035029	0.976190	0.026082
8	0.025228	0.933095	0.035995	0.980952	0.017817
9	0.024626	0.924435	0.034222	0.976190	0.026082
10	0.023078	0.916759	0.036250	0.980952	0.017817
11	0.023078	0.916759	0.036250	0.980952	0.017817
12	0.030729	0.916373	0.041384	0.976190	0.026082
13	0.035774	0.916847	0.048907	0.976190	0.026082
14	0.034036	0.912605	0.046303	0.976190	0.026082
15	0.025869	0.924105	0.032813	0.976190	0.026082
16	0.023757	0.928853	0.034433	0.980952	0.017817
17	0.020867	0.932893	0.030463	0.980952	0.017817
18	0.024626	0.924435	0.034222	0.976190	0.026082
19	0.023078	0.916759	0.036250	0.980952	0.017817
20	0.023078	0.916759	0.036250	0.980952	0.017817

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21   0.030729      0.916373          0.041384   0.976190       0.026082
22   0.032503      0.920615          0.043915   0.976190       0.026082
23   0.034036      0.912605          0.046303   0.976190       0.026082
24   0.021960      0.924610          0.032243   0.980952       0.017817
25   0.021960      0.924610          0.032243   0.980952       0.017817
26   0.019050      0.928650          0.028570   0.980952       0.017817
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & max depth,max samples,n estimators & accuracy D5 & accuracy D5 std & f1 D5 &
f1 D5 std & precision D5 & precision D5 std & recall D5 & recall D5 std \\
\midrule
0 & 15,0.5,100 & 0.984 & 0.008 & 0.945 & 0.026 & 0.916 & 0.037 & 0.976 & 0.026
\\
1 & 15,0.5,150 & 0.985 & 0.007 & 0.947 & 0.023 & 0.917 & 0.036 & \textbf{0.981}
& \textbf{0.018} \\
2 & 15,0.5,200 & 0.984 & 0.008 & 0.945 & 0.026 & 0.916 & 0.037 & 0.976 & 0.026
\\
3 & 15,0.7,100 & 0.984 & 0.010 & 0.945 & 0.036 & 0.917 & 0.049 & 0.976 & 0.026
\\
4 & 15,0.7,150 & 0.984 & 0.010 & 0.945 & 0.036 & 0.917 & 0.049 & 0.976 & 0.026
\\
5 & 15,0.7,200 & 0.984 & 0.010 & 0.945 & 0.036 & 0.917 & 0.049 & 0.976 & 0.026
\\
6 & 15,1.0,100 & 0.985 & 0.008 & 0.947 & 0.029 & 0.920 & 0.038 & 0.976 & 0.026
\\
7 & 15,1.0,150 & 0.986 & 0.008 & 0.951 & 0.028 & 0.928 & 0.035 & 0.976 & 0.026
\\
8 & 15,1.0,200 & \textbf{0.988} & 0.007 & \textbf{0.956} & 0.025 &
\textbf{0.933} & 0.036 & \textbf{0.981} & \textbf{0.018} \\
9 & 20,0.5,100 & 0.986 & 0.007 & 0.949 & 0.025 & 0.924 & 0.034 & 0.976 & 0.026
\\
10 & 20,0.5,150 & 0.985 & 0.007 & 0.947 & 0.023 & 0.917 & 0.036 & \textbf{0.981}
& \textbf{0.018} \\
11 & 20,0.5,200 & 0.985 & 0.007 & 0.947 & 0.023 & 0.917 & 0.036 & \textbf{0.981}
& \textbf{0.018} \\
12 & 20,0.7,100 & 0.984 & 0.009 & 0.945 & 0.031 & 0.916 & 0.041 & 0.976 & 0.026
\\
13 & 20,0.7,150 & 0.984 & 0.010 & 0.945 & 0.036 & 0.917 & 0.049 & 0.976 & 0.026
\\
14 & 20,0.7,200 & 0.984 & 0.010 & 0.943 & 0.034 & 0.913 & 0.046 & 0.976 & 0.026
\\
15 & 20,1.0,100 & 0.986 & 0.007 & 0.949 & 0.026 & 0.924 & 0.033 & 0.976 & 0.026
\\
16 & 20,1.0,150 & 0.987 & 0.007 & 0.954 & 0.024 & 0.929 & 0.034 & \textbf{0.981}
```

```
& \textbf{0.018} \\
17 & 20,1.0,200 & \textbf{0.988} & 0.006 & \textbf{0.956} & 0.021 &
\textbf{0.933} & 0.030 & \textbf{0.981} & \textbf{0.018} \\
18 & 25,0.5,100 & 0.986 & 0.007 & 0.949 & 0.025 & 0.924 & 0.034 & 0.976 & 0.026
\\
19 & 25,0.5,150 & 0.985 & 0.007 & 0.947 & 0.023 & 0.917 & 0.036 & \textbf{0.981}
& \textbf{0.018} \\
20 & 25,0.5,200 & 0.985 & 0.007 & 0.947 & 0.023 & 0.917 & 0.036 & \textbf{0.981}
& \textbf{0.018} \\
21 & 25,0.7,100 & 0.984 & 0.009 & 0.945 & 0.031 & 0.916 & 0.041 & 0.976 & 0.026
\\
22 & 25,0.7,150 & 0.985 & 0.009 & 0.947 & 0.033 & 0.921 & 0.044 & 0.976 & 0.026
\\
23 & 25,0.7,200 & 0.984 & 0.010 & 0.943 & 0.034 & 0.913 & 0.046 & 0.976 & 0.026
\\
24 & 25,1.0,100 & 0.986 & 0.006 & 0.952 & 0.022 & 0.925 & 0.032 & \textbf{0.981}
& \textbf{0.018} \\
25 & 25,1.0,150 & 0.986 & 0.006 & 0.952 & 0.022 & 0.925 & 0.032 & \textbf{0.981}
& \textbf{0.018} \\
26 & 25,1.0,200 & 0.987 & \textbf{0.005} & 0.954 & \textbf{0.019} & 0.929 &
\textbf{0.029} & \textbf{0.981} & \textbf{0.018} \\
\bottomrule
\end{tabular}
\end{table}
```

```
   max_depth,max_samples,n_estimators  accuracy_D6  accuracy_D6_std     f1_D6  \
0                           15,0.5,100     0.996093         0.003799  0.987796
1                           15,0.5,150     0.996093         0.003799  0.987796
2                           15,0.5,200     0.995444         0.003907  0.985776
3                           15,0.7,100     0.996093         0.003799  0.987796
4                           15,0.7,150     0.996745         0.002913  0.989775
5                           15,0.7,200     0.996745         0.002913  0.989775
6                           15,1.0,100     0.996747         0.002909  0.989775
7                           15,1.0,150     0.996747         0.002909  0.989775
8                           15,1.0,200     0.996095         0.003796  0.987796
9                           20,0.5,100     0.995444         0.003907  0.985776
10                          20,0.5,150     0.996093         0.003799  0.987796
11                          20,0.5,200     0.995444         0.003907  0.985776
12                          20,0.7,100     0.996745         0.002913  0.989775
13                          20,0.7,150     0.996745         0.002913  0.989775
14                          20,0.7,200     0.996745         0.002913  0.989775
15                          20,1.0,100     0.997396         0.002437  0.991795
16                          20,1.0,150     0.996745         0.002913  0.989775
17                          20,1.0,200     0.996745         0.002913  0.989775
18                          25,0.5,100     0.995444         0.003907  0.985776
19                          25,0.5,150     0.996093         0.003799  0.987796
20                          25,0.5,200     0.995444         0.003907  0.985776
```

21	25,0.7,100	0.996745	0.002913	0.989775	
22	25,0.7,150	0.996745	0.002913	0.989775	
23	25,0.7,200	0.996745	0.002913	0.989775	
24	25,1.0,100	0.997396	0.002437	0.991795	
25	25,1.0,150	0.996745	0.002913	0.989775	
26	25,1.0,200	0.996745	0.002913	0.989775	

	f1_D6_std	precision_D6	precision_D6_std	recall_D6	recall_D6_std
0	0.011801	0.980072	0.021483	0.995918	0.008163
1	0.011801	0.980072	0.021483	0.995918	0.008163
2	0.012163	0.976154	0.022950	0.995918	0.008163
3	0.011801	0.980072	0.021483	0.995918	0.008163
4	0.009127	0.983837	0.015012	0.995918	0.008163
5	0.009127	0.983837	0.015012	0.995918	0.008163
6	0.009127	0.984000	0.019596	0.995918	0.008163
7	0.009127	0.984000	0.019596	0.995918	0.008163
8	0.011801	0.980235	0.024928	0.995918	0.008163
9	0.012163	0.976154	0.022950	0.995918	0.008163
10	0.011801	0.980072	0.021483	0.995918	0.008163
11	0.012163	0.976154	0.022950	0.995918	0.008163
12	0.009127	0.983837	0.015012	0.995918	0.008163
13	0.009127	0.983837	0.015012	0.995918	0.008163
14	0.009127	0.983837	0.015012	0.995918	0.008163
15	0.007647	0.987918	0.016042	0.995918	0.008163
16	0.009127	0.983837	0.015012	0.995918	0.008163
17	0.009127	0.983837	0.015012	0.995918	0.008163
18	0.012163	0.976154	0.022950	0.995918	0.008163
19	0.011801	0.980072	0.021483	0.995918	0.008163
20	0.012163	0.976154	0.022950	0.995918	0.008163
21	0.009127	0.983837	0.015012	0.995918	0.008163
22	0.009127	0.983837	0.015012	0.995918	0.008163
23	0.009127	0.983837	0.015012	0.995918	0.008163
24	0.007647	0.987918	0.016042	0.995918	0.008163
25	0.009127	0.983837	0.015012	0.995918	0.008163
26	0.009127	0.983837	0.015012	0.995918	0.008163

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & max depth,max samples,n estimators & accuracy D6 & accuracy D6 std & f1 D6 &
f1 D6 std & precision D6 & precision D6 std & recall D6 & recall D6 std \\
\midrule
0 & 15,0.5,100 & 0.996 & 0.004 & 0.988 & 0.012 & 0.980 & 0.021 & \textbf{0.996}
& \textbf{0.008} \\
1 & 15,0.5,150 & 0.996 & 0.004 & 0.988 & 0.012 & 0.980 & 0.021 & \textbf{0.996}
& \textbf{0.008} \\
```

```
2 & 15,0.5,200 & 0.995 & 0.004 & 0.986 & 0.012 & 0.976 & 0.023 & \textbf{0.996}
& \textbf{0.008} \\
3 & 15,0.7,100 & 0.996 & 0.004 & 0.988 & 0.012 & 0.980 & 0.021 & \textbf{0.996}
& \textbf{0.008} \\
4 & 15,0.7,150 & \textbf{0.997} & 0.003 & 0.990 & 0.009 & 0.984 & \textbf{0.015}
& \textbf{0.996} & \textbf{0.008} \\
5 & 15,0.7,200 & \textbf{0.997} & 0.003 & 0.990 & 0.009 & 0.984 & \textbf{0.015}
& \textbf{0.996} & \textbf{0.008} \\
6 & 15,1.0,100 & \textbf{0.997} & 0.003 & 0.990 & 0.009 & 0.984 & 0.020 &
\textbf{0.996} & \textbf{0.008} \\
7 & 15,1.0,150 & \textbf{0.997} & 0.003 & 0.990 & 0.009 & 0.984 & 0.020 &
\textbf{0.996} & \textbf{0.008} \\
8 & 15,1.0,200 & 0.996 & 0.004 & 0.988 & 0.012 & 0.980 & 0.025 & \textbf{0.996}
& \textbf{0.008} \\
9 & 20,0.5,100 & 0.995 & 0.004 & 0.986 & 0.012 & 0.976 & 0.023 & \textbf{0.996}
& \textbf{0.008} \\
10 & 20,0.5,150 & 0.996 & 0.004 & 0.988 & 0.012 & 0.980 & 0.021 & \textbf{0.996}
& \textbf{0.008} \\
11 & 20,0.5,200 & 0.995 & 0.004 & 0.986 & 0.012 & 0.976 & 0.023 & \textbf{0.996}
& \textbf{0.008} \\
12 & 20,0.7,100 & \textbf{0.997} & 0.003 & 0.990 & 0.009 & 0.984 &
\textbf{0.015} & \textbf{0.996} & \textbf{0.008} \\
13 & 20,0.7,150 & \textbf{0.997} & 0.003 & 0.990 & 0.009 & 0.984 &
\textbf{0.015} & \textbf{0.996} & \textbf{0.008} \\
14 & 20,0.7,200 & \textbf{0.997} & 0.003 & 0.990 & 0.009 & 0.984 &
\textbf{0.015} & \textbf{0.996} & \textbf{0.008} \\
15 & 20,1.0,100 & \textbf{0.997} & \textbf{0.002} & \textbf{0.992} &
\textbf{0.008} & \textbf{0.988} & 0.016 & \textbf{0.996} & \textbf{0.008} \\
16 & 20,1.0,150 & \textbf{0.997} & 0.003 & 0.990 & 0.009 & 0.984 &
\textbf{0.015} & \textbf{0.996} & \textbf{0.008} \\
17 & 20,1.0,200 & \textbf{0.997} & 0.003 & 0.990 & 0.009 & 0.984 &
\textbf{0.015} & \textbf{0.996} & \textbf{0.008} \\
18 & 25,0.5,100 & 0.995 & 0.004 & 0.986 & 0.012 & 0.976 & 0.023 & \textbf{0.996}
& \textbf{0.008} \\
19 & 25,0.5,150 & 0.996 & 0.004 & 0.988 & 0.012 & 0.980 & 0.021 & \textbf{0.996}
& \textbf{0.008} \\
20 & 25,0.5,200 & 0.995 & 0.004 & 0.986 & 0.012 & 0.976 & 0.023 & \textbf{0.996}
& \textbf{0.008} \\
21 & 25,0.7,100 & \textbf{0.997} & 0.003 & 0.990 & 0.009 & 0.984 &
\textbf{0.015} & \textbf{0.996} & \textbf{0.008} \\
22 & 25,0.7,150 & \textbf{0.997} & 0.003 & 0.990 & 0.009 & 0.984 &
\textbf{0.015} & \textbf{0.996} & \textbf{0.008} \\
23 & 25,0.7,200 & \textbf{0.997} & 0.003 & 0.990 & 0.009 & 0.984 &
\textbf{0.015} & \textbf{0.996} & \textbf{0.008} \\
24 & 25,1.0,100 & \textbf{0.997} & \textbf{0.002} & \textbf{0.992} &
\textbf{0.008} & \textbf{0.988} & 0.016 & \textbf{0.996} & \textbf{0.008} \\
25 & 25,1.0,150 & \textbf{0.997} & 0.003 & 0.990 & 0.009 & 0.984 &
\textbf{0.015} & \textbf{0.996} & \textbf{0.008} \\
```

```
26 & 25,1.0,200 & \textbf{0.997} & 0.003 & 0.990 & 0.009 & 0.984 &
\textbf{0.015} & \textbf{0.996} & \textbf{0.008} \\
\bottomrule
\end{tabular}
\end{table}
```

[ ]:
```
# Initialize a RandomForestClassifier
from sklearn.ensemble import ExtraTreesClassifier


clf = ExtraTreesClassifier(random_state=RANDOM_STATE)


# Define the parameter grid
param_grid = {
    'n_estimators': [100, 150, 200],
    'max_depth': [15, 20, 25],
    'max_samples': [0.5, 0.7, 1.0],
    'bootstrap': [True]
}
X, y = prepare_dataset()
grid_search, best_params = find_best_params(clf, param_grid, X, y, RANDOM_STATE)
```

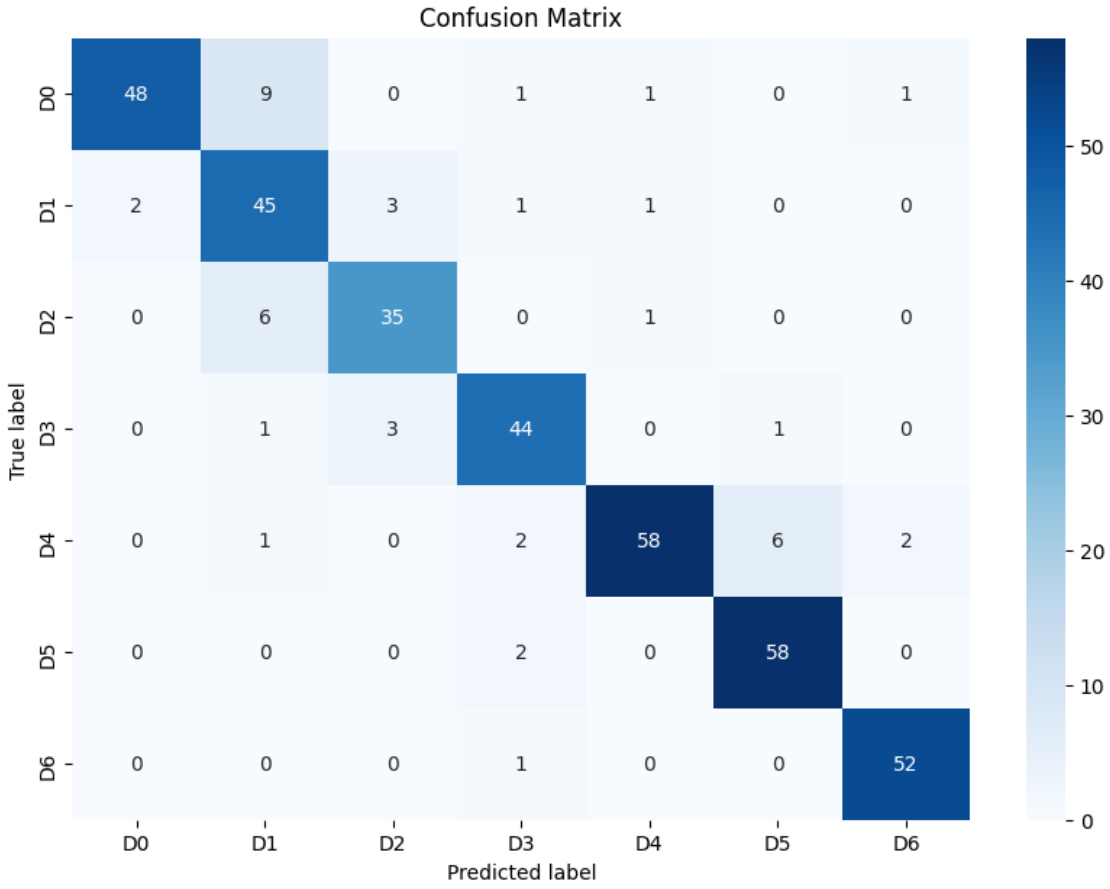
```
Features removed: {'Smoker', 'Calorie_monitoring'}
Features removed: {'Sedentary_hours_daily', 'Est_avg_calorie_intake'}
Best parameters found:  {'bootstrap': True, 'max_depth': 25, 'max_samples': 1.0,
'n_estimators': 150}
```

[ ]:
```
best_clf = ExtraTreesClassifier(**best_params, random_state=RANDOM_STATE)
accuracy, f1, precision, recall, dfs = evaluate_my_model(best_clf, grid_search,␣
 ↪X, y, RANDOM_STATE)
```

```
Model: ExtraTreesClassifier
Index(['mean_fit_time', 'std_fit_time', 'mean_score_time', 'std_score_time',
       'param_bootstrap', 'param_max_depth', 'param_max_samples',
       'param_n_estimators', 'params', 'split0_test_accuracy',
       …
       'std_test_recall_D5', 'rank_test_recall_D5', 'split0_test_recall_D6',
       'split1_test_recall_D6', 'split2_test_recall_D6',
       'split3_test_recall_D6', 'split4_test_recall_D6', 'mean_test_recall_D6',
       'std_test_recall_D6', 'rank_test_recall_D6'],
      dtype='object', length=265)
              precision    recall  f1-score   support

           D0       0.96      0.80      0.87        60
           D1       0.73      0.87      0.79        52
           D2       0.85      0.83      0.84        42
```

D3	0.86	0.90	0.88	49
D4	0.95	0.84	0.89	69
D5	0.89	0.97	0.93	60
D6	0.95	0.98	0.96	53
accuracy			0.88	385
macro avg	0.88	0.88	0.88	385
weighted avg	0.89	0.88	0.88	385



[ ]:
```
print(f"Accuracy: {accuracy}")
print(f"F1 Score: {f1}")
print(f"Precision: {precision}")
print(f"Recall: {recall}")
print(grid_search.best_index_)
for df in dfs:
    # Replace the dictionary values with list
    display(df)
    pd_to_latex(df)
```

```
Accuracy: 0.8831168831168831
F1 Score: 0.8837512272619208
Precision: 0.8901927627246221
Recall: 0.8831168831168831
25
```

	bootstrap,max_depth,max_samples,n_estimators	accuracy_D0	accuracy_D0_std	\
0	True,15,0.5,100	0.983077	0.003776	
1	True,15,0.5,150	0.985680	0.003302	
2	True,15,0.5,200	0.987635	0.004300	
3	True,15,0.7,100	0.985678	0.005289	
4	True,15,0.7,150	0.985027	0.006039	
5	True,15,0.7,200	0.985678	0.004414	
6	True,15,1.0,100	0.987633	0.005204	
7	True,15,1.0,150	0.986332	0.005197	
8	True,15,1.0,200	0.985678	0.004414	
9	True,20,0.5,100	0.983728	0.003541	
10	True,20,0.5,150	0.986332	0.003168	
11	True,20,0.5,200	0.985031	0.004392	
12	True,20,0.7,100	0.985678	0.005676	
13	True,20,0.7,150	0.985678	0.005289	
14	True,20,0.7,200	0.985678	0.004414	
15	True,20,1.0,100	0.986983	0.004100	
16	True,20,1.0,150	0.986983	0.005813	
17	True,20,1.0,200	0.986983	0.005813	
18	True,25,0.5,100	0.983728	0.003541	
19	True,25,0.5,150	0.985031	0.003879	
20	True,25,0.5,200	0.985031	0.004392	
21	True,25,0.7,100	0.985027	0.005290	
22	True,25,0.7,150	0.986330	0.004782	
23	True,25,0.7,200	0.985678	0.004414	
24	True,25,1.0,100	0.986983	0.004100	
25	True,25,1.0,150	0.985680	0.005280	
26	True,25,1.0,200	0.988286	0.005274	

	f1_D0	f1_D0_std	precision_D0	precision_D0_std	recall_D0	\
0	0.930708	0.016306	0.921863	0.020479	0.941252	
1	0.941525	0.013587	0.932564	0.024308	0.951920	
2	0.949107	0.017793	0.947159	0.022189	0.951920	
3	0.940890	0.021720	0.941625	0.029571	0.941110	
4	0.938440	0.024565	0.936789	0.034462	0.941110	
5	0.940536	0.018342	0.946064	0.023366	0.935704	
6	0.948890	0.021193	0.952151	0.029227	0.946515	
7	0.942682	0.022058	0.956130	0.021166	0.930441	
8	0.940536	0.018342	0.946064	0.023366	0.935704	
9	0.933795	0.015830	0.917802	0.016231	0.952063	
10	0.943754	0.014400	0.937437	0.019059	0.952063	
11	0.938498	0.018925	0.931850	0.018177	0.946657	

```
12  0.941242   0.023182      0.937301          0.033887   0.946515
13  0.941317   0.021301      0.937328          0.033814   0.946515
14  0.941247   0.017941      0.937193          0.029976   0.946515
15  0.945781   0.017772      0.951720          0.018733   0.941252
16  0.945495   0.024689      0.956280          0.021282   0.935846
17  0.945780   0.024700      0.951706          0.025123   0.941252
18  0.933795   0.015830      0.917802          0.016231   0.952063
19  0.938432   0.017170      0.931607          0.010492   0.946657
20  0.938498   0.018925      0.931850          0.018177   0.946657
21  0.938370   0.021707      0.936654          0.030702   0.941110
22  0.943773   0.019451      0.942052          0.029254   0.946515
23  0.941247   0.017941      0.937193          0.029976   0.946515
24  0.945781   0.017772      0.951720          0.018733   0.941252
25  0.940159   0.022261      0.951151          0.025467   0.930441
26  0.951189   0.022527      0.956991          0.020396   0.946657
```

```
    recall_D0_std
0        0.038369
1        0.030448
2        0.030448
3        0.030649
4        0.030649
5        0.026679
6        0.028572
7        0.035409
8        0.026679
9        0.041821
10       0.041821
11       0.040494
12       0.033294
13       0.028572
14       0.028572
15       0.038369
16       0.039221
17       0.042004
18       0.041821
19       0.040494
20       0.040494
21       0.030649
22       0.028572
23       0.028572
24       0.038369
25       0.035409
26       0.040494
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
```

```
\begin{tabular}{lllllllllll}
\toprule
 & bootstrap,max depth,max samples,n estimators & accuracy D0 & accuracy D0 std
& f1 D0 & f1 D0 std & precision D0 & precision D0 std & recall D0 & recall D0
std \\
\midrule
0 & True,15,0.5,100 & 0.983 & 0.004 & 0.931 & 0.016 & 0.922 & 0.020 & 0.941 &
0.038 \\
1 & True,15,0.5,150 & 0.986 & \textbf{0.003} & 0.942 & \textbf{0.014} & 0.933 &
0.024 & \textbf{0.952} & 0.030 \\
2 & True,15,0.5,200 & \textbf{0.988} & 0.004 & 0.949 & 0.018 & 0.947 & 0.022 &
\textbf{0.952} & 0.030 \\
3 & True,15,0.7,100 & 0.986 & 0.005 & 0.941 & 0.022 & 0.942 & 0.030 & 0.941 &
0.031 \\
4 & True,15,0.7,150 & 0.985 & 0.006 & 0.938 & 0.025 & 0.937 & 0.034 & 0.941 &
0.031 \\
5 & True,15,0.7,200 & 0.986 & 0.004 & 0.941 & 0.018 & 0.946 & 0.023 & 0.936 &
\textbf{0.027} \\
6 & True,15,1.0,100 & \textbf{0.988} & 0.005 & 0.949 & 0.021 & 0.952 & 0.029 &
0.947 & 0.029 \\
7 & True,15,1.0,150 & 0.986 & 0.005 & 0.943 & 0.022 & 0.956 & 0.021 & 0.930 &
0.035 \\
8 & True,15,1.0,200 & 0.986 & 0.004 & 0.941 & 0.018 & 0.946 & 0.023 & 0.936 &
\textbf{0.027} \\
9 & True,20,0.5,100 & 0.984 & 0.004 & 0.934 & 0.016 & 0.918 & 0.016 &
\textbf{0.952} & 0.042 \\
10 & True,20,0.5,150 & 0.986 & \textbf{0.003} & 0.944 & \textbf{0.014} & 0.937 &
0.019 & \textbf{0.952} & 0.042 \\
11 & True,20,0.5,200 & 0.985 & 0.004 & 0.938 & 0.019 & 0.932 & 0.018 & 0.947 &
0.040 \\
12 & True,20,0.7,100 & 0.986 & 0.006 & 0.941 & 0.023 & 0.937 & 0.034 & 0.947 &
0.033 \\
13 & True,20,0.7,150 & 0.986 & 0.005 & 0.941 & 0.021 & 0.937 & 0.034 & 0.947 &
0.029 \\
14 & True,20,0.7,200 & 0.986 & 0.004 & 0.941 & 0.018 & 0.937 & 0.030 & 0.947 &
0.029 \\
15 & True,20,1.0,100 & 0.987 & 0.004 & 0.946 & 0.018 & 0.952 & 0.019 & 0.941 &
0.038 \\
16 & True,20,1.0,150 & 0.987 & 0.006 & 0.945 & 0.025 & 0.956 & 0.021 & 0.936 &
0.039 \\
17 & True,20,1.0,200 & 0.987 & 0.006 & 0.946 & 0.025 & 0.952 & 0.025 & 0.941 &
0.042 \\
18 & True,25,0.5,100 & 0.984 & 0.004 & 0.934 & 0.016 & 0.918 & 0.016 &
\textbf{0.952} & 0.042 \\
19 & True,25,0.5,150 & 0.985 & 0.004 & 0.938 & 0.017 & 0.932 & \textbf{0.01} &
0.947 & 0.040 \\
20 & True,25,0.5,200 & 0.985 & 0.004 & 0.938 & 0.019 & 0.932 & 0.018 & 0.947 &
0.040 \\
```

```
21 & True,25,0.7,100 & 0.985 & 0.005 & 0.938 & 0.022 & 0.937 & 0.031 & 0.941 &
0.031 \\
22 & True,25,0.7,150 & 0.986 & 0.005 & 0.944 & 0.019 & 0.942 & 0.029 & 0.947 &
0.029 \\
23 & True,25,0.7,200 & 0.986 & 0.004 & 0.941 & 0.018 & 0.937 & 0.030 & 0.947 &
0.029 \\
24 & True,25,1.0,100 & 0.987 & 0.004 & 0.946 & 0.018 & 0.952 & 0.019 & 0.941 &
0.038 \\
25 & True,25,1.0,150 & 0.986 & 0.005 & 0.940 & 0.022 & 0.951 & 0.025 & 0.930 &
0.035 \\
26 & True,25,1.0,200 & \textbf{0.988} & 0.005 & \textbf{0.951} & 0.023 &
\textbf{0.957} & 0.020 & 0.947 & 0.040 \\
\bottomrule
\end{tabular}
\end{table}
```

	bootstrap,max_depth,max_samples,n_estimators	accuracy_D1	accuracy_D1_std	\
0	True,15,0.5,100	0.940095	0.012666	
1	True,15,0.5,150	0.940750	0.012618	
2	True,15,0.5,200	0.944657	0.015430	
3	True,15,0.7,100	0.942699	0.013158	
4	True,15,0.7,150	0.942694	0.016588	
5	True,15,0.7,200	0.941396	0.014155	
6	True,15,1.0,100	0.943997	0.016172	
7	True,15,1.0,150	0.944651	0.014002	
8	True,15,1.0,200	0.945298	0.015773	
9	True,20,0.5,100	0.936840	0.009840	
10	True,20,0.5,150	0.942047	0.012292	
11	True,20,0.5,200	0.939445	0.011429	
12	True,20,0.7,100	0.939443	0.015528	
13	True,20,0.7,150	0.941393	0.015449	
14	True,20,0.7,200	0.941396	0.017627	
15	True,20,1.0,100	0.943354	0.012139	
16	True,20,1.0,150	0.945958	0.011784	
17	True,20,1.0,200	0.944655	0.013052	
18	True,25,0.5,100	0.937489	0.011588	
19	True,25,0.5,150	0.940095	0.010665	
20	True,25,0.5,200	0.940093	0.013482	
21	True,25,0.7,100	0.939443	0.015932	
22	True,25,0.7,150	0.941393	0.016382	
23	True,25,0.7,200	0.940093	0.017091	
24	True,25,1.0,100	0.944657	0.010321	
25	True,25,1.0,150	0.947908	0.013844	
26	True,25,1.0,200	0.945954	0.012663	

	f1_D1	f1_D1_std	precision_D1	precision_D1_std	recall_D1	\
0	0.783700	0.046753	0.773176	0.043178	0.795238	

1	0.789620	0.044874	0.766900	0.041726	0.814286
2	0.804850	0.052340	0.778970	0.055359	0.833333
3	0.799211	0.044014	0.769298	0.048555	0.833333
4	0.800702	0.052859	0.769103	0.064199	0.838095
5	0.795188	0.048487	0.763244	0.050970	0.833333
6	0.802315	0.057752	0.774232	0.052424	0.833333
7	0.805966	0.049530	0.773697	0.046254	0.842857
8	0.805633	0.058364	0.782085	0.053845	0.833333
9	0.775889	0.035196	0.753232	0.032398	0.800000
10	0.796450	0.041809	0.767582	0.044602	0.828571
11	0.782218	0.040093	0.770284	0.041951	0.795238
12	0.785716	0.055428	0.760319	0.051239	0.814286
13	0.793071	0.055285	0.766425	0.052817	0.823810
14	0.795287	0.060070	0.762091	0.058525	0.833333
15	0.804965	0.041952	0.760759	0.041931	0.857143
16	0.812953	0.041533	0.771711	0.040628	0.861905
17	0.807530	0.046060	0.769425	0.043282	0.852381
18	0.777920	0.040280	0.757071	0.041884	0.800000
19	0.790267	0.035104	0.760300	0.043059	0.823810
20	0.786358	0.045882	0.769704	0.051938	0.804762
21	0.785814	0.056451	0.760142	0.051924	0.814286
22	0.793223	0.057834	0.766680	0.056686	0.823810
23	0.790392	0.059380	0.757664	0.055784	0.828571
24	0.808193	0.038078	0.766895	0.033248	0.857143
25	0.817752	0.048753	0.783677	0.046619	0.857143
26	0.810550	0.044741	0.778401	0.043718	0.847619

	recall_D1_std
0	0.055533
1	0.053026
2	0.054294
3	0.052164
4	0.057143
5	0.067344
6	0.069007
7	0.064944
8	0.078246
9	0.038686
10	0.046168
11	0.044160
12	0.069661
13	0.071587
14	0.072218
15	0.062088
16	0.064594
17	0.068014
18	0.038686
19	0.035635

```
20       0.046168
21       0.068014
22       0.071587
23       0.077372
24       0.065638
25       0.065638
26       0.061353
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & bootstrap,max depth,max samples,n estimators & accuracy D1 & accuracy D1 std
& f1 D1 & f1 D1 std & precision D1 & precision D1 std & recall D1 & recall D1
std \\
\midrule
0 & True,15,0.5,100 & 0.940 & 0.013 & 0.784 & 0.047 & 0.773 & 0.043 & 0.795 &
0.056 \\
1 & True,15,0.5,150 & 0.941 & 0.013 & 0.790 & 0.045 & 0.767 & 0.042 & 0.814 &
0.053 \\
2 & True,15,0.5,200 & 0.945 & 0.015 & 0.805 & 0.052 & 0.779 & 0.055 & 0.833 &
0.054 \\
3 & True,15,0.7,100 & 0.943 & 0.013 & 0.799 & 0.044 & 0.769 & 0.049 & 0.833 &
0.052 \\
4 & True,15,0.7,150 & 0.943 & 0.017 & 0.801 & 0.053 & 0.769 & 0.064 & 0.838 &
0.057 \\
5 & True,15,0.7,200 & 0.941 & 0.014 & 0.795 & 0.048 & 0.763 & 0.051 & 0.833 &
0.067 \\
6 & True,15,1.0,100 & 0.944 & 0.016 & 0.802 & 0.058 & 0.774 & 0.052 & 0.833 &
0.069 \\
7 & True,15,1.0,150 & 0.945 & 0.014 & 0.806 & 0.050 & 0.774 & 0.046 & 0.843 &
0.065 \\
8 & True,15,1.0,200 & 0.945 & 0.016 & 0.806 & 0.058 & 0.782 & 0.054 & 0.833 &
0.078 \\
9 & True,20,0.5,100 & 0.937 & \textbf{0.01} & 0.776 & \textbf{0.035} & 0.753 &
\textbf{0.032} & 0.800 & 0.039 \\
10 & True,20,0.5,150 & 0.942 & 0.012 & 0.796 & 0.042 & 0.768 & 0.045 & 0.829 &
0.046 \\
11 & True,20,0.5,200 & 0.939 & 0.011 & 0.782 & 0.040 & 0.770 & 0.042 & 0.795 &
0.044 \\
12 & True,20,0.7,100 & 0.939 & 0.016 & 0.786 & 0.055 & 0.760 & 0.051 & 0.814 &
0.070 \\
13 & True,20,0.7,150 & 0.941 & 0.015 & 0.793 & 0.055 & 0.766 & 0.053 & 0.824 &
0.072 \\
14 & True,20,0.7,200 & 0.941 & 0.018 & 0.795 & 0.060 & 0.762 & 0.059 & 0.833 &
0.072 \\
15 & True,20,1.0,100 & 0.943 & 0.012 & 0.805 & 0.042 & 0.761 & 0.042 & 0.857 &
```

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0.062 \\
16 & True,20,1.0,150 & 0.946 & 0.012 & 0.813 & 0.042 & 0.772 & 0.041 &
\textbf{0.862} & 0.065 \\
17 & True,20,1.0,200 & 0.945 & 0.013 & 0.808 & 0.046 & 0.769 & 0.043 & 0.852 &
0.068 \\
18 & True,25,0.5,100 & 0.937 & 0.012 & 0.778 & 0.040 & 0.757 & 0.042 & 0.800 &
0.039 \\
19 & True,25,0.5,150 & 0.940 & 0.011 & 0.790 & \textbf{0.035} & 0.760 & 0.043 &
0.824 & \textbf{0.036} \\
20 & True,25,0.5,200 & 0.940 & 0.013 & 0.786 & 0.046 & 0.770 & 0.052 & 0.805 &
0.046 \\
21 & True,25,0.7,100 & 0.939 & 0.016 & 0.786 & 0.056 & 0.760 & 0.052 & 0.814 &
0.068 \\
22 & True,25,0.7,150 & 0.941 & 0.016 & 0.793 & 0.058 & 0.767 & 0.057 & 0.824 &
0.072 \\
23 & True,25,0.7,200 & 0.940 & 0.017 & 0.790 & 0.059 & 0.758 & 0.056 & 0.829 &
0.077 \\
24 & True,25,1.0,100 & 0.945 & \textbf{0.01} & 0.808 & 0.038 & 0.767 & 0.033 &
0.857 & 0.066 \\
25 & True,25,1.0,150 & \textbf{0.948} & 0.014 & \textbf{0.818} & 0.049 &
\textbf{0.784} & 0.047 & 0.857 & 0.066 \\
26 & True,25,1.0,200 & 0.946 & 0.013 & 0.811 & 0.045 & 0.778 & 0.044 & 0.848 &
0.061 \\
\bottomrule
\end{tabular}
\end{table}
```

	bootstrap,max_depth,max_samples,n_estimators	accuracy_D2	accuracy_D2_std	\
0	True,15,0.5,100	0.952470	0.017071	
1	True,15,0.5,150	0.953778	0.018922	
2	True,15,0.5,200	0.953778	0.015603	
3	True,15,0.7,100	0.960940	0.010696	
4	True,15,0.7,150	0.960286	0.012259	
5	True,15,0.7,200	0.956379	0.014511	
6	True,15,1.0,100	0.957680	0.014573	
7	True,15,1.0,150	0.958981	0.012809	
8	True,15,1.0,200	0.958981	0.014370	
9	True,20,0.5,100	0.951827	0.018110	
10	True,20,0.5,150	0.953128	0.015759	
11	True,20,0.5,200	0.953128	0.013899	
12	True,20,0.7,100	0.960286	0.016788	
13	True,20,0.7,150	0.959635	0.013290	
14	True,20,0.7,200	0.960937	0.012866	
15	True,20,1.0,100	0.957680	0.014573	
16	True,20,1.0,150	0.957680	0.016227	
17	True,20,1.0,200	0.958334	0.014912	
18	True,25,0.5,100	0.952477	0.016677	

19	True,25,0.5,150	0.953780	0.014900
20	True,25,0.5,200	0.953778	0.014178
21	True,25,0.7,100	0.958332	0.017042
22	True,25,0.7,150	0.958332	0.014484
23	True,25,0.7,200	0.960937	0.012531
24	True,25,1.0,100	0.957680	0.014573
25	True,25,1.0,150	0.958979	0.015782
26	True,25,1.0,200	0.958329	0.014043

	f1_D2	f1_D2_std	precision_D2	precision_D2_std	recall_D2	\
0	0.825262	0.064762	0.847543	0.049983	0.805603	
1	0.828685	0.071133	0.859589	0.061329	0.800951	
2	0.827181	0.060978	0.862911	0.041646	0.796300	
3	0.853567	0.042990	0.894826	0.031544	0.819345	
4	0.850064	0.051164	0.892750	0.020588	0.814588	
5	0.837936	0.055785	0.870984	0.044347	0.810042	
6	0.845288	0.054809	0.864401	0.045124	0.828647	
7	0.847997	0.051117	0.875709	0.025778	0.823996	
8	0.848304	0.055420	0.876426	0.040416	0.823996	
9	0.817947	0.071885	0.860113	0.048901	0.782241	
10	0.824724	0.063127	0.859486	0.044690	0.796195	
11	0.826905	0.054411	0.852253	0.033227	0.805497	
12	0.850732	0.064730	0.893057	0.053850	0.814588	
13	0.848280	0.053669	0.889036	0.033141	0.814588	
14	0.852298	0.052612	0.897954	0.029625	0.814588	
15	0.842531	0.055524	0.878773	0.047641	0.810148	
16	0.842794	0.062073	0.874543	0.049888	0.814693	
17	0.843612	0.058854	0.882437	0.037618	0.810042	
18	0.820820	0.066737	0.861991	0.047499	0.786892	
19	0.826606	0.060483	0.864089	0.039818	0.796195	
20	0.827635	0.057151	0.859304	0.028157	0.800846	
21	0.844641	0.065076	0.879669	0.055348	0.814588	
22	0.844292	0.057514	0.879577	0.038652	0.814588	
23	0.853258	0.050565	0.893625	0.027739	0.819239	
24	0.843235	0.055599	0.875257	0.048210	0.814693	
25	0.849423	0.059348	0.872303	0.049339	0.828647	
26	0.846022	0.055336	0.871157	0.033513	0.823996	

	recall_D2_std
0	0.083842
1	0.083895
2	0.084972
3	0.074328
4	0.084850
5	0.080023
6	0.073060
7	0.077419
8	0.077419

```
9        0.097417
10       0.092509
11       0.081476
12       0.084850
13       0.084850
14       0.084850
15       0.068119
16       0.079437
17       0.082682
18       0.096034
19       0.092509
20       0.086669
21       0.084850
22       0.084850
23       0.080093
24       0.069253
25       0.073060
26       0.078803
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & bootstrap,max depth,max samples,n estimators & accuracy D2 & accuracy D2 std
& f1 D2 & f1 D2 std & precision D2 & precision D2 std & recall D2 & recall D2
std \\
\midrule
0 & True,15,0.5,100 & 0.952 & 0.017 & 0.825 & 0.065 & 0.848 & 0.050 & 0.806 &
0.084 \\
1 & True,15,0.5,150 & 0.954 & 0.019 & 0.829 & 0.071 & 0.860 & 0.061 & 0.801 &
0.084 \\
2 & True,15,0.5,200 & 0.954 & 0.016 & 0.827 & 0.061 & 0.863 & 0.042 & 0.796 &
0.085 \\
3 & True,15,0.7,100 & \textbf{0.961} & \textbf{0.011} & \textbf{0.854} &
\textbf{0.043} & 0.895 & 0.032 & 0.819 & 0.074 \\
4 & True,15,0.7,150 & 0.960 & 0.012 & 0.850 & 0.051 & 0.893 & \textbf{0.021} &
0.815 & 0.085 \\
5 & True,15,0.7,200 & 0.956 & 0.015 & 0.838 & 0.056 & 0.871 & 0.044 & 0.810 &
0.080 \\
6 & True,15,1.0,100 & 0.958 & 0.015 & 0.845 & 0.055 & 0.864 & 0.045 &
\textbf{0.829} & 0.073 \\
7 & True,15,1.0,150 & 0.959 & 0.013 & 0.848 & 0.051 & 0.876 & 0.026 & 0.824 &
0.077 \\
8 & True,15,1.0,200 & 0.959 & 0.014 & 0.848 & 0.055 & 0.876 & 0.040 & 0.824 &
0.077 \\
9 & True,20,0.5,100 & 0.952 & 0.018 & 0.818 & 0.072 & 0.860 & 0.049 & 0.782 &
0.097 \\
```

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10 & True,20,0.5,150 & 0.953 & 0.016 & 0.825 & 0.063 & 0.859 & 0.045 & 0.796 &
0.093 \\
11 & True,20,0.5,200 & 0.953 & 0.014 & 0.827 & 0.054 & 0.852 & 0.033 & 0.805 &
0.081 \\
12 & True,20,0.7,100 & 0.960 & 0.017 & 0.851 & 0.065 & 0.893 & 0.054 & 0.815 &
0.085 \\
13 & True,20,0.7,150 & 0.960 & 0.013 & 0.848 & 0.054 & 0.889 & 0.033 & 0.815 &
0.085 \\
14 & True,20,0.7,200 & \textbf{0.961} & 0.013 & 0.852 & 0.053 & \textbf{0.898} &
0.030 & 0.815 & 0.085 \\
15 & True,20,1.0,100 & 0.958 & 0.015 & 0.843 & 0.056 & 0.879 & 0.048 & 0.810 &
\textbf{0.068} \\
16 & True,20,1.0,150 & 0.958 & 0.016 & 0.843 & 0.062 & 0.875 & 0.050 & 0.815 &
0.079 \\
17 & True,20,1.0,200 & 0.958 & 0.015 & 0.844 & 0.059 & 0.882 & 0.038 & 0.810 &
0.083 \\
18 & True,25,0.5,100 & 0.952 & 0.017 & 0.821 & 0.067 & 0.862 & 0.047 & 0.787 &
0.096 \\
19 & True,25,0.5,150 & 0.954 & 0.015 & 0.827 & 0.060 & 0.864 & 0.040 & 0.796 &
0.093 \\
20 & True,25,0.5,200 & 0.954 & 0.014 & 0.828 & 0.057 & 0.859 & 0.028 & 0.801 &
0.087 \\
21 & True,25,0.7,100 & 0.958 & 0.017 & 0.845 & 0.065 & 0.880 & 0.055 & 0.815 &
0.085 \\
22 & True,25,0.7,150 & 0.958 & 0.014 & 0.844 & 0.058 & 0.880 & 0.039 & 0.815 &
0.085 \\
23 & True,25,0.7,200 & \textbf{0.961} & 0.013 & 0.853 & 0.051 & 0.894 & 0.028 &
0.819 & 0.080 \\
24 & True,25,1.0,100 & 0.958 & 0.015 & 0.843 & 0.056 & 0.875 & 0.048 & 0.815 &
0.069 \\
25 & True,25,1.0,150 & 0.959 & 0.016 & 0.849 & 0.059 & 0.872 & 0.049 &
\textbf{0.829} & 0.073 \\
26 & True,25,1.0,200 & 0.958 & 0.014 & 0.846 & 0.055 & 0.871 & 0.034 & 0.824 &
0.079 \\
\bottomrule
\end{tabular}
\end{table}
```

```
   bootstrap,max_depth,max_samples,n_estimators  accuracy_D3  accuracy_D3_std  \
0                              True,15,0.5,100     0.959630         0.005324
1                              True,15,0.5,150     0.963539         0.006656
2                              True,15,0.5,200     0.964842         0.005222
3                              True,15,0.7,100     0.960286         0.010178
4                              True,15,0.7,150     0.962885         0.009809
5                              True,15,0.7,200     0.960280         0.006674
6                              True,15,1.0,100     0.956381         0.008636
7                              True,15,1.0,150     0.956384         0.006993
```

8	True,15,1.0,200	0.957684	0.005811
9	True,20,0.5,100	0.956375	0.009594
10	True,20,0.5,150	0.958325	0.008864
11	True,20,0.5,200	0.958979	0.005711
12	True,20,0.7,100	0.957680	0.007719
13	True,20,0.7,150	0.958981	0.006725
14	True,20,0.7,200	0.960284	0.006969
15	True,20,1.0,100	0.964188	0.006200
16	True,20,1.0,150	0.964840	0.006334
17	True,20,1.0,200	0.962890	0.004882
18	True,25,0.5,100	0.955724	0.009142
19	True,25,0.5,150	0.958325	0.008864
20	True,25,0.5,200	0.958981	0.004900
21	True,25,0.7,100	0.958983	0.006391
22	True,25,0.7,150	0.958329	0.006664
23	True,25,0.7,200	0.960935	0.006526
24	True,25,1.0,100	0.964188	0.006851
25	True,25,1.0,150	0.965493	0.005301
26	True,25,1.0,200	0.962890	0.006047

	f1_D3	f1_D3_std	precision_D3	precision_D3_std	recall_D3	\
0	0.852565	0.021951	0.893684	0.034890	0.818182	
1	0.866883	0.022498	0.914343	0.054082	0.827273	
2	0.871951	0.019368	0.913158	0.037305	0.836364	
3	0.856739	0.031017	0.899976	0.076293	0.822727	
4	0.864258	0.033551	0.914956	0.064888	0.822727	
5	0.853247	0.025198	0.907073	0.043895	0.809091	
6	0.839457	0.030941	0.893145	0.058475	0.795455	
7	0.842106	0.021511	0.881761	0.057263	0.809091	
8	0.847139	0.019801	0.883505	0.054899	0.818182	
9	0.841068	0.032280	0.885152	0.059829	0.804545	
10	0.844830	0.034664	0.903866	0.041243	0.795455	
11	0.848574	0.022141	0.900882	0.037885	0.804545	
12	0.848136	0.023617	0.881716	0.065078	0.822727	
13	0.851703	0.023493	0.887671	0.053177	0.822727	
14	0.856730	0.022618	0.893868	0.062168	0.827273	
15	0.869597	0.023598	0.912581	0.056418	0.836364	
16	0.872052	0.021389	0.915952	0.052647	0.836364	
17	0.865511	0.013785	0.906679	0.053393	0.831818	
18	0.838916	0.031238	0.879755	0.052581	0.804545	
19	0.843899	0.035540	0.907597	0.037030	0.790909	
20	0.847709	0.020705	0.905391	0.037345	0.800000	
21	0.851990	0.019407	0.889975	0.061820	0.822727	
22	0.848873	0.023935	0.887244	0.052915	0.818182	
23	0.858738	0.020827	0.898355	0.061450	0.827273	
24	0.869887	0.023967	0.914435	0.065309	0.836364	
25	0.874568	0.019530	0.916451	0.051581	0.840909	
26	0.865622	0.018380	0.907077	0.058089	0.831818	

```
    recall_D3_std
0        0.049793
1        0.036927
2        0.036364
3        0.039101
4        0.046355
5        0.053009
6        0.045455
7        0.030829
8        0.045455
9        0.044536
10       0.053783
11       0.044536
12       0.048532
13       0.048532
14       0.044536
15       0.059959
16       0.046355
17       0.036927
18       0.044536
19       0.056408
20       0.048532
21       0.048532
22       0.051826
23       0.044536
24       0.059959
25       0.049793
26       0.036927
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & bootstrap,max depth,max samples,n estimators & accuracy D3 & accuracy D3 std
& f1 D3 & f1 D3 std & precision D3 & precision D3 std & recall D3 & recall D3
std \\
\midrule
0 & True,15,0.5,100 & 0.960 & \textbf{0.005} & 0.853 & 0.022 & 0.894 &
\textbf{0.035} & 0.818 & 0.050 \\
1 & True,15,0.5,150 & 0.964 & 0.007 & 0.867 & 0.022 & 0.914 & 0.054 & 0.827 &
0.037 \\
2 & True,15,0.5,200 & \textbf{0.965} & \textbf{0.005} & 0.872 & 0.019 & 0.913 &
0.037 & 0.836 & 0.036 \\
3 & True,15,0.7,100 & 0.960 & 0.010 & 0.857 & 0.031 & 0.900 & 0.076 & 0.823 &
0.039 \\
4 & True,15,0.7,150 & 0.963 & 0.010 & 0.864 & 0.034 & 0.915 & 0.065 & 0.823 &
```

```
0.046 \\
5 & True,15,0.7,200 & 0.960 & 0.007 & 0.853 & 0.025 & 0.907 & 0.044 & 0.809 &
0.053 \\
6 & True,15,1.0,100 & 0.956 & 0.009 & 0.839 & 0.031 & 0.893 & 0.058 & 0.795 &
0.045 \\
7 & True,15,1.0,150 & 0.956 & 0.007 & 0.842 & 0.022 & 0.882 & 0.057 & 0.809 &
\textbf{0.031} \\
8 & True,15,1.0,200 & 0.958 & 0.006 & 0.847 & 0.020 & 0.884 & 0.055 & 0.818 &
0.045 \\
9 & True,20,0.5,100 & 0.956 & 0.010 & 0.841 & 0.032 & 0.885 & 0.060 & 0.805 &
0.045 \\
10 & True,20,0.5,150 & 0.958 & 0.009 & 0.845 & 0.035 & 0.904 & 0.041 & 0.795 &
0.054 \\
11 & True,20,0.5,200 & 0.959 & 0.006 & 0.849 & 0.022 & 0.901 & 0.038 & 0.805 &
0.045 \\
12 & True,20,0.7,100 & 0.958 & 0.008 & 0.848 & 0.024 & 0.882 & 0.065 & 0.823 &
0.049 \\
13 & True,20,0.7,150 & 0.959 & 0.007 & 0.852 & 0.023 & 0.888 & 0.053 & 0.823 &
0.049 \\
14 & True,20,0.7,200 & 0.960 & 0.007 & 0.857 & 0.023 & 0.894 & 0.062 & 0.827 &
0.045 \\
15 & True,20,1.0,100 & 0.964 & 0.006 & 0.870 & 0.024 & 0.913 & 0.056 & 0.836 &
0.060 \\
16 & True,20,1.0,150 & \textbf{0.965} & 0.006 & 0.872 & 0.021 & \textbf{0.916} &
0.053 & 0.836 & 0.046 \\
17 & True,20,1.0,200 & 0.963 & \textbf{0.005} & 0.866 & \textbf{0.014} & 0.907 &
0.053 & 0.832 & 0.037 \\
18 & True,25,0.5,100 & 0.956 & 0.009 & 0.839 & 0.031 & 0.880 & 0.053 & 0.805 &
0.045 \\
19 & True,25,0.5,150 & 0.958 & 0.009 & 0.844 & 0.036 & 0.908 & 0.037 & 0.791 &
0.056 \\
20 & True,25,0.5,200 & 0.959 & \textbf{0.005} & 0.848 & 0.021 & 0.905 & 0.037 &
0.800 & 0.049 \\
21 & True,25,0.7,100 & 0.959 & 0.006 & 0.852 & 0.019 & 0.890 & 0.062 & 0.823 &
0.049 \\
22 & True,25,0.7,150 & 0.958 & 0.007 & 0.849 & 0.024 & 0.887 & 0.053 & 0.818 &
0.052 \\
23 & True,25,0.7,200 & 0.961 & 0.007 & 0.859 & 0.021 & 0.898 & 0.061 & 0.827 &
0.045 \\
24 & True,25,1.0,100 & 0.964 & 0.007 & 0.870 & 0.024 & 0.914 & 0.065 & 0.836 &
0.060 \\
25 & True,25,1.0,150 & \textbf{0.965} & \textbf{0.005} & \textbf{0.875} & 0.020
& \textbf{0.916} & 0.052 & \textbf{0.841} & 0.050 \\
26 & True,25,1.0,200 & 0.963 & 0.006 & 0.866 & 0.018 & 0.907 & 0.058 & 0.832 &
0.037 \\
\bottomrule
\end{tabular}
\end{table}
```

	bootstrap,max_depth,max_samples,n_estimators	accuracy_D4	accuracy_D4_std	\
0	True,15,0.5,100	0.967442	0.010315	
1	True,15,0.5,150	0.972004	0.010221	
2	True,15,0.5,200	0.969400	0.009353	
3	True,15,0.7,100	0.971355	0.011543	
4	True,15,0.7,150	0.972657	0.010622	
5	True,15,0.7,200	0.970052	0.009532	
6	True,15,1.0,100	0.968097	0.012261	
7	True,15,1.0,150	0.969400	0.010627	
8	True,15,1.0,200	0.970049	0.009972	
9	True,20,0.5,100	0.969396	0.008407	
10	True,20,0.5,150	0.972000	0.008897	
11	True,20,0.5,200	0.973954	0.007439	
12	True,20,0.7,100	0.972006	0.011394	
13	True,20,0.7,150	0.972008	0.011009	
14	True,20,0.7,200	0.970703	0.010705	
15	True,20,1.0,100	0.973305	0.008092	
16	True,20,1.0,150	0.973303	0.007553	
17	True,20,1.0,200	0.972000	0.007612	
18	True,25,0.5,100	0.970699	0.010310	
19	True,25,0.5,150	0.970697	0.010313	
20	True,25,0.5,200	0.973303	0.009084	
21	True,25,0.7,100	0.970703	0.012531	
22	True,25,0.7,150	0.972006	0.012797	
23	True,25,0.7,200	0.972655	0.011398	
24	True,25,1.0,100	0.973305	0.007825	
25	True,25,1.0,150	0.970699	0.006847	
26	True,25,1.0,200	0.972000	0.007612	

	f1_D4	f1_D4_std	precision_D4	precision_D4_std	recall_D4	\
0	0.901489	0.030390	0.895862	0.046483	0.908392	
1	0.915355	0.029724	0.911755	0.049588	0.920471	
2	0.907711	0.026923	0.900288	0.044355	0.916471	
3	0.912865	0.034412	0.914889	0.053944	0.912549	
4	0.917568	0.031320	0.912255	0.051371	0.924471	
5	0.910037	0.027174	0.900952	0.047299	0.920392	
6	0.904273	0.035337	0.898122	0.061936	0.912471	
7	0.907551	0.030539	0.903977	0.051131	0.912471	
8	0.909627	0.028902	0.903908	0.048073	0.916392	
9	0.907257	0.024200	0.903063	0.041424	0.912392	
10	0.915987	0.025353	0.904987	0.045613	0.928314	
11	0.921924	0.021165	0.909110	0.041523	0.936314	
12	0.914656	0.034433	0.914210	0.045319	0.916549	
13	0.914893	0.033211	0.914648	0.048477	0.916549	
14	0.910877	0.031907	0.909964	0.043920	0.912471	
15	0.918487	0.024816	0.916907	0.028339	0.920314	

```
16  0.919110   0.021874      0.914574          0.037981   0.924314
17  0.915493   0.021721      0.907522          0.038415   0.924314
18  0.911093   0.029929      0.910896          0.050400   0.912392
19  0.912104   0.029666      0.901214          0.049165   0.924314
20  0.920277   0.025611      0.906085          0.047406   0.936314
21  0.910725   0.037745      0.910474          0.049428   0.912549
22  0.915331   0.038234      0.911264          0.052227   0.920471
23  0.916881   0.033834      0.918543          0.052558   0.916471
24  0.918531   0.023786      0.916923          0.028301   0.920314
25  0.911389   0.020114      0.902979          0.030766   0.920314
26  0.915041   0.022373      0.910229          0.034694   0.920314

    recall_D4_std
0        0.027025
1        0.024561
2        0.022605
3        0.031624
4        0.025758
5        0.012039
6        0.019666
7        0.019666
8        0.014562
9        0.015723
10       0.009559
11       0.014641
12       0.040046
13       0.033522
14       0.026585
15       0.025306
16       0.007867
17       0.007867
18       0.015723
19       0.014896
20       0.014641
21       0.042428
22       0.032913
23       0.025904
24       0.021918
25       0.012665
26       0.012665
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & bootstrap,max depth,max samples,n estimators & accuracy D4 & accuracy D4 std
& f1 D4 & f1 D4 std & precision D4 & precision D4 std & recall D4 & recall D4
```

```
std \\
\midrule
0 & True,15,0.5,100 & 0.967 & 0.010 & 0.901 & 0.030 & 0.896 & 0.046 & 0.908 &
0.027 \\
1 & True,15,0.5,150 & 0.972 & 0.010 & 0.915 & 0.030 & 0.912 & 0.050 & 0.920 &
0.025 \\
2 & True,15,0.5,200 & 0.969 & 0.009 & 0.908 & 0.027 & 0.900 & 0.044 & 0.916 &
0.023 \\
3 & True,15,0.7,100 & 0.971 & 0.012 & 0.913 & 0.034 & 0.915 & 0.054 & 0.913 &
0.032 \\
4 & True,15,0.7,150 & 0.973 & 0.011 & 0.918 & 0.031 & 0.912 & 0.051 & 0.924 &
0.026 \\
5 & True,15,0.7,200 & 0.970 & 0.010 & 0.910 & 0.027 & 0.901 & 0.047 & 0.920 &
0.012 \\
6 & True,15,1.0,100 & 0.968 & 0.012 & 0.904 & 0.035 & 0.898 & 0.062 & 0.912 &
0.020 \\
7 & True,15,1.0,150 & 0.969 & 0.011 & 0.908 & 0.031 & 0.904 & 0.051 & 0.912 &
0.020 \\
8 & True,15,1.0,200 & 0.970 & 0.010 & 0.910 & 0.029 & 0.904 & 0.048 & 0.916 &
0.015 \\
9 & True,20,0.5,100 & 0.969 & 0.008 & 0.907 & 0.024 & 0.903 & 0.041 & 0.912 &
0.016 \\
10 & True,20,0.5,150 & 0.972 & 0.009 & 0.916 & 0.025 & 0.905 & 0.046 & 0.928 &
0.010 \\
11 & True,20,0.5,200 & \textbf{0.974} & \textbf{0.007} & \textbf{0.922} & 0.021
& 0.909 & 0.042 & \textbf{0.936} & 0.015 \\
12 & True,20,0.7,100 & 0.972 & 0.011 & 0.915 & 0.034 & 0.914 & 0.045 & 0.917 &
0.040 \\
13 & True,20,0.7,150 & 0.972 & 0.011 & 0.915 & 0.033 & 0.915 & 0.048 & 0.917 &
0.034 \\
14 & True,20,0.7,200 & 0.971 & 0.011 & 0.911 & 0.032 & 0.910 & 0.044 & 0.912 &
0.027 \\
15 & True,20,1.0,100 & 0.973 & 0.008 & 0.918 & 0.025 & 0.917 & \textbf{0.028} &
0.920 & 0.025 \\
16 & True,20,1.0,150 & 0.973 & 0.008 & 0.919 & 0.022 & 0.915 & 0.038 & 0.924 &
\textbf{0.008} \\
17 & True,20,1.0,200 & 0.972 & 0.008 & 0.915 & 0.022 & 0.908 & 0.038 & 0.924 &
\textbf{0.008} \\
18 & True,25,0.5,100 & 0.971 & 0.010 & 0.911 & 0.030 & 0.911 & 0.050 & 0.912 &
0.016 \\
19 & True,25,0.5,150 & 0.971 & 0.010 & 0.912 & 0.030 & 0.901 & 0.049 & 0.924 &
0.015 \\
20 & True,25,0.5,200 & 0.973 & 0.009 & 0.920 & 0.026 & 0.906 & 0.047 &
\textbf{0.936} & 0.015 \\
21 & True,25,0.7,100 & 0.971 & 0.013 & 0.911 & 0.038 & 0.910 & 0.049 & 0.913 &
0.042 \\
22 & True,25,0.7,150 & 0.972 & 0.013 & 0.915 & 0.038 & 0.911 & 0.052 & 0.920 &
0.033 \\
```

```
23 & True,25,0.7,200 & 0.973 & 0.011 & 0.917 & 0.034 & \textbf{0.919} & 0.053 &
0.916 & 0.026 \\
24 & True,25,1.0,100 & 0.973 & 0.008 & 0.919 & 0.024 & 0.917 & \textbf{0.028} &
0.920 & 0.022 \\
25 & True,25,1.0,150 & 0.971 & \textbf{0.007} & 0.911 & \textbf{0.02} & 0.903 &
0.031 & 0.920 & 0.013 \\
26 & True,25,1.0,200 & 0.972 & 0.008 & 0.915 & 0.022 & 0.910 & 0.035 & 0.920 &
0.013 \\
\bottomrule
\end{tabular}
\end{table}
```

```
   bootstrap,max_depth,max_samples,n_estimators  accuracy_D5  accuracy_D5_std  \
0                               True,15,0.5,100     0.983730         0.008721
1                               True,15,0.5,150     0.985033         0.009100
2                               True,15,0.5,200     0.984382         0.008573
3                               True,15,0.7,100     0.983081         0.009048
4                               True,15,0.7,150     0.984384         0.009939
5                               True,15,0.7,200     0.985033         0.009100
6                               True,15,1.0,100     0.985031         0.009338
7                               True,15,1.0,150     0.984380         0.009062
8                               True,15,1.0,200     0.985029         0.008636
9                               True,20,0.5,100     0.985685         0.009773
10                              True,20,0.5,150     0.985031         0.008123
11                              True,20,0.5,200     0.983728         0.008483
12                              True,20,0.7,100     0.984386         0.011513
13                              True,20,0.7,150     0.984386         0.011327
14                              True,20,0.7,200     0.985685         0.009554
15                              True,20,1.0,100     0.985680         0.007589
16                              True,20,1.0,150     0.985680         0.007589
17                              True,20,1.0,200     0.985031         0.008123
18                              True,25,0.5,100     0.985033         0.009555
19                              True,25,0.5,150     0.983728         0.008483
20                              True,25,0.5,200     0.983077         0.008074
21                              True,25,0.7,100     0.984386         0.011513
22                              True,25,0.7,150     0.984384         0.011147
23                              True,25,0.7,200     0.986336         0.008813
24                              True,25,1.0,100     0.985029         0.008636
25                              True,25,1.0,150     0.985680         0.008877
26                              True,25,1.0,200     0.985031         0.009338

       f1_D5  f1_D5_std  precision_D5  precision_D5_std  recall_D5  \
0   0.943022   0.029564      0.917445          0.051456   0.971429
1   0.947569   0.030899      0.921591          0.049673   0.976190
2   0.945161   0.028939      0.921380          0.049535   0.971429
3   0.941077   0.030350      0.909528          0.049806   0.976190
4   0.945618   0.033411      0.918403          0.056492   0.976190
```

5	0.947620	0.030888	0.921889	0.051677	0.976190
6	0.947211	0.032000	0.924835	0.047065	0.971429
7	0.944968	0.031075	0.920501	0.045187	0.971429
8	0.947106	0.029583	0.924542	0.043031	0.971429
9	0.950029	0.033390	0.922000	0.051793	0.980952
10	0.947372	0.027833	0.920892	0.043131	0.976190
11	0.943133	0.028711	0.913225	0.047162	0.976190
12	0.945905	0.038468	0.919198	0.063307	0.976190
13	0.945904	0.037741	0.919298	0.063324	0.976190
14	0.949865	0.032474	0.926132	0.053288	0.976190
15	0.948616	0.026893	0.935931	0.035877	0.961905
16	0.948933	0.026683	0.932373	0.039099	0.966667
17	0.946477	0.028638	0.931890	0.039615	0.961905
18	0.947835	0.032653	0.917942	0.051541	0.980952
19	0.943084	0.028755	0.912949	0.045277	0.976190
20	0.940890	0.027343	0.908891	0.044163	0.976190
21	0.945905	0.038468	0.919198	0.063307	0.976190
22	0.945355	0.038019	0.922066	0.058761	0.971429
23	0.951955	0.030027	0.929996	0.049619	0.976190
24	0.946531	0.030237	0.931991	0.041711	0.961905
25	0.948774	0.031074	0.936325	0.042584	0.961905
26	0.946636	0.032607	0.932285	0.045813	0.961905

	recall_D5_std
0	0.009524
1	0.015058
2	0.009524
3	0.015058
4	0.015058
5	0.015058
6	0.017817
7	0.017817
8	0.017817
9	0.017817
10	0.015058
11	0.015058
12	0.015058
13	0.015058
14	0.015058
15	0.019048
16	0.019048
17	0.019048
18	0.017817
19	0.015058
20	0.015058
21	0.015058
22	0.023328
23	0.015058

```
24       0.019048
25       0.019048
26       0.019048
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & bootstrap,max depth,max samples,n estimators & accuracy D5 & accuracy D5 std
& f1 D5 & f1 D5 std & precision D5 & precision D5 std & recall D5 & recall D5
std \\
\midrule
0 & True,15,0.5,100 & 0.984 & 0.009 & 0.943 & 0.030 & 0.917 & 0.051 & 0.971 &
\textbf{0.01} \\
1 & True,15,0.5,150 & 0.985 & 0.009 & 0.948 & 0.031 & 0.922 & 0.050 & 0.976 &
0.015 \\
2 & True,15,0.5,200 & 0.984 & 0.009 & 0.945 & 0.029 & 0.921 & 0.050 & 0.971 &
\textbf{0.01} \\
3 & True,15,0.7,100 & 0.983 & 0.009 & 0.941 & 0.030 & 0.910 & 0.050 & 0.976 &
0.015 \\
4 & True,15,0.7,150 & 0.984 & 0.010 & 0.946 & 0.033 & 0.918 & 0.056 & 0.976 &
0.015 \\
5 & True,15,0.7,200 & 0.985 & 0.009 & 0.948 & 0.031 & 0.922 & 0.052 & 0.976 &
0.015 \\
6 & True,15,1.0,100 & 0.985 & 0.009 & 0.947 & 0.032 & 0.925 & 0.047 & 0.971 &
0.018 \\
7 & True,15,1.0,150 & 0.984 & 0.009 & 0.945 & 0.031 & 0.921 & 0.045 & 0.971 &
0.018 \\
8 & True,15,1.0,200 & 0.985 & 0.009 & 0.947 & 0.030 & 0.925 & 0.043 & 0.971 &
0.018 \\
9 & True,20,0.5,100 & \textbf{0.986} & 0.010 & 0.950 & 0.033 & 0.922 & 0.052 &
\textbf{0.981} & 0.018 \\
10 & True,20,0.5,150 & 0.985 & \textbf{0.008} & 0.947 & 0.028 & 0.921 & 0.043 &
0.976 & 0.015 \\
11 & True,20,0.5,200 & 0.984 & \textbf{0.008} & 0.943 & 0.029 & 0.913 & 0.047 &
0.976 & 0.015 \\
12 & True,20,0.7,100 & 0.984 & 0.012 & 0.946 & 0.038 & 0.919 & 0.063 & 0.976 &
0.015 \\
13 & True,20,0.7,150 & 0.984 & 0.011 & 0.946 & 0.038 & 0.919 & 0.063 & 0.976 &
0.015 \\
14 & True,20,0.7,200 & \textbf{0.986} & 0.010 & 0.950 & 0.032 & 0.926 & 0.053 &
0.976 & 0.015 \\
15 & True,20,1.0,100 & \textbf{0.986} & \textbf{0.008} & 0.949 & \textbf{0.027}
& \textbf{0.936} & \textbf{0.036} & 0.962 & 0.019 \\
16 & True,20,1.0,150 & \textbf{0.986} & \textbf{0.008} & 0.949 & \textbf{0.027}
& 0.932 & 0.039 & 0.967 & 0.019 \\
17 & True,20,1.0,200 & 0.985 & \textbf{0.008} & 0.946 & 0.029 & 0.932 & 0.040 &
```

```
0.962 & 0.019 \\
18 & True,25,0.5,100 & 0.985 & 0.010 & 0.948 & 0.033 & 0.918 & 0.052 &
\textbf{0.981} & 0.018 \\
19 & True,25,0.5,150 & 0.984 & \textbf{0.008} & 0.943 & 0.029 & 0.913 & 0.045 &
0.976 & 0.015 \\
20 & True,25,0.5,200 & 0.983 & \textbf{0.008} & 0.941 & \textbf{0.027} & 0.909 &
0.044 & 0.976 & 0.015 \\
21 & True,25,0.7,100 & 0.984 & 0.012 & 0.946 & 0.038 & 0.919 & 0.063 & 0.976 &
0.015 \\
22 & True,25,0.7,150 & 0.984 & 0.011 & 0.945 & 0.038 & 0.922 & 0.059 & 0.971 &
0.023 \\
23 & True,25,0.7,200 & \textbf{0.986} & 0.009 & \textbf{0.952} & 0.030 & 0.930 &
0.050 & 0.976 & 0.015 \\
24 & True,25,1.0,100 & 0.985 & 0.009 & 0.947 & 0.030 & 0.932 & 0.042 & 0.962 &
0.019 \\
25 & True,25,1.0,150 & \textbf{0.986} & 0.009 & 0.949 & 0.031 & \textbf{0.936} &
0.043 & 0.962 & 0.019 \\
26 & True,25,1.0,200 & 0.985 & 0.009 & 0.947 & 0.033 & 0.932 & 0.046 & 0.962 &
0.019 \\
\bottomrule
\end{tabular}
\end{table}
```

	bootstrap,max_depth,max_samples,n_estimators	accuracy_D6	accuracy_D6_std	\
0	True,15,0.5,100	0.997396	0.002437	
1	True,15,0.5,150	0.997396	0.002437	
2	True,15,0.5,200	0.997396	0.002437	
3	True,15,0.7,100	0.998048	0.001594	
4	True,15,0.7,150	0.998048	0.001594	
5	True,15,0.7,200	0.998048	0.001594	
6	True,15,1.0,100	0.998046	0.002606	
7	True,15,1.0,150	0.998046	0.002606	
8	True,15,1.0,200	0.998046	0.002606	
9	True,20,0.5,100	0.997396	0.002437	
10	True,20,0.5,150	0.997396	0.002437	
11	True,20,0.5,200	0.997396	0.002437	
12	True,20,0.7,100	0.998697	0.001596	
13	True,20,0.7,150	0.998697	0.001596	
14	True,20,0.7,200	0.998697	0.001596	
15	True,20,1.0,100	0.997396	0.002437	
16	True,20,1.0,150	0.998048	0.001594	
17	True,20,1.0,200	0.997396	0.002437	
18	True,25,0.5,100	0.997396	0.002437	
19	True,25,0.5,150	0.997396	0.002437	
20	True,25,0.5,200	0.997396	0.002437	
21	True,25,0.7,100	0.998697	0.001596	
22	True,25,0.7,150	0.998697	0.001596	

23	True,25,0.7,200	0.998048	0.001594
24	True,25,1.0,100	0.998048	0.001594
25	True,25,1.0,150	0.998048	0.001594
26	True,25,1.0,200	0.997396	0.002437

	f1_D6	f1_D6_std	precision_D6	precision_D6_std	recall_D6	\
0	0.991795	0.007647	0.987918	0.016042	0.995918	
1	0.991795	0.007647	0.987918	0.016042	0.995918	
2	0.991795	0.007647	0.987918	0.016042	0.995918	
3	0.993814	0.005050	0.991837	0.009998	0.995918	
4	0.993814	0.005050	0.991837	0.009998	0.995918	
5	0.993814	0.005050	0.991837	0.009998	0.995918	
6	0.993857	0.008174	0.992000	0.016000	0.995918	
7	0.993857	0.008174	0.992000	0.016000	0.995918	
8	0.993857	0.008174	0.992000	0.016000	0.995918	
9	0.991795	0.007647	0.987918	0.016042	0.995918	
10	0.991795	0.007647	0.987918	0.016042	0.995918	
11	0.991795	0.007647	0.987918	0.016042	0.995918	
12	0.995876	0.005050	0.995918	0.008163	0.995918	
13	0.995876	0.005050	0.995918	0.008163	0.995918	
14	0.995876	0.005050	0.995918	0.008163	0.995918	
15	0.991795	0.007647	0.987918	0.016042	0.995918	
16	0.993814	0.005050	0.991837	0.009998	0.995918	
17	0.991795	0.007647	0.987918	0.016042	0.995918	
18	0.991795	0.007647	0.987918	0.016042	0.995918	
19	0.991795	0.007647	0.987918	0.016042	0.995918	
20	0.991795	0.007647	0.987918	0.016042	0.995918	
21	0.995876	0.005050	0.995918	0.008163	0.995918	
22	0.995876	0.005050	0.995918	0.008163	0.995918	
23	0.993814	0.005050	0.991837	0.009998	0.995918	
24	0.993814	0.005050	0.991837	0.009998	0.995918	
25	0.993814	0.005050	0.991837	0.009998	0.995918	
26	0.991795	0.007647	0.987918	0.016042	0.995918	

	recall_D6_std
0	0.008163
1	0.008163
2	0.008163
3	0.008163
4	0.008163
5	0.008163
6	0.008163
7	0.008163
8	0.008163
9	0.008163
10	0.008163
11	0.008163
12	0.008163

```
13       0.008163
14       0.008163
15       0.008163
16       0.008163
17       0.008163
18       0.008163
19       0.008163
20       0.008163
21       0.008163
22       0.008163
23       0.008163
24       0.008163
25       0.008163
26       0.008163
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & bootstrap,max depth,max samples,n estimators & accuracy D6 & accuracy D6 std
& f1 D6 & f1 D6 std & precision D6 & precision D6 std & recall D6 & recall D6
std \\
\midrule
0 & True,15,0.5,100 & 0.997 & \textbf{0.002} & 0.992 & 0.008 & 0.988 & 0.016 &
\textbf{0.996} & \textbf{0.008} \\
1 & True,15,0.5,150 & 0.997 & \textbf{0.002} & 0.992 & 0.008 & 0.988 & 0.016 &
\textbf{0.996} & \textbf{0.008} \\
2 & True,15,0.5,200 & 0.997 & \textbf{0.002} & 0.992 & 0.008 & 0.988 & 0.016 &
\textbf{0.996} & \textbf{0.008} \\
3 & True,15,0.7,100 & 0.998 & \textbf{0.002} & 0.994 & \textbf{0.005} & 0.992 &
0.010 & \textbf{0.996} & \textbf{0.008} \\
4 & True,15,0.7,150 & 0.998 & \textbf{0.002} & 0.994 & \textbf{0.005} & 0.992 &
0.010 & \textbf{0.996} & \textbf{0.008} \\
5 & True,15,0.7,200 & 0.998 & \textbf{0.002} & 0.994 & \textbf{0.005} & 0.992 &
0.010 & \textbf{0.996} & \textbf{0.008} \\
6 & True,15,1.0,100 & 0.998 & 0.003 & 0.994 & 0.008 & 0.992 & 0.016 &
\textbf{0.996} & \textbf{0.008} \\
7 & True,15,1.0,150 & 0.998 & 0.003 & 0.994 & 0.008 & 0.992 & 0.016 &
\textbf{0.996} & \textbf{0.008} \\
8 & True,15,1.0,200 & 0.998 & 0.003 & 0.994 & 0.008 & 0.992 & 0.016 &
\textbf{0.996} & \textbf{0.008} \\
9 & True,20,0.5,100 & 0.997 & \textbf{0.002} & 0.992 & 0.008 & 0.988 & 0.016 &
\textbf{0.996} & \textbf{0.008} \\
10 & True,20,0.5,150 & 0.997 & \textbf{0.002} & 0.992 & 0.008 & 0.988 & 0.016 &
\textbf{0.996} & \textbf{0.008} \\
11 & True,20,0.5,200 & 0.997 & \textbf{0.002} & 0.992 & 0.008 & 0.988 & 0.016 &
\textbf{0.996} & \textbf{0.008} \\
```

```
12 & True,20,0.7,100 & \textbf{0.999} & \textbf{0.002} & \textbf{0.996} &
\textbf{0.005} & \textbf{0.996} & \textbf{0.008} & \textbf{0.996} &
\textbf{0.008} \\
13 & True,20,0.7,150 & \textbf{0.999} & \textbf{0.002} & \textbf{0.996} &
\textbf{0.005} & \textbf{0.996} & \textbf{0.008} & \textbf{0.996} &
\textbf{0.008} \\
14 & True,20,0.7,200 & \textbf{0.999} & \textbf{0.002} & \textbf{0.996} &
\textbf{0.005} & \textbf{0.996} & \textbf{0.008} & \textbf{0.996} &
\textbf{0.008} \\
15 & True,20,1.0,100 & 0.997 & \textbf{0.002} & 0.992 & 0.008 & 0.988 & 0.016 &
\textbf{0.996} & \textbf{0.008} \\
16 & True,20,1.0,150 & 0.998 & \textbf{0.002} & 0.994 & \textbf{0.005} & 0.992 &
0.010 & \textbf{0.996} & \textbf{0.008} \\
17 & True,20,1.0,200 & 0.997 & \textbf{0.002} & 0.992 & 0.008 & 0.988 & 0.016 &
\textbf{0.996} & \textbf{0.008} \\
18 & True,25,0.5,100 & 0.997 & \textbf{0.002} & 0.992 & 0.008 & 0.988 & 0.016 &
\textbf{0.996} & \textbf{0.008} \\
19 & True,25,0.5,150 & 0.997 & \textbf{0.002} & 0.992 & 0.008 & 0.988 & 0.016 &
\textbf{0.996} & \textbf{0.008} \\
20 & True,25,0.5,200 & 0.997 & \textbf{0.002} & 0.992 & 0.008 & 0.988 & 0.016 &
\textbf{0.996} & \textbf{0.008} \\
21 & True,25,0.7,100 & \textbf{0.999} & \textbf{0.002} & \textbf{0.996} &
\textbf{0.005} & \textbf{0.996} & \textbf{0.008} & \textbf{0.996} &
\textbf{0.008} \\
22 & True,25,0.7,150 & \textbf{0.999} & \textbf{0.002} & \textbf{0.996} &
\textbf{0.005} & \textbf{0.996} & \textbf{0.008} & \textbf{0.996} &
\textbf{0.008} \\
23 & True,25,0.7,200 & 0.998 & \textbf{0.002} & 0.994 & \textbf{0.005} & 0.992 &
0.010 & \textbf{0.996} & \textbf{0.008} \\
24 & True,25,1.0,100 & 0.998 & \textbf{0.002} & 0.994 & \textbf{0.005} & 0.992 &
0.010 & \textbf{0.996} & \textbf{0.008} \\
25 & True,25,1.0,150 & 0.998 & \textbf{0.002} & 0.994 & \textbf{0.005} & 0.992 &
0.010 & \textbf{0.996} & \textbf{0.008} \\
26 & True,25,1.0,200 & 0.997 & \textbf{0.002} & 0.992 & 0.008 & 0.988 & 0.016 &
\textbf{0.996} & \textbf{0.008} \\
\bottomrule
\end{tabular}
\end{table}
```

[ ]:
```python
from xgboost import XGBClassifier

# Initialize a XGBClassifier
clf = XGBClassifier(random_state=RANDOM_STATE)

# Define the parameter grid
param_grid = {
```

```
    'n_estimators': [100, 150, 200],
    'max_depth': [10, 15, 20, 25],
    'learning_rate': [0.01, 0.1, 0.2],
}

X, y = prepare_dataset()
grid_search, best_params = find_best_params(clf, param_grid, X, y, RANDOM_STATE)
```

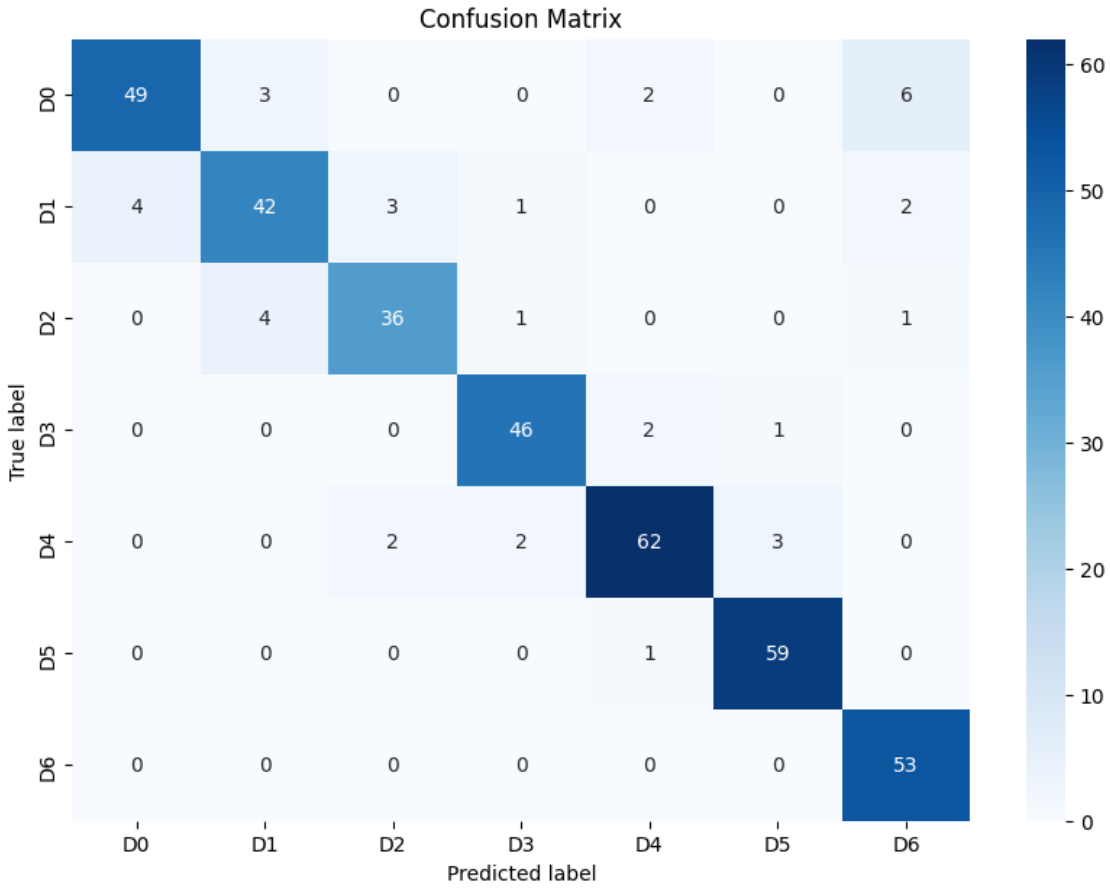
```
Features removed: {'Smoker', 'Calorie_monitoring'}
Features removed: {'Sedentary_hours_daily', 'Est_avg_calorie_intake'}
Best parameters found:  {'learning_rate': 0.1, 'max_depth': 20, 'n_estimators':
150}
```

[ ]:
```
best_clf = XGBClassifier(**best_params, random_state=RANDOM_STATE)
accuracy, f1, precision, recall, dfs = evaluate_my_model(best_clf, grid_search,␣
 ↪X, y, RANDOM_STATE)
```

```
Model: XGBClassifier
Index(['mean_fit_time', 'std_fit_time', 'mean_score_time', 'std_score_time',
       'param_learning_rate', 'param_max_depth', 'param_n_estimators',
       'params', 'split0_test_accuracy', 'split1_test_accuracy',
       …
       'std_test_recall_D5', 'rank_test_recall_D5', 'split0_test_recall_D6',
       'split1_test_recall_D6', 'split2_test_recall_D6',
       'split3_test_recall_D6', 'split4_test_recall_D6', 'mean_test_recall_D6',
       'std_test_recall_D6', 'rank_test_recall_D6'],
      dtype='object', length=264)
              precision    recall  f1-score   support

           D0       0.92      0.82      0.87        60
           D1       0.86      0.81      0.83        52
           D2       0.88      0.86      0.87        42
           D3       0.92      0.94      0.93        49
           D4       0.93      0.90      0.91        69
           D5       0.94      0.98      0.96        60
           D6       0.85      1.00      0.92        53

    accuracy                           0.90       385
   macro avg       0.90      0.90      0.90       385
weighted avg       0.90      0.90      0.90       385
```



[ ]:
```
print(f"Accuracy: {accuracy}")
print(f"F1 Score: {f1}")
print(f"Precision: {precision}")
print(f"Recall: {recall}")
print(grid_search.best_index_)
for df in dfs:
    # Replace the dictionary values with list
    display(df)
    pd_to_latex(df)
```

```
Accuracy: 0.9012987012987013
F1 Score: 0.900199806977554
Precision: 0.9022048039926235
Recall: 0.9012987012987013
19
```

	learning_rate,max_depth,n_estimators	accuracy_D0	accuracy_D0_std	\
0	0.01,10,100	0.980475	0.005416	
1	0.01,10,150	0.980473	0.004583	
2	0.01,10,200	0.981776	0.004848	

3	0.01,15,100	0.980475	0.005416
4	0.01,15,150	0.979821	0.004298
5	0.01,15,200	0.981776	0.004848
6	0.01,20,100	0.980475	0.005416
7	0.01,20,150	0.979821	0.004298
8	0.01,20,200	0.981776	0.004848
9	0.01,25,100	0.980475	0.005416
10	0.01,25,150	0.979821	0.004298
11	0.01,25,200	0.981776	0.004848
12	0.1,10,100	0.985031	0.004392
13	0.1,10,150	0.985683	0.004849
14	0.1,10,200	0.985683	0.004849
15	0.1,15,100	0.985031	0.004392
16	0.1,15,150	0.985683	0.004849
17	0.1,15,200	0.985031	0.004392
18	0.1,20,100	0.985031	0.004392
19	0.1,20,150	0.985683	0.004849
20	0.1,20,200	0.985031	0.004392
21	0.1,25,100	0.985031	0.004392
22	0.1,25,150	0.985683	0.004849
23	0.1,25,200	0.985031	0.004392
24	0.2,10,100	0.986985	0.005018
25	0.2,10,150	0.986334	0.004759
26	0.2,10,200	0.986334	0.004759
27	0.2,15,100	0.985683	0.004849
28	0.2,15,150	0.985683	0.004849
29	0.2,15,200	0.985683	0.004849
30	0.2,20,100	0.985683	0.004849
31	0.2,20,150	0.985683	0.004849
32	0.2,20,200	0.985683	0.004849
33	0.2,25,100	0.985683	0.004849
34	0.2,25,150	0.985683	0.004849
35	0.2,25,200	0.985683	0.004849

	f1_D0	f1_D0_std	precision_D0	precision_D0_std	recall_D0	\
0	0.919539	0.023559	0.915317	0.017358	0.925178	
1	0.919297	0.020952	0.915671	0.016028	0.925178	
2	0.924966	0.020984	0.922233	0.032701	0.930583	
3	0.919539	0.023559	0.915317	0.017358	0.925178	
4	0.916899	0.019657	0.911281	0.021716	0.925178	
5	0.924966	0.020984	0.922233	0.032701	0.930583	
6	0.919539	0.023559	0.915317	0.017358	0.925178	
7	0.916899	0.019657	0.911281	0.021716	0.925178	
8	0.924966	0.020984	0.922233	0.032701	0.930583	
9	0.919539	0.023559	0.915317	0.017358	0.925178	
10	0.916899	0.019657	0.911281	0.021716	0.925178	
11	0.924966	0.020984	0.922233	0.032701	0.930583	
12	0.938436	0.019125	0.931486	0.011241	0.946657	

13	0.940962	0.020891	0.936345	0.011793	0.946657
14	0.940962	0.020891	0.936345	0.011793	0.946657
15	0.938436	0.019125	0.931486	0.011241	0.946657
16	0.940962	0.020891	0.936345	0.011793	0.946657
17	0.938436	0.019125	0.931486	0.011241	0.946657
18	0.938436	0.019125	0.931486	0.011241	0.946657
19	0.940962	0.020891	0.936345	0.011793	0.946657
20	0.938436	0.019125	0.931486	0.011241	0.946657
21	0.938436	0.019125	0.931486	0.011241	0.946657
22	0.940962	0.020891	0.936345	0.011793	0.946657
23	0.938436	0.019125	0.931486	0.011241	0.946657
24	0.946296	0.021653	0.941608	0.009429	0.952063
25	0.943769	0.020619	0.936750	0.011285	0.952063
26	0.943769	0.020619	0.936750	0.011285	0.952063
27	0.940962	0.020891	0.936345	0.011793	0.946657
28	0.940962	0.020891	0.936345	0.011793	0.946657
29	0.940962	0.020891	0.936345	0.011793	0.946657
30	0.940962	0.020891	0.936345	0.011793	0.946657
31	0.940962	0.020891	0.936345	0.011793	0.946657
32	0.940962	0.020891	0.936345	0.011793	0.946657
33	0.940962	0.020891	0.936345	0.011793	0.946657
34	0.940962	0.020891	0.936345	0.011793	0.946657
35	0.940962	0.020891	0.936345	0.011793	0.946657

	recall_D0_std
0	0.044916
1	0.051008
2	0.048568
3	0.044916
4	0.051008
5	0.048568
6	0.044916
7	0.051008
8	0.048568
9	0.044916
10	0.051008
11	0.048568
12	0.040494
13	0.040494
14	0.040494
15	0.040494
16	0.040494
17	0.040494
18	0.040494
19	0.040494
20	0.040494
21	0.040494
22	0.040494

```
23       0.040494
24       0.041821
25       0.041821
26       0.041821
27       0.040494
28       0.040494
29       0.040494
30       0.040494
31       0.040494
32       0.040494
33       0.040494
34       0.040494
35       0.040494
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & learning rate,max depth,n estimators & accuracy D0 & accuracy D0 std & f1 D0
& f1 D0 std & precision D0 & precision D0 std & recall D0 & recall D0 std \\
\midrule
0 & 0.01,10,100 & 0.980 & 0.005 & 0.920 & 0.024 & 0.915 & 0.017 & 0.925 & 0.045
\\
1 & 0.01,10,150 & 0.980 & 0.005 & 0.919 & 0.021 & 0.916 & 0.016 & 0.925 & 0.051
\\
2 & 0.01,10,200 & 0.982 & 0.005 & 0.925 & 0.021 & 0.922 & 0.033 & 0.931 & 0.049
\\
3 & 0.01,15,100 & 0.980 & 0.005 & 0.920 & 0.024 & 0.915 & 0.017 & 0.925 & 0.045
\\
4 & 0.01,15,150 & 0.980 & \textbf{0.004} & 0.917 & 0.020 & 0.911 & 0.022 & 0.925
& 0.051 \\
5 & 0.01,15,200 & 0.982 & 0.005 & 0.925 & 0.021 & 0.922 & 0.033 & 0.931 & 0.049
\\
6 & 0.01,20,100 & 0.980 & 0.005 & 0.920 & 0.024 & 0.915 & 0.017 & 0.925 & 0.045
\\
7 & 0.01,20,150 & 0.980 & \textbf{0.004} & 0.917 & 0.020 & 0.911 & 0.022 & 0.925
& 0.051 \\
8 & 0.01,20,200 & 0.982 & 0.005 & 0.925 & 0.021 & 0.922 & 0.033 & 0.931 & 0.049
\\
9 & 0.01,25,100 & 0.980 & 0.005 & 0.920 & 0.024 & 0.915 & 0.017 & 0.925 & 0.045
\\
10 & 0.01,25,150 & 0.980 & \textbf{0.004} & 0.917 & 0.020 & 0.911 & 0.022 &
0.925 & 0.051 \\
11 & 0.01,25,200 & 0.982 & 0.005 & 0.925 & 0.021 & 0.922 & 0.033 & 0.931 & 0.049
\\
12 & 0.1,10,100 & 0.985 & \textbf{0.004} & 0.938 & \textbf{0.019} & 0.931 &
0.011 & 0.947 & \textbf{0.04} \\
```

```
13 & 0.1,10,150 & 0.986 & 0.005 & 0.941 & 0.021 & 0.936 & 0.012 & 0.947 &
\textbf{0.04} \\
14 & 0.1,10,200 & 0.986 & 0.005 & 0.941 & 0.021 & 0.936 & 0.012 & 0.947 &
\textbf{0.04} \\
15 & 0.1,15,100 & 0.985 & \textbf{0.004} & 0.938 & \textbf{0.019} & 0.931 &
0.011 & 0.947 & \textbf{0.04} \\
16 & 0.1,15,150 & 0.986 & 0.005 & 0.941 & 0.021 & 0.936 & 0.012 & 0.947 &
\textbf{0.04} \\
17 & 0.1,15,200 & 0.985 & \textbf{0.004} & 0.938 & \textbf{0.019} & 0.931 &
0.011 & 0.947 & \textbf{0.04} \\
18 & 0.1,20,100 & 0.985 & \textbf{0.004} & 0.938 & \textbf{0.019} & 0.931 &
0.011 & 0.947 & \textbf{0.04} \\
19 & 0.1,20,150 & 0.986 & 0.005 & 0.941 & 0.021 & 0.936 & 0.012 & 0.947 &
\textbf{0.04} \\
20 & 0.1,20,200 & 0.985 & \textbf{0.004} & 0.938 & \textbf{0.019} & 0.931 &
0.011 & 0.947 & \textbf{0.04} \\
21 & 0.1,25,100 & 0.985 & \textbf{0.004} & 0.938 & \textbf{0.019} & 0.931 &
0.011 & 0.947 & \textbf{0.04} \\
22 & 0.1,25,150 & 0.986 & 0.005 & 0.941 & 0.021 & 0.936 & 0.012 & 0.947 &
\textbf{0.04} \\
23 & 0.1,25,200 & 0.985 & \textbf{0.004} & 0.938 & \textbf{0.019} & 0.931 &
0.011 & 0.947 & \textbf{0.04} \\
24 & 0.2,10,100 & \textbf{0.987} & 0.005 & \textbf{0.946} & 0.022 &
\textbf{0.942} & \textbf{0.009} & \textbf{0.952} & 0.042 \\
25 & 0.2,10,150 & 0.986 & 0.005 & 0.944 & 0.021 & 0.937 & 0.011 & \textbf{0.952}
& 0.042 \\
26 & 0.2,10,200 & 0.986 & 0.005 & 0.944 & 0.021 & 0.937 & 0.011 & \textbf{0.952}
& 0.042 \\
27 & 0.2,15,100 & 0.986 & 0.005 & 0.941 & 0.021 & 0.936 & 0.012 & 0.947 &
\textbf{0.04} \\
28 & 0.2,15,150 & 0.986 & 0.005 & 0.941 & 0.021 & 0.936 & 0.012 & 0.947 &
\textbf{0.04} \\
29 & 0.2,15,200 & 0.986 & 0.005 & 0.941 & 0.021 & 0.936 & 0.012 & 0.947 &
\textbf{0.04} \\
30 & 0.2,20,100 & 0.986 & 0.005 & 0.941 & 0.021 & 0.936 & 0.012 & 0.947 &
\textbf{0.04} \\
31 & 0.2,20,150 & 0.986 & 0.005 & 0.941 & 0.021 & 0.936 & 0.012 & 0.947 &
\textbf{0.04} \\
32 & 0.2,20,200 & 0.986 & 0.005 & 0.941 & 0.021 & 0.936 & 0.012 & 0.947 &
\textbf{0.04} \\
33 & 0.2,25,100 & 0.986 & 0.005 & 0.941 & 0.021 & 0.936 & 0.012 & 0.947 &
\textbf{0.04} \\
34 & 0.2,25,150 & 0.986 & 0.005 & 0.941 & 0.021 & 0.936 & 0.012 & 0.947 &
\textbf{0.04} \\
35 & 0.2,25,200 & 0.986 & 0.005 & 0.941 & 0.021 & 0.936 & 0.012 & 0.947 &
\textbf{0.04} \\
\bottomrule
\end{tabular}
```

\end{table}

	learning_rate,max_depth,n_estimators	accuracy_D1	accuracy_D1_std	\
0	0.01,10,100	0.944006	0.008370	
1	0.01,10,150	0.947255	0.010820	
2	0.01,10,200	0.947910	0.008013	
3	0.01,15,100	0.943356	0.009367	
4	0.01,15,150	0.944655	0.005877	
5	0.01,15,200	0.946609	0.007628	
6	0.01,20,100	0.943356	0.009367	
7	0.01,20,150	0.944655	0.005877	
8	0.01,20,200	0.946609	0.007628	
9	0.01,25,100	0.943356	0.009367	
10	0.01,25,150	0.944655	0.005877	
11	0.01,25,200	0.946609	0.007628	
12	0.1,10,100	0.957682	0.010705	
13	0.1,10,150	0.958334	0.010381	
14	0.1,10,200	0.960286	0.010785	
15	0.1,15,100	0.958983	0.012636	
16	0.1,15,150	0.960288	0.010972	
17	0.1,15,200	0.960940	0.009871	
18	0.1,20,100	0.958983	0.012636	
19	0.1,20,150	0.960940	0.011463	
20	0.1,20,200	0.961591	0.010372	
21	0.1,25,100	0.958983	0.012636	
22	0.1,25,150	0.960940	0.011463	
23	0.1,25,200	0.961591	0.010372	
24	0.2,10,100	0.958336	0.013406	
25	0.2,10,150	0.958334	0.013254	
26	0.2,10,200	0.958332	0.013420	
27	0.2,15,100	0.962240	0.009571	
28	0.2,15,150	0.961587	0.009081	
29	0.2,15,200	0.962238	0.010827	
30	0.2,20,100	0.962240	0.009571	
31	0.2,20,150	0.961587	0.009081	
32	0.2,20,200	0.962238	0.010827	
33	0.2,25,100	0.962240	0.009571	
34	0.2,25,150	0.961587	0.009081	
35	0.2,25,200	0.962238	0.010827	

	f1_D1	f1_D1_std	precision_D1	precision_D1_std	recall_D1	\
0	0.789849	0.025848	0.817267	0.056819	0.766667	
1	0.803035	0.039107	0.821945	0.046147	0.785714	
2	0.806997	0.027665	0.819677	0.037922	0.795238	
3	0.787048	0.029724	0.815854	0.058275	0.761905	
4	0.793331	0.019518	0.812605	0.035296	0.776190	
5	0.802282	0.025305	0.815113	0.039460	0.790476	

6	0.787048	0.029724	0.815854	0.058275	0.761905
7	0.793331	0.019518	0.812605	0.035296	0.776190
8	0.802282	0.025305	0.815113	0.039460	0.790476
9	0.787048	0.029724	0.815854	0.058275	0.761905
10	0.793331	0.019518	0.812605	0.035296	0.776190
11	0.802282	0.025305	0.815113	0.039460	0.790476
12	0.845645	0.035862	0.849393	0.055267	0.842857
13	0.848381	0.034569	0.850239	0.054749	0.847619
14	0.854535	0.036051	0.862647	0.056686	0.847619
15	0.852421	0.040673	0.849740	0.068559	0.857143
16	0.855956	0.036022	0.856087	0.056533	0.857143
17	0.857785	0.033010	0.859469	0.050968	0.857143
18	0.852421	0.040673	0.849740	0.068559	0.857143
19	0.858124	0.037579	0.860703	0.060717	0.857143
20	0.859953	0.034588	0.864084	0.055291	0.857143
21	0.852421	0.040673	0.849740	0.068559	0.857143
22	0.858124	0.037579	0.860703	0.060717	0.857143
23	0.859953	0.034588	0.864084	0.055291	0.857143
24	0.847681	0.046161	0.853095	0.060673	0.842857
25	0.846935	0.045592	0.856463	0.059905	0.838095
26	0.847681	0.046161	0.853095	0.060673	0.842857
27	0.862557	0.031585	0.864180	0.049922	0.861905
28	0.859853	0.029495	0.863693	0.049557	0.857143
29	0.862454	0.037019	0.863746	0.050590	0.861905
30	0.862557	0.031585	0.864180	0.049922	0.861905
31	0.859853	0.029495	0.863693	0.049557	0.857143
32	0.862454	0.037019	0.863746	0.050590	0.861905
33	0.862557	0.031585	0.864180	0.049922	0.861905
34	0.859853	0.029495	0.863693	0.049557	0.857143
35	0.862454	0.037019	0.863746	0.050590	0.861905

	recall_D1_std
0	0.023328
1	0.039841
2	0.024281
3	0.015058
4	0.024281
5	0.017817
6	0.015058
7	0.024281
8	0.017817
9	0.015058
10	0.024281
11	0.017817
12	0.019048
13	0.019048
14	0.019048
15	0.015058

```
16       0.021296
17       0.021296
18       0.015058
19       0.021296
20       0.021296
21       0.015058
22       0.021296
23       0.021296
24       0.032297
25       0.031587
26       0.032297
27       0.017817
28       0.015058
29       0.027766
30       0.017817
31       0.015058
32       0.027766
33       0.017817
34       0.015058
35       0.027766
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & learning rate,max depth,n estimators & accuracy D1 & accuracy D1 std & f1 D1
& f1 D1 std & precision D1 & precision D1 std & recall D1 & recall D1 std \\
\midrule
0 & 0.01,10,100 & 0.944 & 0.008 & 0.790 & 0.026 & 0.817 & 0.057 & 0.767 & 0.023
\\
1 & 0.01,10,150 & 0.947 & 0.011 & 0.803 & 0.039 & 0.822 & 0.046 & 0.786 & 0.040
\\
2 & 0.01,10,200 & 0.948 & 0.008 & 0.807 & 0.028 & 0.820 & 0.038 & 0.795 & 0.024
\\
3 & 0.01,15,100 & 0.943 & 0.009 & 0.787 & 0.030 & 0.816 & 0.058 & 0.762 &
\textbf{0.015} \\
4 & 0.01,15,150 & 0.945 & \textbf{0.006} & 0.793 & \textbf{0.02} & 0.813 &
\textbf{0.035} & 0.776 & 0.024 \\
5 & 0.01,15,200 & 0.947 & 0.008 & 0.802 & 0.025 & 0.815 & 0.039 & 0.790 & 0.018
\\
6 & 0.01,20,100 & 0.943 & 0.009 & 0.787 & 0.030 & 0.816 & 0.058 & 0.762 &
\textbf{0.015} \\
7 & 0.01,20,150 & 0.945 & \textbf{0.006} & 0.793 & \textbf{0.02} & 0.813 &
\textbf{0.035} & 0.776 & 0.024 \\
8 & 0.01,20,200 & 0.947 & 0.008 & 0.802 & 0.025 & 0.815 & 0.039 & 0.790 & 0.018
\\
9 & 0.01,25,100 & 0.943 & 0.009 & 0.787 & 0.030 & 0.816 & 0.058 & 0.762 &
```

```
\textbf{0.015} \\
10 & 0.01,25,150 & 0.945 & \textbf{0.006} & 0.793 & \textbf{0.02} & 0.813 &
\textbf{0.035} & 0.776 & 0.024 \\
11 & 0.01,25,200 & 0.947 & 0.008 & 0.802 & 0.025 & 0.815 & 0.039 & 0.790 & 0.018
\\
12 & 0.1,10,100 & 0.958 & 0.011 & 0.846 & 0.036 & 0.849 & 0.055 & 0.843 & 0.019
\\
13 & 0.1,10,150 & 0.958 & 0.010 & 0.848 & 0.035 & 0.850 & 0.055 & 0.848 & 0.019
\\
14 & 0.1,10,200 & 0.960 & 0.011 & 0.855 & 0.036 & 0.863 & 0.057 & 0.848 & 0.019
\\
15 & 0.1,15,100 & 0.959 & 0.013 & 0.852 & 0.041 & 0.850 & 0.069 & 0.857 &
\textbf{0.015} \\
16 & 0.1,15,150 & 0.960 & 0.011 & 0.856 & 0.036 & 0.856 & 0.057 & 0.857 & 0.021
\\
17 & 0.1,15,200 & 0.961 & 0.010 & 0.858 & 0.033 & 0.859 & 0.051 & 0.857 & 0.021
\\
18 & 0.1,20,100 & 0.959 & 0.013 & 0.852 & 0.041 & 0.850 & 0.069 & 0.857 &
\textbf{0.015} \\
19 & 0.1,20,150 & 0.961 & 0.011 & 0.858 & 0.038 & 0.861 & 0.061 & 0.857 & 0.021
\\
20 & 0.1,20,200 & \textbf{0.962} & 0.010 & 0.860 & 0.035 & \textbf{0.864} &
0.055 & 0.857 & 0.021 \\
21 & 0.1,25,100 & 0.959 & 0.013 & 0.852 & 0.041 & 0.850 & 0.069 & 0.857 &
\textbf{0.015} \\
22 & 0.1,25,150 & 0.961 & 0.011 & 0.858 & 0.038 & 0.861 & 0.061 & 0.857 & 0.021
\\
23 & 0.1,25,200 & \textbf{0.962} & 0.010 & 0.860 & 0.035 & \textbf{0.864} &
0.055 & 0.857 & 0.021 \\
24 & 0.2,10,100 & 0.958 & 0.013 & 0.848 & 0.046 & 0.853 & 0.061 & 0.843 & 0.032
\\
25 & 0.2,10,150 & 0.958 & 0.013 & 0.847 & 0.046 & 0.856 & 0.060 & 0.838 & 0.032
\\
26 & 0.2,10,200 & 0.958 & 0.013 & 0.848 & 0.046 & 0.853 & 0.061 & 0.843 & 0.032
\\
27 & 0.2,15,100 & \textbf{0.962} & 0.010 & \textbf{0.863} & 0.032 &
\textbf{0.864} & 0.050 & \textbf{0.862} & 0.018 \\
28 & 0.2,15,150 & \textbf{0.962} & 0.009 & 0.860 & 0.029 & \textbf{0.864} &
0.050 & 0.857 & \textbf{0.015} \\
29 & 0.2,15,200 & \textbf{0.962} & 0.011 & 0.862 & 0.037 & \textbf{0.864} &
0.051 & \textbf{0.862} & 0.028 \\
30 & 0.2,20,100 & \textbf{0.962} & 0.010 & \textbf{0.863} & 0.032 &
\textbf{0.864} & 0.050 & \textbf{0.862} & 0.018 \\
31 & 0.2,20,150 & \textbf{0.962} & 0.009 & 0.860 & 0.029 & \textbf{0.864} &
0.050 & 0.857 & \textbf{0.015} \\
32 & 0.2,20,200 & \textbf{0.962} & 0.011 & 0.862 & 0.037 & \textbf{0.864} &
0.051 & \textbf{0.862} & 0.028 \\
33 & 0.2,25,100 & \textbf{0.962} & 0.010 & \textbf{0.863} & 0.032 &
```

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\textbf{0.864} & 0.050 & \textbf{0.862} & 0.018 \\
34 & 0.2,25,150 & \textbf{0.962} & 0.009 & 0.860 & 0.029 & \textbf{0.864} &
0.050 & 0.857 & \textbf{0.015} \\
35 & 0.2,25,200 & \textbf{0.962} & 0.011 & 0.862 & 0.037 & \textbf{0.864} &
0.051 & \textbf{0.862} & 0.028 \\
\bottomrule
\end{tabular}
\end{table}
```

	learning_rate,max_depth,n_estimators	accuracy_D2	accuracy_D2_std	\
0	0.01,10,100	0.944010	0.011361	
1	0.01,10,150	0.945311	0.012090	
2	0.01,10,200	0.947917	0.011094	
3	0.01,15,100	0.943361	0.011011	
4	0.01,15,150	0.944010	0.010786	
5	0.01,15,200	0.947267	0.009956	
6	0.01,20,100	0.943361	0.011011	
7	0.01,20,150	0.944010	0.010786	
8	0.01,20,200	0.947267	0.009956	
9	0.01,25,100	0.943361	0.011011	
10	0.01,25,150	0.944010	0.010786	
11	0.01,25,200	0.947267	0.009956	
12	0.1,10,100	0.954429	0.014849	
13	0.1,10,150	0.955078	0.015607	
14	0.1,10,200	0.955730	0.015768	
15	0.1,15,100	0.957033	0.013876	
16	0.1,15,150	0.957682	0.014421	
17	0.1,15,200	0.958334	0.013571	
18	0.1,20,100	0.957684	0.013658	
19	0.1,20,150	0.958985	0.013756	
20	0.1,20,200	0.958985	0.013124	
21	0.1,25,100	0.957684	0.013658	
22	0.1,25,150	0.958985	0.013756	
23	0.1,25,200	0.958985	0.013124	
24	0.2,10,100	0.957031	0.015609	
25	0.2,10,150	0.955076	0.016665	
26	0.2,10,200	0.955728	0.014658	
27	0.2,15,100	0.958338	0.012064	
28	0.2,15,150	0.957033	0.012593	
29	0.2,15,200	0.957033	0.011537	
30	0.2,20,100	0.958338	0.012064	
31	0.2,20,150	0.957033	0.012593	
32	0.2,20,200	0.957033	0.011537	
33	0.2,25,100	0.958338	0.012064	
34	0.2,25,150	0.957033	0.012593	
35	0.2,25,200	0.957033	0.011537	

	f1_D2	f1_D2_std	precision_D2	precision_D2_std	recall_D2	\
0	0.799813	0.043789	0.801456	0.035404	0.801057	
1	0.801808	0.046646	0.814428	0.040947	0.791543	
2	0.811590	0.041151	0.824942	0.042833	0.800846	
3	0.797808	0.043632	0.796721	0.025799	0.801057	
4	0.797328	0.041168	0.809795	0.036463	0.787104	
5	0.809700	0.037326	0.820805	0.036809	0.800951	
6	0.797808	0.043632	0.796721	0.025799	0.801057	
7	0.797328	0.041168	0.809795	0.036463	0.787104	
8	0.809700	0.037326	0.820805	0.036809	0.800951	
9	0.797808	0.043632	0.796721	0.025799	0.801057	
10	0.797328	0.041168	0.809795	0.036463	0.787104	
11	0.809700	0.037326	0.820805	0.036809	0.800951	
12	0.833879	0.053140	0.855502	0.056885	0.814799	
13	0.836151	0.055133	0.860579	0.063499	0.814905	
14	0.838905	0.055765	0.861092	0.063804	0.819450	
15	0.843506	0.049656	0.864951	0.053415	0.824101	
16	0.845668	0.051136	0.870008	0.060296	0.824101	
17	0.847486	0.048941	0.873602	0.054663	0.824101	
18	0.846317	0.048591	0.865683	0.053230	0.828753	
19	0.850430	0.048594	0.874886	0.057735	0.828753	
20	0.850287	0.047052	0.874415	0.054024	0.828753	
21	0.846317	0.048591	0.865683	0.053230	0.828753	
22	0.850430	0.048594	0.874886	0.057735	0.828753	
23	0.850287	0.047052	0.874415	0.054024	0.828753	
24	0.842631	0.056613	0.868107	0.058436	0.819450	
25	0.836903	0.059322	0.856108	0.064052	0.819450	
26	0.838809	0.052375	0.860149	0.055933	0.819556	
27	0.846183	0.045788	0.876093	0.041056	0.819450	
28	0.842297	0.046690	0.868071	0.045299	0.819450	
29	0.843126	0.042492	0.864678	0.041198	0.824101	
30	0.846183	0.045788	0.876093	0.041056	0.819450	
31	0.842297	0.046690	0.868071	0.045299	0.819450	
32	0.843126	0.042492	0.864678	0.041198	0.824101	
33	0.846183	0.045788	0.876093	0.041056	0.819450	
34	0.842297	0.046690	0.868071	0.045299	0.819450	
35	0.843126	0.042492	0.864678	0.041198	0.824101	

	recall_D2_std
0	0.071001
1	0.066097
2	0.058320
3	0.071001
4	0.061068
5	0.056075
6	0.071001
7	0.061068
8	0.056075

```
9        0.071001
10       0.061068
11       0.056075
12       0.060667
13       0.060308
14       0.059522
15       0.054123
16       0.054123
17       0.054123
18       0.052010
19       0.052010
20       0.052010
21       0.052010
22       0.052010
23       0.052010
24       0.061312
25       0.061312
26       0.057289
27       0.059522
28       0.059522
29       0.056086
30       0.059522
31       0.059522
32       0.056086
33       0.059522
34       0.059522
35       0.056086
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & learning rate,max depth,n estimators & accuracy D2 & accuracy D2 std & f1 D2
& f1 D2 std & precision D2 & precision D2 std & recall D2 & recall D2 std \\
\midrule
0 & 0.01,10,100 & 0.944 & 0.011 & 0.800 & 0.044 & 0.801 & 0.035 & 0.801 & 0.071
\\
1 & 0.01,10,150 & 0.945 & 0.012 & 0.802 & 0.047 & 0.814 & 0.041 & 0.792 & 0.066
\\
2 & 0.01,10,200 & 0.948 & 0.011 & 0.812 & 0.041 & 0.825 & 0.043 & 0.801 & 0.058
\\
3 & 0.01,15,100 & 0.943 & 0.011 & 0.798 & 0.044 & 0.797 & \textbf{0.026} & 0.801
& 0.071 \\
4 & 0.01,15,150 & 0.944 & 0.011 & 0.797 & 0.041 & 0.810 & 0.036 & 0.787 & 0.061
\\
5 & 0.01,15,200 & 0.947 & \textbf{0.01} & 0.810 & \textbf{0.037} & 0.821 & 0.037
& 0.801 & 0.056 \\
```

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6 & 0.01,20,100 & 0.943 & 0.011 & 0.798 & 0.044 & 0.797 & \textbf{0.026} & 0.801
& 0.071 \\
7 & 0.01,20,150 & 0.944 & 0.011 & 0.797 & 0.041 & 0.810 & 0.036 & 0.787 & 0.061
\\
8 & 0.01,20,200 & 0.947 & \textbf{0.01} & 0.810 & \textbf{0.037} & 0.821 & 0.037
& 0.801 & 0.056 \\
9 & 0.01,25,100 & 0.943 & 0.011 & 0.798 & 0.044 & 0.797 & \textbf{0.026} & 0.801
& 0.071 \\
10 & 0.01,25,150 & 0.944 & 0.011 & 0.797 & 0.041 & 0.810 & 0.036 & 0.787 & 0.061
\\
11 & 0.01,25,200 & 0.947 & \textbf{0.01} & 0.810 & \textbf{0.037} & 0.821 &
0.037 & 0.801 & 0.056 \\
12 & 0.1,10,100 & 0.954 & 0.015 & 0.834 & 0.053 & 0.856 & 0.057 & 0.815 & 0.061
\\
13 & 0.1,10,150 & 0.955 & 0.016 & 0.836 & 0.055 & 0.861 & 0.063 & 0.815 & 0.060
\\
14 & 0.1,10,200 & 0.956 & 0.016 & 0.839 & 0.056 & 0.861 & 0.064 & 0.819 & 0.060
\\
15 & 0.1,15,100 & 0.957 & 0.014 & 0.844 & 0.050 & 0.865 & 0.053 & 0.824 & 0.054
\\
16 & 0.1,15,150 & 0.958 & 0.014 & 0.846 & 0.051 & 0.870 & 0.060 & 0.824 & 0.054
\\
17 & 0.1,15,200 & 0.958 & 0.014 & 0.847 & 0.049 & 0.874 & 0.055 & 0.824 & 0.054
\\
18 & 0.1,20,100 & 0.958 & 0.014 & 0.846 & 0.049 & 0.866 & 0.053 & \textbf{0.829}
& \textbf{0.052} \\
19 & 0.1,20,150 & \textbf{0.959} & 0.014 & \textbf{0.85} & 0.049 & 0.875 & 0.058
& \textbf{0.829} & \textbf{0.052} \\
20 & 0.1,20,200 & \textbf{0.959} & 0.013 & \textbf{0.85} & 0.047 & 0.874 & 0.054
& \textbf{0.829} & \textbf{0.052} \\
21 & 0.1,25,100 & 0.958 & 0.014 & 0.846 & 0.049 & 0.866 & 0.053 & \textbf{0.829}
& \textbf{0.052} \\
22 & 0.1,25,150 & \textbf{0.959} & 0.014 & \textbf{0.85} & 0.049 & 0.875 & 0.058
& \textbf{0.829} & \textbf{0.052} \\
23 & 0.1,25,200 & \textbf{0.959} & 0.013 & \textbf{0.85} & 0.047 & 0.874 & 0.054
& \textbf{0.829} & \textbf{0.052} \\
24 & 0.2,10,100 & 0.957 & 0.016 & 0.843 & 0.057 & 0.868 & 0.058 & 0.819 & 0.061
\\
25 & 0.2,10,150 & 0.955 & 0.017 & 0.837 & 0.059 & 0.856 & 0.064 & 0.819 & 0.061
\\
26 & 0.2,10,200 & 0.956 & 0.015 & 0.839 & 0.052 & 0.860 & 0.056 & 0.820 & 0.057
\\
27 & 0.2,15,100 & 0.958 & 0.012 & 0.846 & 0.046 & \textbf{0.876} & 0.041 & 0.819
& 0.060 \\
28 & 0.2,15,150 & 0.957 & 0.013 & 0.842 & 0.047 & 0.868 & 0.045 & 0.819 & 0.060
\\
29 & 0.2,15,200 & 0.957 & 0.012 & 0.843 & 0.042 & 0.865 & 0.041 & 0.824 & 0.056
\\
```

```
30 & 0.2,20,100 & 0.958 & 0.012 & 0.846 & 0.046 & \textbf{0.876} & 0.041 & 0.819
& 0.060 \\
31 & 0.2,20,150 & 0.957 & 0.013 & 0.842 & 0.047 & 0.868 & 0.045 & 0.819 & 0.060
\\
32 & 0.2,20,200 & 0.957 & 0.012 & 0.843 & 0.042 & 0.865 & 0.041 & 0.824 & 0.056
\\
33 & 0.2,25,100 & 0.958 & 0.012 & 0.846 & 0.046 & \textbf{0.876} & 0.041 & 0.819
& 0.060 \\
34 & 0.2,25,150 & 0.957 & 0.013 & 0.842 & 0.047 & 0.868 & 0.045 & 0.819 & 0.060
\\
35 & 0.2,25,200 & 0.957 & 0.012 & 0.843 & 0.042 & 0.865 & 0.041 & 0.824 & 0.056
\\
\bottomrule
\end{tabular}
\end{table}
```

	learning_rate,max_depth,n_estimators	accuracy_D3	accuracy_D3_std	\
0	0.01,10,100	0.953776	0.008345	
1	0.01,10,150	0.955078	0.006953	
2	0.01,10,200	0.958983	0.003922	
3	0.01,15,100	0.954427	0.008980	
4	0.01,15,150	0.954431	0.006801	
5	0.01,15,200	0.960286	0.003197	
6	0.01,20,100	0.954427	0.008980	
7	0.01,20,150	0.954431	0.006801	
8	0.01,20,200	0.960286	0.003197	
9	0.01,25,100	0.954427	0.008980	
10	0.01,25,150	0.954431	0.006801	
11	0.01,25,200	0.960286	0.003197	
12	0.1,10,100	0.965496	0.004412	
13	0.1,10,150	0.964193	0.005451	
14	0.1,10,200	0.964842	0.005614	
15	0.1,15,100	0.966151	0.006347	
16	0.1,15,150	0.967450	0.005031	
17	0.1,15,200	0.967448	0.005046	
18	0.1,20,100	0.966803	0.006277	
19	0.1,20,150	0.968101	0.004768	
20	0.1,20,200	0.967448	0.005046	
21	0.1,25,100	0.966803	0.006277	
22	0.1,25,150	0.968101	0.004768	
23	0.1,25,200	0.967448	0.005046	
24	0.2,10,100	0.964842	0.005980	
25	0.2,10,150	0.966145	0.004425	
26	0.2,10,200	0.966799	0.002413	
27	0.2,15,100	0.964197	0.005418	
28	0.2,15,150	0.965496	0.004412	
29	0.2,15,200	0.966149	0.004389	

30		0.2,20,100	0.964197	0.005418
31		0.2,20,150	0.965496	0.004412
32		0.2,20,200	0.966149	0.004389
33		0.2,25,100	0.964197	0.005418
34		0.2,25,150	0.965496	0.004412
35		0.2,25,200	0.966149	0.004389

	f1_D3	f1_D3_std	precision_D3	precision_D3_std	recall_D3	\
0	0.837430	0.024635	0.850343	0.052571	0.827273	
1	0.840347	0.020742	0.861400	0.048979	0.822727	
2	0.853349	0.010447	0.878098	0.037431	0.831818	
3	0.839496	0.026559	0.854958	0.057509	0.827273	
4	0.837423	0.022438	0.860037	0.044785	0.818182	
5	0.857894	0.008871	0.882643	0.033848	0.836364	
6	0.839496	0.026559	0.854958	0.057509	0.827273	
7	0.837423	0.022438	0.860037	0.044785	0.818182	
8	0.857894	0.008871	0.882643	0.033848	0.836364	
9	0.839496	0.026559	0.854958	0.057509	0.827273	
10	0.837423	0.022438	0.860037	0.044785	0.818182	
11	0.857894	0.008871	0.882643	0.033848	0.836364	
12	0.877666	0.015098	0.892418	0.021850	0.863636	
13	0.873567	0.018782	0.884410	0.025644	0.863636	
14	0.876683	0.019669	0.880914	0.020792	0.872727	
15	0.879489	0.023426	0.896097	0.019351	0.863636	
16	0.884763	0.017926	0.897564	0.021397	0.872727	
17	0.885292	0.017927	0.893885	0.021424	0.877273	
18	0.881521	0.023264	0.900305	0.018470	0.863636	
19	0.887390	0.016568	0.898029	0.021522	0.877273	
20	0.885292	0.017927	0.893885	0.021424	0.877273	
21	0.881521	0.023264	0.900305	0.018470	0.863636	
22	0.887390	0.016568	0.898029	0.021522	0.877273	
23	0.885292	0.017927	0.893885	0.021424	0.877273	
24	0.876938	0.019359	0.881521	0.030284	0.872727	
25	0.881892	0.014621	0.882422	0.023346	0.881818	
26	0.883826	0.008343	0.886338	0.016974	0.881818	
27	0.874694	0.019054	0.876985	0.021601	0.872727	
28	0.879860	0.014853	0.878225	0.020779	0.881818	
29	0.881326	0.014986	0.885871	0.023133	0.877273	
30	0.874694	0.019054	0.876985	0.021601	0.872727	
31	0.879860	0.014853	0.878225	0.020779	0.881818	
32	0.881326	0.014986	0.885871	0.023133	0.877273	
33	0.874694	0.019054	0.876985	0.021601	0.872727	
34	0.879860	0.014853	0.878225	0.020779	0.881818	
35	0.881326	0.014986	0.885871	0.023133	0.877273	

	recall_D3_std
0	0.023177
1	0.026504

```
2        0.023177
3        0.023177
4        0.032141
5        0.026504
6        0.023177
7        0.032141
8        0.026504
9        0.023177
10       0.032141
11       0.026504
12       0.014374
13       0.024896
14       0.023177
15       0.028748
16       0.023177
17       0.023177
18       0.028748
19       0.018182
20       0.023177
21       0.028748
22       0.018182
23       0.023177
24       0.011134
25       0.017008
26       0.017008
27       0.023177
28       0.017008
29       0.018182
30       0.023177
31       0.017008
32       0.018182
33       0.023177
34       0.017008
35       0.018182
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & learning rate,max depth,n estimators & accuracy D3 & accuracy D3 std & f1 D3
& f1 D3 std & precision D3 & precision D3 std & recall D3 & recall D3 std \\
\midrule
0 & 0.01,10,100 & 0.954 & 0.008 & 0.837 & 0.025 & 0.850 & 0.053 & 0.827 & 0.023
\\
1 & 0.01,10,150 & 0.955 & 0.007 & 0.840 & 0.021 & 0.861 & 0.049 & 0.823 & 0.027
\\
2 & 0.01,10,200 & 0.959 & 0.004 & 0.853 & 0.010 & 0.878 & 0.037 & 0.832 & 0.023
```

```
\\
3 & 0.01,15,100 & 0.954 & 0.009 & 0.839 & 0.027 & 0.855 & 0.058 & 0.827 & 0.023
\\
4 & 0.01,15,150 & 0.954 & 0.007 & 0.837 & 0.022 & 0.860 & 0.045 & 0.818 & 0.032
\\
5 & 0.01,15,200 & 0.960 & 0.003 & 0.858 & 0.009 & 0.883 & 0.034 & 0.836 & 0.027
\\
6 & 0.01,20,100 & 0.954 & 0.009 & 0.839 & 0.027 & 0.855 & 0.058 & 0.827 & 0.023
\\
7 & 0.01,20,150 & 0.954 & 0.007 & 0.837 & 0.022 & 0.860 & 0.045 & 0.818 & 0.032
\\
8 & 0.01,20,200 & 0.960 & 0.003 & 0.858 & 0.009 & 0.883 & 0.034 & 0.836 & 0.027
\\
9 & 0.01,25,100 & 0.954 & 0.009 & 0.839 & 0.027 & 0.855 & 0.058 & 0.827 & 0.023
\\
10 & 0.01,25,150 & 0.954 & 0.007 & 0.837 & 0.022 & 0.860 & 0.045 & 0.818 & 0.032
\\
11 & 0.01,25,200 & 0.960 & 0.003 & 0.858 & 0.009 & 0.883 & 0.034 & 0.836 & 0.027
\\
12 & 0.1,10,100 & 0.965 & 0.004 & 0.878 & 0.015 & 0.892 & 0.022 & 0.864 & 0.014
\\
13 & 0.1,10,150 & 0.964 & 0.005 & 0.874 & 0.019 & 0.884 & 0.026 & 0.864 & 0.025
\\
14 & 0.1,10,200 & 0.965 & 0.006 & 0.877 & 0.020 & 0.881 & 0.021 & 0.873 & 0.023
\\
15 & 0.1,15,100 & 0.966 & 0.006 & 0.879 & 0.023 & 0.896 & 0.019 & 0.864 & 0.029
\\
16 & 0.1,15,150 & 0.967 & 0.005 & 0.885 & 0.018 & 0.898 & 0.021 & 0.873 & 0.023
\\
17 & 0.1,15,200 & 0.967 & 0.005 & 0.885 & 0.018 & 0.894 & 0.021 & 0.877 & 0.023
\\
18 & 0.1,20,100 & 0.967 & 0.006 & 0.882 & 0.023 & \textbf{0.9} & 0.018 & 0.864 &
0.029 \\
19 & 0.1,20,150 & \textbf{0.968} & 0.005 & \textbf{0.887} & 0.017 & 0.898 &
0.022 & 0.877 & 0.018 \\
20 & 0.1,20,200 & 0.967 & 0.005 & 0.885 & 0.018 & 0.894 & 0.021 & 0.877 & 0.023
\\
21 & 0.1,25,100 & 0.967 & 0.006 & 0.882 & 0.023 & \textbf{0.9} & 0.018 & 0.864 &
0.029 \\
22 & 0.1,25,150 & \textbf{0.968} & 0.005 & \textbf{0.887} & 0.017 & 0.898 &
0.022 & 0.877 & 0.018 \\
23 & 0.1,25,200 & 0.967 & 0.005 & 0.885 & 0.018 & 0.894 & 0.021 & 0.877 & 0.023
\\
24 & 0.2,10,100 & 0.965 & 0.006 & 0.877 & 0.019 & 0.882 & 0.030 & 0.873 &
\textbf{0.011} \\
25 & 0.2,10,150 & 0.966 & 0.004 & 0.882 & 0.015 & 0.882 & 0.023 & \textbf{0.882}
& 0.017 \\
26 & 0.2,10,200 & 0.967 & \textbf{0.002} & 0.884 & \textbf{0.008} & 0.886 &
```

```
\textbf{0.017} & \textbf{0.882} & 0.017 \\
27 & 0.2,15,100 & 0.964 & 0.005 & 0.875 & 0.019 & 0.877 & 0.022 & 0.873 & 0.023
\\
28 & 0.2,15,150 & 0.965 & 0.004 & 0.880 & 0.015 & 0.878 & 0.021 & \textbf{0.882}
& 0.017 \\
29 & 0.2,15,200 & 0.966 & 0.004 & 0.881 & 0.015 & 0.886 & 0.023 & 0.877 & 0.018
\\
30 & 0.2,20,100 & 0.964 & 0.005 & 0.875 & 0.019 & 0.877 & 0.022 & 0.873 & 0.023
\\
31 & 0.2,20,150 & 0.965 & 0.004 & 0.880 & 0.015 & 0.878 & 0.021 & \textbf{0.882}
& 0.017 \\
32 & 0.2,20,200 & 0.966 & 0.004 & 0.881 & 0.015 & 0.886 & 0.023 & 0.877 & 0.018
\\
33 & 0.2,25,100 & 0.964 & 0.005 & 0.875 & 0.019 & 0.877 & 0.022 & 0.873 & 0.023
\\
34 & 0.2,25,150 & 0.965 & 0.004 & 0.880 & 0.015 & 0.878 & 0.021 & \textbf{0.882}
& 0.017 \\
35 & 0.2,25,200 & 0.966 & 0.004 & 0.881 & 0.015 & 0.886 & 0.023 & 0.877 & 0.018
\\
\bottomrule
\end{tabular}
\end{table}
```

	learning_rate,max_depth,n_estimators	accuracy_D4	accuracy_D4_std	\
0	0.01,10,100	0.957031	0.015196	
1	0.01,10,150	0.957684	0.011646	
2	0.01,10,200	0.960290	0.011892	
3	0.01,15,100	0.957031	0.015196	
4	0.01,15,150	0.957684	0.011646	
5	0.01,15,200	0.960942	0.010884	
6	0.01,20,100	0.957031	0.015196	
7	0.01,20,150	0.957684	0.011646	
8	0.01,20,200	0.960942	0.010884	
9	0.01,25,100	0.957031	0.015196	
10	0.01,25,150	0.957684	0.011646	
11	0.01,25,200	0.960942	0.010884	
12	0.1,10,100	0.968095	0.008097	
13	0.1,10,150	0.968747	0.008895	
14	0.1,10,200	0.970697	0.009676	
15	0.1,15,100	0.968097	0.009310	
16	0.1,15,150	0.970045	0.009979	
17	0.1,15,200	0.970045	0.009979	
18	0.1,20,100	0.968097	0.009310	
19	0.1,20,150	0.970045	0.009979	
20	0.1,20,200	0.970045	0.009979	
21	0.1,25,100	0.968097	0.009310	
22	0.1,25,150	0.970045	0.009979	

23		0.1,25,200	0.970045	0.009979
24		0.2,10,100	0.969396	0.007329
25		0.2,10,150	0.971346	0.009319
26		0.2,10,200	0.970697	0.008509
27		0.2,15,100	0.968099	0.006314
28		0.2,15,150	0.969396	0.007613
29		0.2,15,200	0.968747	0.007029
30		0.2,20,100	0.968099	0.006314
31		0.2,20,150	0.969396	0.007613
32		0.2,20,200	0.968747	0.007029
33		0.2,25,100	0.968099	0.006314
34		0.2,25,150	0.969396	0.007613
35		0.2,25,200	0.968747	0.007029

	f1_D4	f1_D4_std	precision_D4	precision_D4_std	recall_D4	\
0	0.868160	0.046508	0.873603	0.062902	0.868235	
1	0.873070	0.033717	0.862056	0.054956	0.888235	
2	0.880122	0.034318	0.876412	0.060127	0.888235	
3	0.868160	0.046508	0.873603	0.062902	0.868235	
4	0.873070	0.033717	0.862056	0.054956	0.888235	
5	0.881586	0.032789	0.878409	0.051850	0.888235	
6	0.868160	0.046508	0.873603	0.062902	0.868235	
7	0.873070	0.033717	0.862056	0.054956	0.888235	
8	0.881586	0.032789	0.878409	0.051850	0.888235	
9	0.868160	0.046508	0.873603	0.062902	0.868235	
10	0.873070	0.033717	0.862056	0.054956	0.888235	
11	0.881586	0.032789	0.878409	0.051850	0.888235	
12	0.901381	0.025723	0.909658	0.037816	0.896157	
13	0.903242	0.028012	0.913344	0.039651	0.896157	
14	0.909395	0.030075	0.917192	0.038439	0.904078	
15	0.900973	0.029798	0.914011	0.044903	0.892157	
16	0.906798	0.031410	0.920068	0.038096	0.896157	
17	0.906798	0.031410	0.920068	0.038096	0.896157	
18	0.900973	0.029798	0.914011	0.044903	0.892157	
19	0.906798	0.031410	0.920068	0.038096	0.896157	
20	0.906798	0.031410	0.920068	0.038096	0.896157	
21	0.900973	0.029798	0.914011	0.044903	0.892157	
22	0.906798	0.031410	0.920068	0.038096	0.896157	
23	0.906798	0.031410	0.920068	0.038096	0.896157	
24	0.905378	0.023571	0.912587	0.029560	0.900157	
25	0.910550	0.030218	0.924050	0.033731	0.900078	
26	0.908753	0.027852	0.920683	0.034213	0.900078	
27	0.901695	0.019375	0.909551	0.035845	0.896235	
28	0.904850	0.025085	0.916276	0.030831	0.896157	
29	0.903089	0.023266	0.912976	0.032444	0.896157	
30	0.901695	0.019375	0.909551	0.035845	0.896235	
31	0.904850	0.025085	0.916276	0.030831	0.896157	
32	0.903089	0.023266	0.912976	0.032444	0.896157	

```
33  0.901695   0.019375      0.909551          0.035845   0.896235
34  0.904850   0.025085      0.916276          0.030831   0.896157
35  0.903089   0.023266      0.912976          0.032444   0.896157

    recall_D4_std
0        0.070215
1        0.048587
2        0.048587
3        0.070215
4        0.048587
5        0.048587
6        0.070215
7        0.048587
8        0.048587
9        0.070215
10       0.048587
11       0.048587
12       0.049842
13       0.049842
14       0.049759
15       0.056191
16       0.049842
17       0.049842
18       0.056191
19       0.049842
20       0.049842
21       0.056191
22       0.049842
23       0.049842
24       0.044033
25       0.055250
26       0.055250
27       0.039050
28       0.049842
29       0.049842
30       0.039050
31       0.049842
32       0.049842
33       0.039050
34       0.049842
35       0.049842
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & learning rate,max depth,n estimators & accuracy D4 & accuracy D4 std & f1 D4
```

```
& f1 D4 std & precision D4 & precision D4 std & recall D4 & recall D4 std \\
\midrule
0 & 0.01,10,100 & 0.957 & 0.015 & 0.868 & 0.047 & 0.874 & 0.063 & 0.868 & 0.070
\\
1 & 0.01,10,150 & 0.958 & 0.012 & 0.873 & 0.034 & 0.862 & 0.055 & 0.888 & 0.049
\\
2 & 0.01,10,200 & 0.960 & 0.012 & 0.880 & 0.034 & 0.876 & 0.060 & 0.888 & 0.049
\\
3 & 0.01,15,100 & 0.957 & 0.015 & 0.868 & 0.047 & 0.874 & 0.063 & 0.868 & 0.070
\\
4 & 0.01,15,150 & 0.958 & 0.012 & 0.873 & 0.034 & 0.862 & 0.055 & 0.888 & 0.049
\\
5 & 0.01,15,200 & 0.961 & 0.011 & 0.882 & 0.033 & 0.878 & 0.052 & 0.888 & 0.049
\\
6 & 0.01,20,100 & 0.957 & 0.015 & 0.868 & 0.047 & 0.874 & 0.063 & 0.868 & 0.070
\\
7 & 0.01,20,150 & 0.958 & 0.012 & 0.873 & 0.034 & 0.862 & 0.055 & 0.888 & 0.049
\\
8 & 0.01,20,200 & 0.961 & 0.011 & 0.882 & 0.033 & 0.878 & 0.052 & 0.888 & 0.049
\\
9 & 0.01,25,100 & 0.957 & 0.015 & 0.868 & 0.047 & 0.874 & 0.063 & 0.868 & 0.070
\\
10 & 0.01,25,150 & 0.958 & 0.012 & 0.873 & 0.034 & 0.862 & 0.055 & 0.888 & 0.049
\\
11 & 0.01,25,200 & 0.961 & 0.011 & 0.882 & 0.033 & 0.878 & 0.052 & 0.888 & 0.049
\\
12 & 0.1,10,100 & 0.968 & 0.008 & 0.901 & 0.026 & 0.910 & 0.038 & 0.896 & 0.050
\\
13 & 0.1,10,150 & 0.969 & 0.009 & 0.903 & 0.028 & 0.913 & 0.040 & 0.896 & 0.050
\\
14 & 0.1,10,200 & \textbf{0.971} & 0.010 & 0.909 & 0.030 & 0.917 & 0.038 &
\textbf{0.904} & 0.050 \\
15 & 0.1,15,100 & 0.968 & 0.009 & 0.901 & 0.030 & 0.914 & 0.045 & 0.892 & 0.056
\\
16 & 0.1,15,150 & 0.970 & 0.010 & 0.907 & 0.031 & 0.920 & 0.038 & 0.896 & 0.050
\\
17 & 0.1,15,200 & 0.970 & 0.010 & 0.907 & 0.031 & 0.920 & 0.038 & 0.896 & 0.050
\\
18 & 0.1,20,100 & 0.968 & 0.009 & 0.901 & 0.030 & 0.914 & 0.045 & 0.892 & 0.056
\\
19 & 0.1,20,150 & 0.970 & 0.010 & 0.907 & 0.031 & 0.920 & 0.038 & 0.896 & 0.050
\\
20 & 0.1,20,200 & 0.970 & 0.010 & 0.907 & 0.031 & 0.920 & 0.038 & 0.896 & 0.050
\\
21 & 0.1,25,100 & 0.968 & 0.009 & 0.901 & 0.030 & 0.914 & 0.045 & 0.892 & 0.056
\\
22 & 0.1,25,150 & 0.970 & 0.010 & 0.907 & 0.031 & 0.920 & 0.038 & 0.896 & 0.050
\\
```

```
23 & 0.1,25,200 & 0.970 & 0.010 & 0.907 & 0.031 & 0.920 & 0.038 & 0.896 & 0.050
\\
24 & 0.2,10,100 & 0.969 & 0.007 & 0.905 & 0.024 & 0.913 & \textbf{0.03} & 0.900
& 0.044 \\
25 & 0.2,10,150 & \textbf{0.971} & 0.009 & \textbf{0.911} & 0.030 &
\textbf{0.924} & 0.034 & 0.900 & 0.055 \\
26 & 0.2,10,200 & \textbf{0.971} & 0.009 & 0.909 & 0.028 & 0.921 & 0.034 & 0.900
& 0.055 \\
27 & 0.2,15,100 & 0.968 & \textbf{0.006} & 0.902 & \textbf{0.019} & 0.910 &
0.036 & 0.896 & \textbf{0.039} \\
28 & 0.2,15,150 & 0.969 & 0.008 & 0.905 & 0.025 & 0.916 & 0.031 & 0.896 & 0.050
\\
29 & 0.2,15,200 & 0.969 & 0.007 & 0.903 & 0.023 & 0.913 & 0.032 & 0.896 & 0.050
\\
30 & 0.2,20,100 & 0.968 & \textbf{0.006} & 0.902 & \textbf{0.019} & 0.910 &
0.036 & 0.896 & \textbf{0.039} \\
31 & 0.2,20,150 & 0.969 & 0.008 & 0.905 & 0.025 & 0.916 & 0.031 & 0.896 & 0.050
\\
32 & 0.2,20,200 & 0.969 & 0.007 & 0.903 & 0.023 & 0.913 & 0.032 & 0.896 & 0.050
\\
33 & 0.2,25,100 & 0.968 & \textbf{0.006} & 0.902 & \textbf{0.019} & 0.910 &
0.036 & 0.896 & \textbf{0.039} \\
34 & 0.2,25,150 & 0.969 & 0.008 & 0.905 & 0.025 & 0.916 & 0.031 & 0.896 & 0.050
\\
35 & 0.2,25,200 & 0.969 & 0.007 & 0.903 & 0.023 & 0.913 & 0.032 & 0.896 & 0.050
\\
\bottomrule
\end{tabular}
\end{table}
```

```
   learning_rate,max_depth,n_estimators  accuracy_D5  accuracy_D5_std  \
0                            0.01,10,100     0.978521         0.008868
1                            0.01,10,150     0.977865         0.006954
2                            0.01,10,200     0.977218         0.006815
3                            0.01,15,100     0.977869         0.007800
4                            0.01,15,150     0.977865         0.006954
5                            0.01,15,200     0.977218         0.006815
6                            0.01,20,100     0.977869         0.007800
7                            0.01,20,150     0.977865         0.006954
8                            0.01,20,200     0.977218         0.006815
9                            0.01,25,100     0.977869         0.007800
10                           0.01,25,150     0.977865         0.006954
11                           0.01,25,200     0.977218         0.006815
12                            0.1,10,100     0.983077         0.008332
13                            0.1,10,150     0.982427         0.008869
14                            0.1,10,200     0.983726         0.007974
15                            0.1,15,100     0.983075         0.009070
```

16		0.1,15,150	0.981776	0.009780
17		0.1,15,200	0.982425	0.009342
18		0.1,20,100	0.983075	0.009070
19		0.1,20,150	0.981776	0.009780
20		0.1,20,200	0.982425	0.009342
21		0.1,25,100	0.983075	0.009070
22		0.1,25,150	0.981776	0.009780
23		0.1,25,200	0.982425	0.009342
24		0.2,10,100	0.983728	0.007415
25		0.2,10,150	0.984378	0.006949
26		0.2,10,200	0.985027	0.006705
27		0.2,15,100	0.983726	0.006508
28		0.2,15,150	0.984375	0.006315
29		0.2,15,200	0.985027	0.006705
30		0.2,20,100	0.983726	0.006508
31		0.2,20,150	0.984375	0.006315
32		0.2,20,200	0.985027	0.006705
33		0.2,25,100	0.983726	0.006508
34		0.2,25,150	0.984375	0.006315
35		0.2,25,200	0.985027	0.006705

	f1_D5	f1_D5_std	precision_D5	precision_D5_std	recall_D5	\
0	0.923228	0.031740	0.905434	0.040908	0.942857	
1	0.919846	0.026456	0.907461	0.019786	0.933333	
2	0.918417	0.024420	0.900383	0.030041	0.938095	
3	0.920931	0.028022	0.900893	0.033368	0.942857	
4	0.919846	0.026456	0.907461	0.019786	0.933333	
5	0.918417	0.024420	0.900383	0.030041	0.938095	
6	0.920931	0.028022	0.900893	0.033368	0.942857	
7	0.919846	0.026456	0.907461	0.019786	0.933333	
8	0.918417	0.024420	0.900383	0.030041	0.938095	
9	0.920931	0.028022	0.900893	0.033368	0.942857	
10	0.919846	0.026456	0.907461	0.019786	0.933333	
11	0.918417	0.024420	0.900383	0.030041	0.938095	
12	0.940265	0.028851	0.915959	0.043341	0.966667	
13	0.938218	0.030440	0.912325	0.047417	0.966667	
14	0.942359	0.027761	0.919752	0.040064	0.966667	
15	0.940321	0.031208	0.915984	0.045409	0.966667	
16	0.936180	0.033362	0.908557	0.051471	0.966667	
17	0.938227	0.032049	0.912191	0.048028	0.966667	
18	0.940321	0.031208	0.915984	0.045409	0.966667	
19	0.936180	0.033362	0.908557	0.051471	0.966667	
20	0.938227	0.032049	0.912191	0.048028	0.966667	
21	0.940321	0.031208	0.915984	0.045409	0.966667	
22	0.936180	0.033362	0.908557	0.051471	0.966667	
23	0.938227	0.032049	0.912191	0.048028	0.966667	
24	0.942350	0.025835	0.919899	0.039397	0.966667	
25	0.944444	0.024435	0.923692	0.035340	0.966667	

26	0.946586	0.023692	0.927653	0.032482	0.966667
27	0.942201	0.022941	0.919358	0.032646	0.966667
28	0.944343	0.022364	0.923319	0.030104	0.966667
29	0.946586	0.023692	0.927653	0.032482	0.966667
30	0.942201	0.022941	0.919358	0.032646	0.966667
31	0.944343	0.022364	0.923319	0.030104	0.966667
32	0.946586	0.023692	0.927653	0.032482	0.966667
33	0.942201	0.022941	0.919358	0.032646	0.966667
34	0.944343	0.022364	0.923319	0.030104	0.966667
35	0.946586	0.023692	0.927653	0.032482	0.966667

	recall_D5_std
0	0.035635
1	0.040963
2	0.032297
3	0.035635
4	0.040963
5	0.032297
6	0.035635
7	0.040963
8	0.032297
9	0.035635
10	0.040963
11	0.032297
12	0.019048
13	0.019048
14	0.019048
15	0.019048
16	0.019048
17	0.019048
18	0.019048
19	0.019048
20	0.019048
21	0.019048
22	0.019048
23	0.019048
24	0.019048
25	0.019048
26	0.019048
27	0.019048
28	0.019048
29	0.019048
30	0.019048
31	0.019048
32	0.019048
33	0.019048
34	0.019048
35	0.019048

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & learning rate,max depth,n estimators & accuracy D5 & accuracy D5 std & f1 D5
& f1 D5 std & precision D5 & precision D5 std & recall D5 & recall D5 std \\
\midrule
0 & 0.01,10,100 & 0.979 & 0.009 & 0.923 & 0.032 & 0.905 & 0.041 & 0.943 & 0.036
\\
1 & 0.01,10,150 & 0.978 & 0.007 & 0.920 & 0.026 & 0.907 & \textbf{0.02} & 0.933
& 0.041 \\
2 & 0.01,10,200 & 0.977 & 0.007 & 0.918 & 0.024 & 0.900 & 0.030 & 0.938 & 0.032
\\
3 & 0.01,15,100 & 0.978 & 0.008 & 0.921 & 0.028 & 0.901 & 0.033 & 0.943 & 0.036
\\
4 & 0.01,15,150 & 0.978 & 0.007 & 0.920 & 0.026 & 0.907 & \textbf{0.02} & 0.933
& 0.041 \\
5 & 0.01,15,200 & 0.977 & 0.007 & 0.918 & 0.024 & 0.900 & 0.030 & 0.938 & 0.032
\\
6 & 0.01,20,100 & 0.978 & 0.008 & 0.921 & 0.028 & 0.901 & 0.033 & 0.943 & 0.036
\\
7 & 0.01,20,150 & 0.978 & 0.007 & 0.920 & 0.026 & 0.907 & \textbf{0.02} & 0.933
& 0.041 \\
8 & 0.01,20,200 & 0.977 & 0.007 & 0.918 & 0.024 & 0.900 & 0.030 & 0.938 & 0.032
\\
9 & 0.01,25,100 & 0.978 & 0.008 & 0.921 & 0.028 & 0.901 & 0.033 & 0.943 & 0.036
\\
10 & 0.01,25,150 & 0.978 & 0.007 & 0.920 & 0.026 & 0.907 & \textbf{0.02} & 0.933
& 0.041 \\
11 & 0.01,25,200 & 0.977 & 0.007 & 0.918 & 0.024 & 0.900 & 0.030 & 0.938 & 0.032
\\
12 & 0.1,10,100 & 0.983 & 0.008 & 0.940 & 0.029 & 0.916 & 0.043 & \textbf{0.967}
& \textbf{0.019} \\
13 & 0.1,10,150 & 0.982 & 0.009 & 0.938 & 0.030 & 0.912 & 0.047 & \textbf{0.967}
& \textbf{0.019} \\
14 & 0.1,10,200 & 0.984 & 0.008 & 0.942 & 0.028 & 0.920 & 0.040 & \textbf{0.967}
& \textbf{0.019} \\
15 & 0.1,15,100 & 0.983 & 0.009 & 0.940 & 0.031 & 0.916 & 0.045 & \textbf{0.967}
& \textbf{0.019} \\
16 & 0.1,15,150 & 0.982 & 0.010 & 0.936 & 0.033 & 0.909 & 0.051 & \textbf{0.967}
& \textbf{0.019} \\
17 & 0.1,15,200 & 0.982 & 0.009 & 0.938 & 0.032 & 0.912 & 0.048 & \textbf{0.967}
& \textbf{0.019} \\
18 & 0.1,20,100 & 0.983 & 0.009 & 0.940 & 0.031 & 0.916 & 0.045 & \textbf{0.967}
& \textbf{0.019} \\
19 & 0.1,20,150 & 0.982 & 0.010 & 0.936 & 0.033 & 0.909 & 0.051 & \textbf{0.967}
& \textbf{0.019} \\
```

```
20 & 0.1,20,200 & 0.982 & 0.009 & 0.938 & 0.032 & 0.912 & 0.048 & \textbf{0.967}
& \textbf{0.019} \\
21 & 0.1,25,100 & 0.983 & 0.009 & 0.940 & 0.031 & 0.916 & 0.045 & \textbf{0.967}
& \textbf{0.019} \\
22 & 0.1,25,150 & 0.982 & 0.010 & 0.936 & 0.033 & 0.909 & 0.051 & \textbf{0.967}
& \textbf{0.019} \\
23 & 0.1,25,200 & 0.982 & 0.009 & 0.938 & 0.032 & 0.912 & 0.048 & \textbf{0.967}
& \textbf{0.019} \\
24 & 0.2,10,100 & 0.984 & 0.007 & 0.942 & 0.026 & 0.920 & 0.039 & \textbf{0.967}
& \textbf{0.019} \\
25 & 0.2,10,150 & 0.984 & 0.007 & 0.944 & 0.024 & 0.924 & 0.035 & \textbf{0.967}
& \textbf{0.019} \\
26 & 0.2,10,200 & \textbf{0.985} & 0.007 & \textbf{0.947} & 0.024 &
\textbf{0.928} & 0.032 & \textbf{0.967} & \textbf{0.019} \\
27 & 0.2,15,100 & 0.984 & 0.007 & 0.942 & 0.023 & 0.919 & 0.033 & \textbf{0.967}
& \textbf{0.019} \\
28 & 0.2,15,150 & 0.984 & \textbf{0.006} & 0.944 & \textbf{0.022} & 0.923 &
0.030 & \textbf{0.967} & \textbf{0.019} \\
29 & 0.2,15,200 & \textbf{0.985} & 0.007 & \textbf{0.947} & 0.024 &
\textbf{0.928} & 0.032 & \textbf{0.967} & \textbf{0.019} \\
30 & 0.2,20,100 & 0.984 & 0.007 & 0.942 & 0.023 & 0.919 & 0.033 & \textbf{0.967}
& \textbf{0.019} \\
31 & 0.2,20,150 & 0.984 & \textbf{0.006} & 0.944 & \textbf{0.022} & 0.923 &
0.030 & \textbf{0.967} & \textbf{0.019} \\
32 & 0.2,20,200 & \textbf{0.985} & 0.007 & \textbf{0.947} & 0.024 &
\textbf{0.928} & 0.032 & \textbf{0.967} & \textbf{0.019} \\
33 & 0.2,25,100 & 0.984 & 0.007 & 0.942 & 0.023 & 0.919 & 0.033 & \textbf{0.967}
& \textbf{0.019} \\
34 & 0.2,25,150 & 0.984 & \textbf{0.006} & 0.944 & \textbf{0.022} & 0.923 &
0.030 & \textbf{0.967} & \textbf{0.019} \\
35 & 0.2,25,200 & \textbf{0.985} & 0.007 & \textbf{0.947} & 0.024 &
\textbf{0.928} & 0.032 & \textbf{0.967} & \textbf{0.019} \\
\bottomrule
\end{tabular}
\end{table}
```

```
   learning_rate,max_depth,n_estimators  accuracy_D6  accuracy_D6_std  \
0                            0.01,10,100     0.993492         0.006177
1                            0.01,10,150     0.994141         0.005970
2                            0.01,10,200     0.994141         0.005970
3                            0.01,15,100     0.993492         0.006177
4                            0.01,15,150     0.994141         0.005970
5                            0.01,15,200     0.994141         0.005970
6                            0.01,20,100     0.993492         0.006177
7                            0.01,20,150     0.994141         0.005970
8                            0.01,20,200     0.994141         0.005970
9                            0.01,25,100     0.993492         0.006177
```

10	0.01,25,150	0.994141	0.005970
11	0.01,25,200	0.994141	0.005970
12	0.1,10,100	0.994790	0.006042
13	0.1,10,150	0.995442	0.004876
14	0.1,10,200	0.995442	0.004876
15	0.1,15,100	0.995442	0.004876
16	0.1,15,150	0.994793	0.004874
17	0.1,15,200	0.994793	0.004874
18	0.1,20,100	0.995442	0.004876
19	0.1,20,150	0.994793	0.004874
20	0.1,20,200	0.994793	0.004874
21	0.1,25,100	0.995442	0.004876
22	0.1,25,150	0.994793	0.004874
23	0.1,25,200	0.994793	0.004874
24	0.2,10,100	0.994793	0.004874
25	0.2,10,150	0.994793	0.004874
26	0.2,10,200	0.994793	0.004874
27	0.2,15,100	0.995442	0.004876
28	0.2,15,150	0.995442	0.004876
29	0.2,15,200	0.995442	0.004876
30	0.2,20,100	0.995442	0.004876
31	0.2,20,150	0.995442	0.004876
32	0.2,20,200	0.995442	0.004876
33	0.2,25,100	0.995442	0.004876
34	0.2,25,150	0.995442	0.004876
35	0.2,25,200	0.995442	0.004876

	f1_D6	f1_D6_std	precision_D6	precision_D6_std	recall_D6	\
0	0.979832	0.018921	0.968887	0.035050	0.991752	
1	0.981936	0.018178	0.969050	0.035006	0.995918	
2	0.981936	0.018178	0.969050	0.035006	0.995918	
3	0.979832	0.018921	0.968887	0.035050	0.991752	
4	0.981936	0.018178	0.969050	0.035006	0.995918	
5	0.981936	0.018178	0.969050	0.035006	0.995918	
6	0.979832	0.018921	0.968887	0.035050	0.991752	
7	0.981936	0.018178	0.969050	0.035006	0.995918	
8	0.981936	0.018178	0.969050	0.035006	0.995918	
9	0.979832	0.018921	0.968887	0.035050	0.991752	
10	0.981936	0.018178	0.969050	0.035006	0.995918	
11	0.981936	0.018178	0.969050	0.035006	0.995918	
12	0.983956	0.018365	0.972969	0.034870	0.995918	
13	0.985857	0.014984	0.976452	0.028205	0.995918	
14	0.985857	0.014984	0.976452	0.028205	0.995918	
15	0.985857	0.014984	0.976452	0.028205	0.995918	
16	0.983837	0.015012	0.972534	0.028850	0.995918	
17	0.983837	0.015012	0.972534	0.028850	0.995918	
18	0.985857	0.014984	0.976452	0.028205	0.995918	
19	0.983837	0.015012	0.972534	0.028850	0.995918	

20	0.983837	0.015012	0.972534	0.028850	0.995918
21	0.985857	0.014984	0.976452	0.028205	0.995918
22	0.983837	0.015012	0.972534	0.028850	0.995918
23	0.983837	0.015012	0.972534	0.028850	0.995918
24	0.983837	0.015012	0.972534	0.028850	0.995918
25	0.983837	0.015012	0.972534	0.028850	0.995918
26	0.983837	0.015012	0.972534	0.028850	0.995918
27	0.985857	0.014984	0.976452	0.028205	0.995918
28	0.985857	0.014984	0.976452	0.028205	0.995918
29	0.985857	0.014984	0.976452	0.028205	0.995918
30	0.985857	0.014984	0.976452	0.028205	0.995918
31	0.985857	0.014984	0.976452	0.028205	0.995918
32	0.985857	0.014984	0.976452	0.028205	0.995918
33	0.985857	0.014984	0.976452	0.028205	0.995918
34	0.985857	0.014984	0.976452	0.028205	0.995918
35	0.985857	0.014984	0.976452	0.028205	0.995918

	recall_D6_std
0	0.010103
1	0.008163
2	0.008163
3	0.010103
4	0.008163
5	0.008163
6	0.010103
7	0.008163
8	0.008163
9	0.010103
10	0.008163
11	0.008163
12	0.008163
13	0.008163
14	0.008163
15	0.008163
16	0.008163
17	0.008163
18	0.008163
19	0.008163
20	0.008163
21	0.008163
22	0.008163
23	0.008163
24	0.008163
25	0.008163
26	0.008163
27	0.008163
28	0.008163
29	0.008163

```
30       0.008163
31       0.008163
32       0.008163
33       0.008163
34       0.008163
35       0.008163
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & learning rate,max depth,n estimators & accuracy D6 & accuracy D6 std & f1 D6
& f1 D6 std & precision D6 & precision D6 std & recall D6 & recall D6 std \\
\midrule
0 & 0.01,10,100 & 0.993 & 0.006 & 0.980 & 0.019 & 0.969 & 0.035 & 0.992 & 0.010
\\
1 & 0.01,10,150 & 0.994 & 0.006 & 0.982 & 0.018 & 0.969 & 0.035 & \textbf{0.996}
& \textbf{0.008} \\
2 & 0.01,10,200 & 0.994 & 0.006 & 0.982 & 0.018 & 0.969 & 0.035 & \textbf{0.996}
& \textbf{0.008} \\
3 & 0.01,15,100 & 0.993 & 0.006 & 0.980 & 0.019 & 0.969 & 0.035 & 0.992 & 0.010
\\
4 & 0.01,15,150 & 0.994 & 0.006 & 0.982 & 0.018 & 0.969 & 0.035 & \textbf{0.996}
& \textbf{0.008} \\
5 & 0.01,15,200 & 0.994 & 0.006 & 0.982 & 0.018 & 0.969 & 0.035 & \textbf{0.996}
& \textbf{0.008} \\
6 & 0.01,20,100 & 0.993 & 0.006 & 0.980 & 0.019 & 0.969 & 0.035 & 0.992 & 0.010
\\
7 & 0.01,20,150 & 0.994 & 0.006 & 0.982 & 0.018 & 0.969 & 0.035 & \textbf{0.996}
& \textbf{0.008} \\
8 & 0.01,20,200 & 0.994 & 0.006 & 0.982 & 0.018 & 0.969 & 0.035 & \textbf{0.996}
& \textbf{0.008} \\
9 & 0.01,25,100 & 0.993 & 0.006 & 0.980 & 0.019 & 0.969 & 0.035 & 0.992 & 0.010
\\
10 & 0.01,25,150 & 0.994 & 0.006 & 0.982 & 0.018 & 0.969 & 0.035 &
\textbf{0.996} & \textbf{0.008} \\
11 & 0.01,25,200 & 0.994 & 0.006 & 0.982 & 0.018 & 0.969 & 0.035 &
\textbf{0.996} & \textbf{0.008} \\
12 & 0.1,10,100 & \textbf{0.995} & 0.006 & 0.984 & 0.018 & 0.973 & 0.035 &
\textbf{0.996} & \textbf{0.008} \\
13 & 0.1,10,150 & \textbf{0.995} & \textbf{0.005} & \textbf{0.986} &
\textbf{0.015} & \textbf{0.976} & \textbf{0.028} & \textbf{0.996} &
\textbf{0.008} \\
14 & 0.1,10,200 & \textbf{0.995} & \textbf{0.005} & \textbf{0.986} &
\textbf{0.015} & \textbf{0.976} & \textbf{0.028} & \textbf{0.996} &
\textbf{0.008} \\
15 & 0.1,15,100 & \textbf{0.995} & \textbf{0.005} & \textbf{0.986} &
```

```
\textbf{0.015} & \textbf{0.976} & \textbf{0.028} & \textbf{0.996} &
\textbf{0.008} \\
16 & 0.1,15,150 & \textbf{0.995} & \textbf{0.005} & 0.984 & \textbf{0.015} &
0.973 & 0.029 & \textbf{0.996} & \textbf{0.008} \\
17 & 0.1,15,200 & \textbf{0.995} & \textbf{0.005} & 0.984 & \textbf{0.015} &
0.973 & 0.029 & \textbf{0.996} & \textbf{0.008} \\
18 & 0.1,20,100 & \textbf{0.995} & \textbf{0.005} & \textbf{0.986} &
\textbf{0.015} & \textbf{0.976} & \textbf{0.028} & \textbf{0.996} &
\textbf{0.008} \\
19 & 0.1,20,150 & \textbf{0.995} & \textbf{0.005} & 0.984 & \textbf{0.015} &
0.973 & 0.029 & \textbf{0.996} & \textbf{0.008} \\
20 & 0.1,20,200 & \textbf{0.995} & \textbf{0.005} & 0.984 & \textbf{0.015} &
0.973 & 0.029 & \textbf{0.996} & \textbf{0.008} \\
21 & 0.1,25,100 & \textbf{0.995} & \textbf{0.005} & \textbf{0.986} &
\textbf{0.015} & \textbf{0.976} & \textbf{0.028} & \textbf{0.996} &
\textbf{0.008} \\
22 & 0.1,25,150 & \textbf{0.995} & \textbf{0.005} & 0.984 & \textbf{0.015} &
0.973 & 0.029 & \textbf{0.996} & \textbf{0.008} \\
23 & 0.1,25,200 & \textbf{0.995} & \textbf{0.005} & 0.984 & \textbf{0.015} &
0.973 & 0.029 & \textbf{0.996} & \textbf{0.008} \\
24 & 0.2,10,100 & \textbf{0.995} & \textbf{0.005} & 0.984 & \textbf{0.015} &
0.973 & 0.029 & \textbf{0.996} & \textbf{0.008} \\
25 & 0.2,10,150 & \textbf{0.995} & \textbf{0.005} & 0.984 & \textbf{0.015} &
0.973 & 0.029 & \textbf{0.996} & \textbf{0.008} \\
26 & 0.2,10,200 & \textbf{0.995} & \textbf{0.005} & 0.984 & \textbf{0.015} &
0.973 & 0.029 & \textbf{0.996} & \textbf{0.008} \\
27 & 0.2,15,100 & \textbf{0.995} & \textbf{0.005} & \textbf{0.986} &
\textbf{0.015} & \textbf{0.976} & \textbf{0.028} & \textbf{0.996} &
\textbf{0.008} \\
28 & 0.2,15,150 & \textbf{0.995} & \textbf{0.005} & \textbf{0.986} &
\textbf{0.015} & \textbf{0.976} & \textbf{0.028} & \textbf{0.996} &
\textbf{0.008} \\
29 & 0.2,15,200 & \textbf{0.995} & \textbf{0.005} & \textbf{0.986} &
\textbf{0.015} & \textbf{0.976} & \textbf{0.028} & \textbf{0.996} &
\textbf{0.008} \\
30 & 0.2,20,100 & \textbf{0.995} & \textbf{0.005} & \textbf{0.986} &
\textbf{0.015} & \textbf{0.976} & \textbf{0.028} & \textbf{0.996} &
\textbf{0.008} \\
31 & 0.2,20,150 & \textbf{0.995} & \textbf{0.005} & \textbf{0.986} &
\textbf{0.015} & \textbf{0.976} & \textbf{0.028} & \textbf{0.996} &
\textbf{0.008} \\
32 & 0.2,20,200 & \textbf{0.995} & \textbf{0.005} & \textbf{0.986} &
\textbf{0.015} & \textbf{0.976} & \textbf{0.028} & \textbf{0.996} &
\textbf{0.008} \\
33 & 0.2,25,100 & \textbf{0.995} & \textbf{0.005} & \textbf{0.986} &
\textbf{0.015} & \textbf{0.976} & \textbf{0.028} & \textbf{0.996} &
\textbf{0.008} \\
34 & 0.2,25,150 & \textbf{0.995} & \textbf{0.005} & \textbf{0.986} &
```

```
\textbf{0.015} & \textbf{0.976} & \textbf{0.028} & \textbf{0.996} &
\textbf{0.008} \\
35 & 0.2,25,200 & \textbf{0.995} & \textbf{0.005} & \textbf{0.986} &
\textbf{0.015} & \textbf{0.976} & \textbf{0.028} & \textbf{0.996} &
\textbf{0.008} \\
\bottomrule
\end{tabular}
\end{table}
```

[ ]:
```
from sklearn.svm import SVC

# Initialize a SVC
clf = SVC(random_state=RANDOM_STATE)

# Define the parameter grid
param_grid = {
    'C': [0.1, 10, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000],
    'kernel': ['rbf', 'poly', 'sigmoid']
}

X, y = prepare_dataset()
grid_serach, best_params = find_best_params(clf, param_grid, X, y, RANDOM_STATE)
```

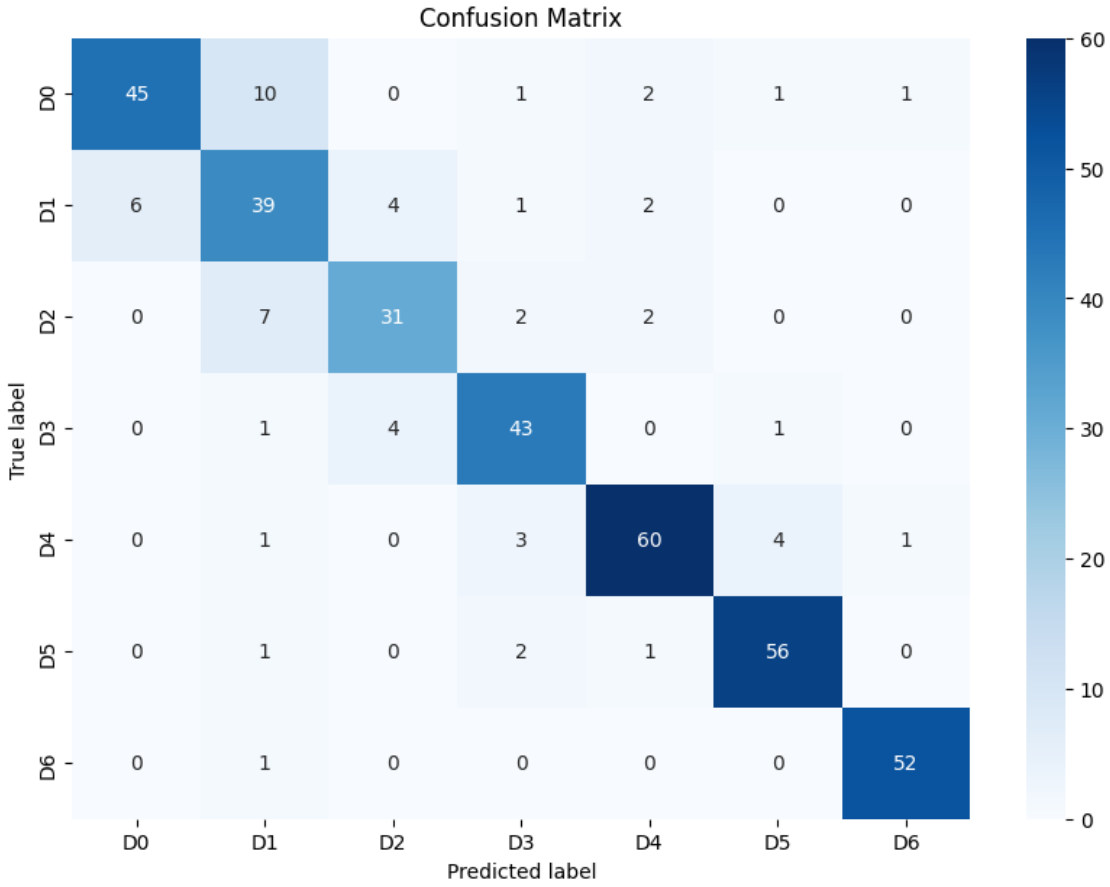
```
Features removed: {'Smoker', 'Calorie_monitoring'}
Features removed: {'Sedentary_hours_daily', 'Est_avg_calorie_intake'}
Best parameters found:  {'C': 100, 'kernel': 'rbf'}
```

[ ]:
```
best_clf = SVC(**best_params, random_state=RANDOM_STATE)
accuracy, f1, precision, recall, dfs = evaluate_my_model(best_clf, grid_serach,␣
↪X, y, RANDOM_STATE)
```

```
Model: SVC
Index(['mean_fit_time', 'std_fit_time', 'mean_score_time', 'std_score_time',
       'param_C', 'param_kernel', 'params', 'split0_test_accuracy',
       'split1_test_accuracy', 'split2_test_accuracy',
       …
       'std_test_recall_D5', 'rank_test_recall_D5', 'split0_test_recall_D6',
       'split1_test_recall_D6', 'split2_test_recall_D6',
       'split3_test_recall_D6', 'split4_test_recall_D6', 'mean_test_recall_D6',
       'std_test_recall_D6', 'rank_test_recall_D6'],
      dtype='object', length=263)
              precision    recall  f1-score   support

           D0       0.88      0.75      0.81        60
           D1       0.65      0.75      0.70        52
           D2       0.79      0.74      0.77        42
           D3       0.83      0.88      0.85        49
```

D4	0.90	0.87	0.88	69
D5	0.90	0.93	0.92	60
D6	0.96	0.98	0.97	53
accuracy			0.85	385
macro avg	0.85	0.84	0.84	385
weighted avg	0.85	0.85	0.85	385



[ ]:
```
print(f"Accuracy: {accuracy}")
print(f"F1 Score: {f1}")
print(f"Precision: {precision}")
print(f"Recall: {recall}")
print(grid_search.best_index_)
for df in dfs:
    # Replace the dictionary values with list
    display(df)
    pd_to_latex(df)
```

```
Accuracy: 0.8467532467532467
```

F1 Score: 0.8473043990498447
Precision: 0.8510822151290588
Recall: 0.8467532467532467
19

	C,kernel	accuracy_D0	accuracy_D0_std	f1_D0	f1_D0_std	\
0	0.1,rbf	0.928381	0.011858	0.633622	0.083893	
1	0.1,poly	0.939458	0.014631	0.696724	0.096075	
2	0.1,sigmoid	0.904952	0.008550	0.612029	0.046228	
3	10,rbf	0.977211	0.009218	0.906627	0.037919	
4	10,poly	0.975908	0.011023	0.902937	0.038364	
5	10,sigmoid	0.810550	0.017849	0.417086	0.061372	
6	100,rbf	0.981120	0.007253	0.922487	0.029621	
7	100,poly	0.978516	0.009348	0.913110	0.035878	
8	100,sigmoid	0.802748	0.027426	0.401598	0.083216	
9	200,rbf	0.981120	0.007253	0.922487	0.029621	
10	200,poly	0.974608	0.006322	0.897546	0.022900	
11	200,sigmoid	0.804057	0.022679	0.404143	0.071265	
12	300,rbf	0.981120	0.007253	0.922487	0.029621	
13	300,poly	0.971352	0.005612	0.885659	0.020089	
14	300,sigmoid	0.796895	0.026573	0.389863	0.075460	
15	400,rbf	0.981120	0.007253	0.922487	0.029621	
16	400,poly	0.972004	0.007876	0.888340	0.027857	
17	400,sigmoid	0.809258	0.027736	0.419369	0.080144	
18	500,rbf	0.981120	0.007253	0.922487	0.029621	
19	500,poly	0.972655	0.006711	0.891171	0.023056	
20	500,sigmoid	0.811217	0.019980	0.432013	0.054352	
21	600,rbf	0.981120	0.007253	0.922487	0.029621	
22	600,poly	0.972655	0.006711	0.891171	0.023056	
23	600,sigmoid	0.811215	0.020939	0.424660	0.065626	
24	700,rbf	0.981120	0.007253	0.922487	0.029621	
25	700,poly	0.972655	0.006711	0.891171	0.023056	
26	700,sigmoid	0.804704	0.025669	0.414376	0.078858	
27	800,rbf	0.981120	0.007253	0.922487	0.029621	
28	800,poly	0.972655	0.006711	0.891171	0.023056	
29	800,sigmoid	0.807312	0.026239	0.412507	0.087141	
30	900,rbf	0.981120	0.007253	0.922487	0.029621	
31	900,poly	0.972004	0.007876	0.888340	0.027857	
32	900,sigmoid	0.804059	0.028466	0.417591	0.074199	
33	1000,rbf	0.981120	0.007253	0.922487	0.029621	
34	1000,poly	0.972004	0.007876	0.888340	0.027857	
35	1000,sigmoid	0.805360	0.024986	0.419424	0.067477	

	precision_D0	precision_D0_std	recall_D0	recall_D0_std
0	0.819331	0.061547	0.521479	0.094239
1	0.870612	0.082941	0.597582	0.136540
2	0.603226	0.025647	0.623898	0.074956
3	0.904199	0.062976	0.914367	0.061555

```
4       0.902680          0.078831   0.908819       0.035841
5       0.332433          0.044821   0.564865       0.110910
6       0.918908          0.051437   0.930583       0.056881
7       0.903498          0.054976   0.925036       0.034685
8       0.317903          0.065816   0.548791       0.125408
9       0.918908          0.051437   0.930583       0.056881
10      0.884657          0.052277   0.914225       0.034906
11      0.320316          0.053745   0.554765       0.126867
12      0.918908          0.051437   0.930583       0.056881
13      0.861280          0.042734   0.914225       0.034906
14      0.307430          0.060466   0.538265       0.119354
15      0.918908          0.051437   0.930583       0.056881
16      0.866822          0.053351   0.914225       0.034906
17      0.333051          0.063937   0.570413       0.120875
18      0.918908          0.051437   0.930583       0.056881
19      0.867832          0.051579   0.919630       0.037230
20      0.340597          0.038600   0.597155       0.106294
21      0.918908          0.051437   0.930583       0.056881
22      0.867832          0.051579   0.919630       0.037230
23      0.336872          0.047498   0.581223       0.121345
24      0.918908          0.051437   0.930583       0.056881
25      0.867832          0.051579   0.919630       0.037230
26      0.325744          0.059936   0.575676       0.132294
27      0.918908          0.051437   0.930583       0.056881
28      0.867832          0.051579   0.919630       0.037230
29      0.326683          0.065615   0.565007       0.141484
30      0.918908          0.051437   0.930583       0.056881
31      0.866822          0.053351   0.914225       0.034906
32      0.327960          0.060147   0.581223       0.118913
33      0.918908          0.051437   0.930583       0.056881
34      0.866822          0.053351   0.914225       0.034906
35      0.329232          0.054139   0.581081       0.102560

\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & C,kernel & accuracy D0 & accuracy D0 std & f1 D0 & f1 D0 std & precision D0 &
precision D0 std & recall D0 & recall D0 std \\
\midrule
0 & 0.1,rbf & 0.928 & 0.012 & 0.634 & 0.084 & 0.819 & 0.062 & 0.521 & 0.094 \\
1 & 0.1,poly & 0.939 & 0.015 & 0.697 & 0.096 & 0.871 & 0.083 & 0.598 & 0.137 \\
2 & 0.1,sigmoid & 0.905 & 0.009 & 0.612 & 0.046 & 0.603 & \textbf{0.026} & 0.624
& 0.075 \\
3 & 10,rbf & 0.977 & 0.009 & 0.907 & 0.038 & 0.904 & 0.063 & 0.914 & 0.062 \\
4 & 10,poly & 0.976 & 0.011 & 0.903 & 0.038 & 0.903 & 0.079 & 0.909 & 0.036 \\
5 & 10,sigmoid & 0.811 & 0.018 & 0.417 & 0.061 & 0.332 & 0.045 & 0.565 & 0.111
```

```
\\
6 & 100,rbf & \textbf{0.981} & 0.007 & \textbf{0.922} & 0.030 & \textbf{0.919} &
0.051 & \textbf{0.931} & 0.057 \\
7 & 100,poly & 0.979 & 0.009 & 0.913 & 0.036 & 0.903 & 0.055 & 0.925 &
\textbf{0.035} \\
8 & 100,sigmoid & 0.803 & 0.027 & 0.402 & 0.083 & 0.318 & 0.066 & 0.549 & 0.125
\\
9 & 200,rbf & \textbf{0.981} & 0.007 & \textbf{0.922} & 0.030 & \textbf{0.919} &
0.051 & \textbf{0.931} & 0.057 \\
10 & 200,poly & 0.975 & \textbf{0.006} & 0.898 & 0.023 & 0.885 & 0.052 & 0.914 &
\textbf{0.035} \\
11 & 200,sigmoid & 0.804 & 0.023 & 0.404 & 0.071 & 0.320 & 0.054 & 0.555 & 0.127
\\
12 & 300,rbf & \textbf{0.981} & 0.007 & \textbf{0.922} & 0.030 & \textbf{0.919}
& 0.051 & \textbf{0.931} & 0.057 \\
13 & 300,poly & 0.971 & \textbf{0.006} & 0.886 & \textbf{0.02} & 0.861 & 0.043 &
0.914 & \textbf{0.035} \\
14 & 300,sigmoid & 0.797 & 0.027 & 0.390 & 0.075 & 0.307 & 0.060 & 0.538 & 0.119
\\
15 & 400,rbf & \textbf{0.981} & 0.007 & \textbf{0.922} & 0.030 & \textbf{0.919}
& 0.051 & \textbf{0.931} & 0.057 \\
16 & 400,poly & 0.972 & 0.008 & 0.888 & 0.028 & 0.867 & 0.053 & 0.914 &
\textbf{0.035} \\
17 & 400,sigmoid & 0.809 & 0.028 & 0.419 & 0.080 & 0.333 & 0.064 & 0.570 & 0.121
\\
18 & 500,rbf & \textbf{0.981} & 0.007 & \textbf{0.922} & 0.030 & \textbf{0.919}
& 0.051 & \textbf{0.931} & 0.057 \\
19 & 500,poly & 0.973 & 0.007 & 0.891 & 0.023 & 0.868 & 0.052 & 0.920 & 0.037 \\
20 & 500,sigmoid & 0.811 & 0.020 & 0.432 & 0.054 & 0.341 & 0.039 & 0.597 & 0.106
\\
21 & 600,rbf & \textbf{0.981} & 0.007 & \textbf{0.922} & 0.030 & \textbf{0.919}
& 0.051 & \textbf{0.931} & 0.057 \\
22 & 600,poly & 0.973 & 0.007 & 0.891 & 0.023 & 0.868 & 0.052 & 0.920 & 0.037 \\
23 & 600,sigmoid & 0.811 & 0.021 & 0.425 & 0.066 & 0.337 & 0.047 & 0.581 & 0.121
\\
24 & 700,rbf & \textbf{0.981} & 0.007 & \textbf{0.922} & 0.030 & \textbf{0.919}
& 0.051 & \textbf{0.931} & 0.057 \\
25 & 700,poly & 0.973 & 0.007 & 0.891 & 0.023 & 0.868 & 0.052 & 0.920 & 0.037 \\
26 & 700,sigmoid & 0.805 & 0.026 & 0.414 & 0.079 & 0.326 & 0.060 & 0.576 & 0.132
\\
27 & 800,rbf & \textbf{0.981} & 0.007 & \textbf{0.922} & 0.030 & \textbf{0.919}
& 0.051 & \textbf{0.931} & 0.057 \\
28 & 800,poly & 0.973 & 0.007 & 0.891 & 0.023 & 0.868 & 0.052 & 0.920 & 0.037 \\
29 & 800,sigmoid & 0.807 & 0.026 & 0.413 & 0.087 & 0.327 & 0.066 & 0.565 & 0.141
\\
30 & 900,rbf & \textbf{0.981} & 0.007 & \textbf{0.922} & 0.030 & \textbf{0.919}
& 0.051 & \textbf{0.931} & 0.057 \\
31 & 900,poly & 0.972 & 0.008 & 0.888 & 0.028 & 0.867 & 0.053 & 0.914 &
```

```
\textbf{0.035} \\
32 & 900,sigmoid & 0.804 & 0.028 & 0.418 & 0.074 & 0.328 & 0.060 & 0.581 & 0.119
\\
33 & 1000,rbf & \textbf{0.981} & 0.007 & \textbf{0.922} & 0.030 & \textbf{0.919}
& 0.051 & \textbf{0.931} & 0.057 \\
34 & 1000,poly & 0.972 & 0.008 & 0.888 & 0.028 & 0.867 & 0.053 & 0.914 &
\textbf{0.035} \\
35 & 1000,sigmoid & 0.805 & 0.025 & 0.419 & 0.067 & 0.329 & 0.054 & 0.581 &
0.103 \\
\bottomrule
\end{tabular}
\end{table}
```

	C,kernel	accuracy_D1	accuracy_D1_std	f1_D1	f1_D1_std	\
0	0.1,rbf	0.847659	0.023053	0.535644	0.056722	
1	0.1,poly	0.884756	0.016358	0.502244	0.081785	
2	0.1,sigmoid	0.843754	0.024085	0.393326	0.075820	
3	10,rbf	0.925760	0.018056	0.729287	0.067155	
4	10,poly	0.910144	0.014421	0.639640	0.062140	
5	10,sigmoid	0.813793	0.021912	0.315623	0.079613	
6	100,rbf	0.927717	0.018168	0.736323	0.070216	
7	100,poly	0.910148	0.025221	0.649739	0.104121	
8	100,sigmoid	0.825515	0.022383	0.300174	0.078524	
9	200,rbf	0.927717	0.018168	0.736323	0.070216	
10	200,poly	0.908190	0.024011	0.640232	0.100801	
11	200,sigmoid	0.831387	0.015803	0.315627	0.064257	
12	300,rbf	0.927717	0.018168	0.736323	0.070216	
13	300,poly	0.907536	0.026711	0.635959	0.112534	
14	300,sigmoid	0.820961	0.029796	0.298756	0.073155	
15	400,rbf	0.927717	0.018168	0.736323	0.070216	
16	400,poly	0.906885	0.024124	0.634506	0.101866	
17	400,sigmoid	0.833986	0.028385	0.295545	0.080374	
18	500,rbf	0.927717	0.018168	0.736323	0.070216	
19	500,poly	0.907534	0.026634	0.637262	0.112135	
20	500,sigmoid	0.844414	0.011156	0.306736	0.072814	
21	600,rbf	0.927717	0.018168	0.736323	0.070216	
22	600,poly	0.906885	0.025157	0.639079	0.101376	
23	600,sigmoid	0.841157	0.012446	0.326824	0.083039	
24	700,rbf	0.927717	0.018168	0.736323	0.070216	
25	700,poly	0.908841	0.022888	0.644411	0.092803	
26	700,sigmoid	0.840497	0.023834	0.312937	0.098923	
27	800,rbf	0.927717	0.018168	0.736323	0.070216	
28	800,poly	0.906889	0.023581	0.636181	0.095579	
29	800,sigmoid	0.839858	0.018901	0.310398	0.087559	
30	900,rbf	0.927717	0.018168	0.736323	0.070216	
31	900,poly	0.905584	0.026342	0.633893	0.101526	
32	900,sigmoid	0.830735	0.020444	0.303586	0.095561	

33	1000,rbf	0.927717	0.018168	0.736323	0.070216
34	1000,poly	0.906885	0.025905	0.642653	0.098568
35	1000,sigmoid	0.817057	0.018013	0.282140	0.084217

	precision_D1	precision_D1_std	recall_D1	recall_D1_std
0	0.463612	0.065861	0.638095	0.053026
1	0.608771	0.081861	0.428571	0.079682
2	0.427480	0.107991	0.366667	0.057538
3	0.726040	0.059211	0.738095	0.099887
4	0.706285	0.060487	0.585714	0.068346
5	0.320019	0.059035	0.323810	0.115274
6	0.733176	0.066756	0.747619	0.112284
7	0.693007	0.105721	0.614286	0.111066
8	0.338525	0.074572	0.280952	0.101463
9	0.733176	0.066756	0.747619	0.112284
10	0.685571	0.097261	0.604762	0.118187
11	0.364211	0.059932	0.295238	0.102795
12	0.733176	0.066756	0.747619	0.112284
13	0.682193	0.103668	0.600000	0.130757
14	0.338232	0.082567	0.285714	0.109627
15	0.733176	0.066756	0.747619	0.112284
16	0.679459	0.091553	0.600000	0.122706
17	0.365116	0.111129	0.252381	0.064944
18	0.733176	0.066756	0.747619	0.112284
19	0.680469	0.100414	0.604762	0.135191
20	0.389972	0.060785	0.257143	0.080249
21	0.733176	0.066756	0.747619	0.112284
22	0.677090	0.095536	0.609524	0.118187
23	0.390980	0.066304	0.295238	0.120091
24	0.733176	0.066756	0.747619	0.112284
25	0.688103	0.088453	0.609524	0.107116
26	0.382657	0.094147	0.271429	0.106053
27	0.733176	0.066756	0.747619	0.112284
28	0.680540	0.092718	0.600000	0.105839
29	0.376981	0.094155	0.266667	0.087027
30	0.733176	0.066756	0.747619	0.112284
31	0.674543	0.103381	0.600000	0.105839
32	0.344400	0.083944	0.276190	0.106053
33	0.733176	0.066756	0.747619	0.112284
34	0.676296	0.100365	0.614286	0.103674
35	0.305199	0.054765	0.276190	0.118187

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & C,kernel & accuracy D1 & accuracy D1 std & f1 D1 & f1 D1 std & precision D1 &
```

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precision D1 std & recall D1 & recall D1 std \\
\midrule
0 & 0.1,rbf & 0.848 & 0.023 & 0.536 & \textbf{0.057} & 0.464 & 0.066 & 0.638 &
\textbf{0.053} \\
1 & 0.1,poly & 0.885 & 0.016 & 0.502 & 0.082 & 0.609 & 0.082 & 0.429 & 0.080 \\
2 & 0.1,sigmoid & 0.844 & 0.024 & 0.393 & 0.076 & 0.427 & 0.108 & 0.367 & 0.058
\\
3 & 10,rbf & 0.926 & 0.018 & 0.729 & 0.067 & 0.726 & 0.059 & 0.738 & 0.100 \\
4 & 10,poly & 0.910 & 0.014 & 0.640 & 0.062 & 0.706 & 0.060 & 0.586 & 0.068 \\
5 & 10,sigmoid & 0.814 & 0.022 & 0.316 & 0.080 & 0.320 & 0.059 & 0.324 & 0.115
\\
6 & 100,rbf & \textbf{0.928} & 0.018 & \textbf{0.736} & 0.070 & \textbf{0.733} &
0.067 & \textbf{0.748} & 0.112 \\
7 & 100,poly & 0.910 & 0.025 & 0.650 & 0.104 & 0.693 & 0.106 & 0.614 & 0.111 \\
8 & 100,sigmoid & 0.826 & 0.022 & 0.300 & 0.079 & 0.339 & 0.075 & 0.281 & 0.101
\\
9 & 200,rbf & \textbf{0.928} & 0.018 & \textbf{0.736} & 0.070 & \textbf{0.733} &
0.067 & \textbf{0.748} & 0.112 \\
10 & 200,poly & 0.908 & 0.024 & 0.640 & 0.101 & 0.686 & 0.097 & 0.605 & 0.118 \\
11 & 200,sigmoid & 0.831 & 0.016 & 0.316 & 0.064 & 0.364 & 0.060 & 0.295 & 0.103
\\
12 & 300,rbf & \textbf{0.928} & 0.018 & \textbf{0.736} & 0.070 & \textbf{0.733}
& 0.067 & \textbf{0.748} & 0.112 \\
13 & 300,poly & 0.908 & 0.027 & 0.636 & 0.113 & 0.682 & 0.104 & 0.600 & 0.131 \\
14 & 300,sigmoid & 0.821 & 0.030 & 0.299 & 0.073 & 0.338 & 0.083 & 0.286 & 0.110
\\
15 & 400,rbf & \textbf{0.928} & 0.018 & \textbf{0.736} & 0.070 & \textbf{0.733}
& 0.067 & \textbf{0.748} & 0.112 \\
16 & 400,poly & 0.907 & 0.024 & 0.635 & 0.102 & 0.679 & 0.092 & 0.600 & 0.123 \\
17 & 400,sigmoid & 0.834 & 0.028 & 0.296 & 0.080 & 0.365 & 0.111 & 0.252 & 0.065
\\
18 & 500,rbf & \textbf{0.928} & 0.018 & \textbf{0.736} & 0.070 & \textbf{0.733}
& 0.067 & \textbf{0.748} & 0.112 \\
19 & 500,poly & 0.908 & 0.027 & 0.637 & 0.112 & 0.680 & 0.100 & 0.605 & 0.135 \\
20 & 500,sigmoid & 0.844 & \textbf{0.011} & 0.307 & 0.073 & 0.390 & 0.061 &
0.257 & 0.080 \\
21 & 600,rbf & \textbf{0.928} & 0.018 & \textbf{0.736} & 0.070 & \textbf{0.733}
& 0.067 & \textbf{0.748} & 0.112 \\
22 & 600,poly & 0.907 & 0.025 & 0.639 & 0.101 & 0.677 & 0.096 & 0.610 & 0.118 \\
23 & 600,sigmoid & 0.841 & 0.012 & 0.327 & 0.083 & 0.391 & 0.066 & 0.295 & 0.120
\\
24 & 700,rbf & \textbf{0.928} & 0.018 & \textbf{0.736} & 0.070 & \textbf{0.733}
& 0.067 & \textbf{0.748} & 0.112 \\
25 & 700,poly & 0.909 & 0.023 & 0.644 & 0.093 & 0.688 & 0.088 & 0.610 & 0.107 \\
26 & 700,sigmoid & 0.840 & 0.024 & 0.313 & 0.099 & 0.383 & 0.094 & 0.271 & 0.106
\\
27 & 800,rbf & \textbf{0.928} & 0.018 & \textbf{0.736} & 0.070 & \textbf{0.733}
& 0.067 & \textbf{0.748} & 0.112 \\
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28 & 800,poly & 0.907 & 0.024 & 0.636 & 0.096 & 0.681 & 0.093 & 0.600 & 0.106 \\
29 & 800,sigmoid & 0.840 & 0.019 & 0.310 & 0.088 & 0.377 & 0.094 & 0.267 & 0.087
\\
30 & 900,rbf & \textbf{0.928} & 0.018 & \textbf{0.736} & 0.070 & \textbf{0.733}
& 0.067 & \textbf{0.748} & 0.112 \\
31 & 900,poly & 0.906 & 0.026 & 0.634 & 0.102 & 0.675 & 0.103 & 0.600 & 0.106 \\
32 & 900,sigmoid & 0.831 & 0.020 & 0.304 & 0.096 & 0.344 & 0.084 & 0.276 & 0.106
\\
33 & 1000,rbf & \textbf{0.928} & 0.018 & \textbf{0.736} & 0.070 & \textbf{0.733}
& 0.067 & \textbf{0.748} & 0.112 \\
34 & 1000,poly & 0.907 & 0.026 & 0.643 & 0.099 & 0.676 & 0.100 & 0.614 & 0.104
\\
35 & 1000,sigmoid & 0.817 & 0.018 & 0.282 & 0.084 & 0.305 & \textbf{0.055} &
0.276 & 0.118 \\
\bottomrule
\end{tabular}
\end{table}
```

	C,kernel	accuracy_D2	accuracy_D2_std	f1_D2	f1_D2_std	\
0	0.1,rbf	0.873045	0.014143	0.476203	0.078155	
1	0.1,poly	0.876304	0.010276	0.355929	0.071278	
2	0.1,sigmoid	0.868499	0.018761	0.469992	0.100617	
3	10,rbf	0.938132	0.019791	0.781517	0.067557	
4	10,poly	0.910157	0.013121	0.700763	0.043905	
5	10,sigmoid	0.833988	0.016567	0.264715	0.032073	
6	100,rbf	0.941391	0.020316	0.792759	0.063643	
7	100,poly	0.923819	0.019421	0.733210	0.064454	
8	100,sigmoid	0.839845	0.023604	0.277040	0.039780	
9	200,rbf	0.941391	0.020316	0.792759	0.063643	
10	200,poly	0.916663	0.012985	0.708661	0.046445	
11	200,sigmoid	0.825509	0.031479	0.240003	0.063983	
12	300,rbf	0.941391	0.020316	0.792759	0.063643	
13	300,poly	0.917310	0.015937	0.711055	0.052723	
14	300,sigmoid	0.833324	0.022001	0.238163	0.071243	
15	400,rbf	0.941391	0.020316	0.792759	0.063643	
16	400,poly	0.918609	0.016264	0.715640	0.053678	
17	400,sigmoid	0.828115	0.020096	0.267164	0.075858	
18	500,rbf	0.941391	0.020316	0.792759	0.063643	
19	500,poly	0.918607	0.018121	0.717908	0.054471	
20	500,sigmoid	0.822905	0.029602	0.260907	0.066755	
21	600,rbf	0.941391	0.020316	0.792759	0.063643	
22	600,poly	0.919912	0.014984	0.720597	0.046009	
23	600,sigmoid	0.814438	0.038162	0.246747	0.070999	
24	700,rbf	0.941391	0.020316	0.792759	0.063643	
25	700,poly	0.919912	0.014698	0.721584	0.046175	
26	700,sigmoid	0.830720	0.024169	0.257999	0.049467	
27	800,rbf	0.941391	0.020316	0.792759	0.063643	

28	800,poly	0.919263	0.015370	0.719987	0.048315
29	800,sigmoid	0.804664	0.031565	0.259905	0.048040
30	900,rbf	0.941391	0.020316	0.792759	0.063643
31	900,poly	0.917308	0.014984	0.711285	0.047644
32	900,sigmoid	0.818994	0.029337	0.225004	0.095384
33	1000,rbf	0.941391	0.020316	0.792759	0.063643
34	1000,poly	0.918611	0.013552	0.715272	0.045776
35	1000,sigmoid	0.844399	0.008626	0.220253	0.077613

	precision_D2	precision_D2_std	recall_D2	recall_D2_std
0	0.560988	0.053745	0.416808	0.091198
1	0.657760	0.075753	0.245772	0.057311
2	0.531818	0.066635	0.426110	0.126697
3	0.783986	0.088454	0.782664	0.070417
4	0.660743	0.043834	0.749789	0.067056
5	0.371970	0.053791	0.217865	0.060629
6	0.804384	0.100193	0.787315	0.061820
7	0.727178	0.076153	0.740803	0.059221
8	0.409045	0.092636	0.217865	0.038892
9	0.804384	0.100193	0.787315	0.061820
10	0.698774	0.050880	0.722199	0.064162
11	0.337204	0.096215	0.198837	0.064154
12	0.804384	0.100193	0.787315	0.061820
13	0.703647	0.065870	0.722304	0.061949
14	0.347872	0.080625	0.189323	0.069014
15	0.804384	0.100193	0.787315	0.061820
16	0.708109	0.068766	0.726850	0.061309
17	0.341976	0.069140	0.231184	0.083395
18	0.804384	0.100193	0.787315	0.061820
19	0.709184	0.080559	0.731501	0.054083
20	0.333793	0.081058	0.226638	0.068720
21	0.804384	0.100193	0.787315	0.061820
22	0.712942	0.064917	0.731607	0.049270
23	0.311973	0.107546	0.213002	0.055926
24	0.804384	0.100193	0.787315	0.061820
25	0.710847	0.063087	0.736258	0.055351
26	0.352871	0.080760	0.208140	0.040347
27	0.804384	0.100193	0.787315	0.061820
28	0.707117	0.061345	0.736258	0.055351
29	0.297253	0.056366	0.250000	0.071111
30	0.804384	0.100193	0.787315	0.061820
31	0.702865	0.061467	0.722304	0.050395
32	0.298493	0.080836	0.204017	0.120203
33	0.804384	0.100193	0.787315	0.061820
34	0.706386	0.054193	0.726956	0.057117
35	0.368462	0.080036	0.162156	0.072271

\begin{table}

```
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & C,kernel & accuracy D2 & accuracy D2 std & f1 D2 & f1 D2 std & precision D2 &
precision D2 std & recall D2 & recall D2 std \\
\midrule
0 & 0.1,rbf & 0.873 & 0.014 & 0.476 & 0.078 & 0.561 & 0.054 & 0.417 & 0.091 \\
1 & 0.1,poly & 0.876 & 0.010 & 0.356 & 0.071 & 0.658 & 0.076 & 0.246 & 0.057 \\
2 & 0.1,sigmoid & 0.868 & 0.019 & 0.470 & 0.101 & 0.532 & 0.067 & 0.426 & 0.127
\\
3 & 10,rbf & 0.938 & 0.020 & 0.782 & 0.068 & 0.784 & 0.088 & 0.783 & 0.070 \\
4 & 10,poly & 0.910 & 0.013 & 0.701 & 0.044 & 0.661 & \textbf{0.044} & 0.750 &
0.067 \\
5 & 10,sigmoid & 0.834 & 0.017 & 0.265 & \textbf{0.032} & 0.372 & 0.054 & 0.218
& 0.061 \\
6 & 100,rbf & \textbf{0.941} & 0.020 & \textbf{0.793} & 0.064 & \textbf{0.804} &
0.100 & \textbf{0.787} & 0.062 \\
7 & 100,poly & 0.924 & 0.019 & 0.733 & 0.064 & 0.727 & 0.076 & 0.741 & 0.059 \\
8 & 100,sigmoid & 0.840 & 0.024 & 0.277 & 0.040 & 0.409 & 0.093 & 0.218 &
\textbf{0.039} \\
9 & 200,rbf & \textbf{0.941} & 0.020 & \textbf{0.793} & 0.064 & \textbf{0.804} &
0.100 & \textbf{0.787} & 0.062 \\
10 & 200,poly & 0.917 & 0.013 & 0.709 & 0.046 & 0.699 & 0.051 & 0.722 & 0.064 \\
11 & 200,sigmoid & 0.826 & 0.031 & 0.240 & 0.064 & 0.337 & 0.096 & 0.199 & 0.064
\\
12 & 300,rbf & \textbf{0.941} & 0.020 & \textbf{0.793} & 0.064 & \textbf{0.804}
& 0.100 & \textbf{0.787} & 0.062 \\
13 & 300,poly & 0.917 & 0.016 & 0.711 & 0.053 & 0.704 & 0.066 & 0.722 & 0.062 \\
14 & 300,sigmoid & 0.833 & 0.022 & 0.238 & 0.071 & 0.348 & 0.081 & 0.189 & 0.069
\\
15 & 400,rbf & \textbf{0.941} & 0.020 & \textbf{0.793} & 0.064 & \textbf{0.804}
& 0.100 & \textbf{0.787} & 0.062 \\
16 & 400,poly & 0.919 & 0.016 & 0.716 & 0.054 & 0.708 & 0.069 & 0.727 & 0.061 \\
17 & 400,sigmoid & 0.828 & 0.020 & 0.267 & 0.076 & 0.342 & 0.069 & 0.231 & 0.083
\\
18 & 500,rbf & \textbf{0.941} & 0.020 & \textbf{0.793} & 0.064 & \textbf{0.804}
& 0.100 & \textbf{0.787} & 0.062 \\
19 & 500,poly & 0.919 & 0.018 & 0.718 & 0.054 & 0.709 & 0.081 & 0.732 & 0.054 \\
20 & 500,sigmoid & 0.823 & 0.030 & 0.261 & 0.067 & 0.334 & 0.081 & 0.227 & 0.069
\\
21 & 600,rbf & \textbf{0.941} & 0.020 & \textbf{0.793} & 0.064 & \textbf{0.804}
& 0.100 & \textbf{0.787} & 0.062 \\
22 & 600,poly & 0.920 & 0.015 & 0.721 & 0.046 & 0.713 & 0.065 & 0.732 & 0.049 \\
23 & 600,sigmoid & 0.814 & 0.038 & 0.247 & 0.071 & 0.312 & 0.108 & 0.213 & 0.056
\\
24 & 700,rbf & \textbf{0.941} & 0.020 & \textbf{0.793} & 0.064 & \textbf{0.804}
& 0.100 & \textbf{0.787} & 0.062 \\
```

```
25 & 700,poly & 0.920 & 0.015 & 0.722 & 0.046 & 0.711 & 0.063 & 0.736 & 0.055 \\
26 & 700,sigmoid & 0.831 & 0.024 & 0.258 & 0.049 & 0.353 & 0.081 & 0.208 & 0.040
\\
27 & 800,rbf & \textbf{0.941} & 0.020 & \textbf{0.793} & 0.064 & \textbf{0.804}
& 0.100 & \textbf{0.787} & 0.062 \\
28 & 800,poly & 0.919 & 0.015 & 0.720 & 0.048 & 0.707 & 0.061 & 0.736 & 0.055 \\
29 & 800,sigmoid & 0.805 & 0.032 & 0.260 & 0.048 & 0.297 & 0.056 & 0.250 & 0.071
\\
30 & 900,rbf & \textbf{0.941} & 0.020 & \textbf{0.793} & 0.064 & \textbf{0.804}
& 0.100 & \textbf{0.787} & 0.062 \\
31 & 900,poly & 0.917 & 0.015 & 0.711 & 0.048 & 0.703 & 0.061 & 0.722 & 0.050 \\
32 & 900,sigmoid & 0.819 & 0.029 & 0.225 & 0.095 & 0.298 & 0.081 & 0.204 & 0.120
\\
33 & 1000,rbf & \textbf{0.941} & 0.020 & \textbf{0.793} & 0.064 & \textbf{0.804}
& 0.100 & \textbf{0.787} & 0.062 \\
34 & 1000,poly & 0.919 & 0.014 & 0.715 & 0.046 & 0.706 & 0.054 & 0.727 & 0.057
\\
35 & 1000,sigmoid & 0.844 & \textbf{0.009} & 0.220 & 0.078 & 0.368 & 0.080 &
0.162 & 0.072 \\
\bottomrule
\end{tabular}
\end{table}
```

	C,kernel	accuracy_D3	accuracy_D3_std	f1_D3	f1_D3_std	\
0	0.1,rbf	0.862632	0.011708	0.320844	0.046349	
1	0.1,poly	0.889323	0.017602	0.498690	0.129953	
2	0.1,sigmoid	0.840492	0.015846	0.173315	0.054850	
3	10,rbf	0.947265	0.004327	0.809845	0.016693	
4	10,poly	0.918639	0.017482	0.712459	0.041106	
5	10,sigmoid	0.772169	0.027683	0.236995	0.061092	
6	100,rbf	0.945321	0.007171	0.807452	0.019816	
7	100,poly	0.927087	0.003243	0.736541	0.007664	
8	100,sigmoid	0.741556	0.038478	0.214955	0.074437	
9	200,rbf	0.945321	0.007171	0.807452	0.019816	
10	200,poly	0.927082	0.007880	0.738134	0.026392	
11	200,sigmoid	0.753947	0.038851	0.207020	0.059921	
12	300,rbf	0.945321	0.007171	0.807452	0.019816	
13	300,poly	0.927078	0.008922	0.735122	0.034337	
14	300,sigmoid	0.746131	0.045669	0.194580	0.079398	
15	400,rbf	0.945321	0.007171	0.807452	0.019816	
16	400,poly	0.927732	0.013585	0.736897	0.052054	
17	400,sigmoid	0.738961	0.027810	0.198518	0.071346	
18	500,rbf	0.945321	0.007171	0.807452	0.019816	
19	500,poly	0.928383	0.011297	0.735460	0.048253	
20	500,sigmoid	0.738314	0.031364	0.197400	0.058434	
21	600,rbf	0.945321	0.007171	0.807452	0.019816	
22	600,poly	0.928385	0.008980	0.736023	0.037273	

23	600,sigmoid	0.753945	0.038266	0.204296	0.061135
24	700,rbf	0.945321	0.007171	0.807452	0.019816
25	700,poly	0.929037	0.009748	0.737581	0.041561
26	700,sigmoid	0.735708	0.031299	0.201836	0.076319
27	800,rbf	0.945321	0.007171	0.807452	0.019816
28	800,poly	0.929688	0.008878	0.740957	0.035974
29	800,sigmoid	0.759161	0.050889	0.232105	0.092098
30	900,rbf	0.945321	0.007171	0.807452	0.019816
31	900,poly	0.928383	0.008258	0.736743	0.038017
32	900,sigmoid	0.757854	0.048953	0.223535	0.079118
33	1000,rbf	0.945321	0.007171	0.807452	0.019816
34	1000,poly	0.928383	0.006854	0.733879	0.035526
35	1000,sigmoid	0.733100	0.039895	0.202755	0.045617

	precision_D3	precision_D3_std	recall_D3	recall_D3_std
0	0.570389	0.125594	0.227273	0.040656
1	0.705364	0.101936	0.413636	0.175692
2	0.365657	0.159546	0.118182	0.041660
3	0.841996	0.051640	0.786364	0.058564
4	0.738974	0.087836	0.695455	0.036927
5	0.230569	0.061956	0.245455	0.061658
6	0.822382	0.056953	0.800000	0.054545
7	0.769890	0.051510	0.713636	0.060302
8	0.193880	0.061843	0.254545	0.118007
9	0.822382	0.056953	0.800000	0.054545
10	0.765863	0.059589	0.718182	0.054923
11	0.197409	0.048089	0.231818	0.103053
12	0.822382	0.056953	0.800000	0.054545
13	0.769693	0.056227	0.709091	0.063311
14	0.186135	0.067853	0.222727	0.129685
15	0.822382	0.056953	0.800000	0.054545
16	0.772163	0.065409	0.709091	0.071002
17	0.176814	0.048187	0.236364	0.121628
18	0.822382	0.056953	0.800000	0.054545
19	0.780553	0.050945	0.700000	0.075241
20	0.177540	0.040872	0.231818	0.101028
21	0.822382	0.056953	0.800000	0.054545
22	0.781059	0.046812	0.700000	0.061658
23	0.195271	0.041773	0.231818	0.114452
24	0.822382	0.056953	0.800000	0.054545
25	0.785099	0.048597	0.700000	0.066494
26	0.177682	0.052285	0.245455	0.131268
27	0.822382	0.056953	0.800000	0.054545
28	0.786444	0.048104	0.704545	0.059265
29	0.224048	0.099526	0.245455	0.084306
30	0.822382	0.056953	0.800000	0.054545
31	0.777203	0.035595	0.704545	0.068935
32	0.218770	0.088827	0.236364	0.075515

```
33      0.822382          0.056953   0.800000       0.054545
34      0.784473          0.037139   0.695455       0.074134
35      0.183122          0.042457   0.240909       0.085763
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & C,kernel & accuracy D3 & accuracy D3 std & f1 D3 & f1 D3 std & precision D3 &
precision D3 std & recall D3 & recall D3 std \\
\midrule
0 & 0.1,rbf & 0.863 & 0.012 & 0.321 & 0.046 & 0.570 & 0.126 & 0.227 & 0.041 \\
1 & 0.1,poly & 0.889 & 0.018 & 0.499 & 0.130 & 0.705 & 0.102 & 0.414 & 0.176 \\
2 & 0.1,sigmoid & 0.840 & 0.016 & 0.173 & 0.055 & 0.366 & 0.160 & 0.118 & 0.042
\\
3 & 10,rbf & \textbf{0.947} & 0.004 & \textbf{0.81} & 0.017 & \textbf{0.842} &
0.052 & 0.786 & 0.059 \\
4 & 10,poly & 0.919 & 0.017 & 0.712 & 0.041 & 0.739 & 0.088 & 0.695 &
\textbf{0.037} \\
5 & 10,sigmoid & 0.772 & 0.028 & 0.237 & 0.061 & 0.231 & 0.062 & 0.245 & 0.062
\\
6 & 100,rbf & 0.945 & 0.007 & 0.807 & 0.020 & 0.822 & 0.057 & \textbf{0.8} &
0.055 \\
7 & 100,poly & 0.927 & \textbf{0.003} & 0.737 & \textbf{0.008} & 0.770 & 0.052 &
0.714 & 0.060 \\
8 & 100,sigmoid & 0.742 & 0.038 & 0.215 & 0.074 & 0.194 & 0.062 & 0.255 & 0.118
\\
9 & 200,rbf & 0.945 & 0.007 & 0.807 & 0.020 & 0.822 & 0.057 & \textbf{0.8} &
0.055 \\
10 & 200,poly & 0.927 & 0.008 & 0.738 & 0.026 & 0.766 & 0.060 & 0.718 & 0.055 \\
11 & 200,sigmoid & 0.754 & 0.039 & 0.207 & 0.060 & 0.197 & 0.048 & 0.232 & 0.103
\\
12 & 300,rbf & 0.945 & 0.007 & 0.807 & 0.020 & 0.822 & 0.057 & \textbf{0.8} &
0.055 \\
13 & 300,poly & 0.927 & 0.009 & 0.735 & 0.034 & 0.770 & 0.056 & 0.709 & 0.063 \\
14 & 300,sigmoid & 0.746 & 0.046 & 0.195 & 0.079 & 0.186 & 0.068 & 0.223 & 0.130
\\
15 & 400,rbf & 0.945 & 0.007 & 0.807 & 0.020 & 0.822 & 0.057 & \textbf{0.8} &
0.055 \\
16 & 400,poly & 0.928 & 0.014 & 0.737 & 0.052 & 0.772 & 0.065 & 0.709 & 0.071 \\
17 & 400,sigmoid & 0.739 & 0.028 & 0.199 & 0.071 & 0.177 & 0.048 & 0.236 & 0.122
\\
18 & 500,rbf & 0.945 & 0.007 & 0.807 & 0.020 & 0.822 & 0.057 & \textbf{0.8} &
0.055 \\
19 & 500,poly & 0.928 & 0.011 & 0.735 & 0.048 & 0.781 & 0.051 & 0.700 & 0.075 \\
20 & 500,sigmoid & 0.738 & 0.031 & 0.197 & 0.058 & 0.178 & 0.041 & 0.232 & 0.101
\\
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21 & 600,rbf & 0.945 & 0.007 & 0.807 & 0.020 & 0.822 & 0.057 & \textbf{0.8} &
0.055 \\
22 & 600,poly & 0.928 & 0.009 & 0.736 & 0.037 & 0.781 & 0.047 & 0.700 & 0.062 \\
23 & 600,sigmoid & 0.754 & 0.038 & 0.204 & 0.061 & 0.195 & 0.042 & 0.232 & 0.114
\\
24 & 700,rbf & 0.945 & 0.007 & 0.807 & 0.020 & 0.822 & 0.057 & \textbf{0.8} &
0.055 \\
25 & 700,poly & 0.929 & 0.010 & 0.738 & 0.042 & 0.785 & 0.049 & 0.700 & 0.066 \\
26 & 700,sigmoid & 0.736 & 0.031 & 0.202 & 0.076 & 0.178 & 0.052 & 0.245 & 0.131
\\
27 & 800,rbf & 0.945 & 0.007 & 0.807 & 0.020 & 0.822 & 0.057 & \textbf{0.8} &
0.055 \\
28 & 800,poly & 0.930 & 0.009 & 0.741 & 0.036 & 0.786 & 0.048 & 0.705 & 0.059 \\
29 & 800,sigmoid & 0.759 & 0.051 & 0.232 & 0.092 & 0.224 & 0.100 & 0.245 & 0.084
\\
30 & 900,rbf & 0.945 & 0.007 & 0.807 & 0.020 & 0.822 & 0.057 & \textbf{0.8} &
0.055 \\
31 & 900,poly & 0.928 & 0.008 & 0.737 & 0.038 & 0.777 & \textbf{0.036} & 0.705 &
0.069 \\
32 & 900,sigmoid & 0.758 & 0.049 & 0.224 & 0.079 & 0.219 & 0.089 & 0.236 & 0.076
\\
33 & 1000,rbf & 0.945 & 0.007 & 0.807 & 0.020 & 0.822 & 0.057 & \textbf{0.8} &
0.055 \\
34 & 1000,poly & 0.928 & 0.007 & 0.734 & 0.036 & 0.784 & 0.037 & 0.695 & 0.074
\\
35 & 1000,sigmoid & 0.733 & 0.040 & 0.203 & 0.046 & 0.183 & 0.042 & 0.241 &
0.086 \\
\bottomrule
\end{tabular}
\end{table}
```

	C,kernel	accuracy_D4	accuracy_D4_std	f1_D4	f1_D4_std	\
0	0.1,rbf	0.846360	0.008969	0.631971	0.025251	
1	0.1,poly	0.781234	0.040935	0.532993	0.036248	
2	0.1,sigmoid	0.832028	0.015536	0.530475	0.045153	
3	10,rbf	0.963543	0.009523	0.886494	0.030252	
4	10,poly	0.950529	0.013057	0.842807	0.045574	
5	10,sigmoid	0.793604	0.019648	0.260352	0.071155	
6	100,rbf	0.960942	0.007110	0.878367	0.022968	
7	100,poly	0.950527	0.007495	0.849402	0.024610	
8	100,sigmoid	0.781245	0.016074	0.231815	0.060279	
9	200,rbf	0.960942	0.007110	0.878367	0.022968	
10	200,poly	0.952485	0.010950	0.853398	0.035024	
11	200,sigmoid	0.772784	0.009574	0.217818	0.041786	
12	300,rbf	0.960942	0.007110	0.878367	0.022968	
13	300,poly	0.954438	0.010442	0.859221	0.032883	
14	300,sigmoid	0.774081	0.015047	0.219014	0.061866	

15	400,rbf	0.960942	0.007110	0.878367	0.022968
16	400,poly	0.955089	0.011299	0.860977	0.035358
17	400,sigmoid	0.774075	0.016471	0.225468	0.067540
18	500,rbf	0.960942	0.007110	0.878367	0.022968
19	500,poly	0.954438	0.009814	0.858913	0.031810
20	500,sigmoid	0.773438	0.014644	0.225761	0.048883
21	600,rbf	0.960942	0.007110	0.878367	0.022968
22	600,poly	0.953788	0.010906	0.856672	0.034630
23	600,sigmoid	0.776027	0.017816	0.240905	0.066709
24	700,rbf	0.960942	0.007110	0.878367	0.022968
25	700,poly	0.952487	0.012042	0.853385	0.037198
26	700,sigmoid	0.776033	0.011874	0.227660	0.050141
27	800,rbf	0.960942	0.007110	0.878367	0.022968
28	800,poly	0.951836	0.012184	0.851088	0.037597
29	800,sigmoid	0.774724	0.018062	0.216382	0.066776
30	900,rbf	0.960942	0.007110	0.878367	0.022968
31	900,poly	0.951836	0.012184	0.851088	0.037597
32	900,sigmoid	0.771484	0.009765	0.228670	0.062471
33	1000,rbf	0.960942	0.007110	0.878367	0.022968
34	1000,poly	0.951834	0.010314	0.850980	0.032690
35	1000,sigmoid	0.771481	0.009141	0.224953	0.056632

	precision_D4	precision_D4_std	recall_D4	recall_D4_std
0	0.519327	0.016512	0.809176	0.056634
1	0.416765	0.039975	0.761725	0.110823
2	0.488620	0.041019	0.581725	0.058846
3	0.901159	0.027653	0.872627	0.036571
4	0.868745	0.021840	0.821098	0.075533
5	0.314862	0.086461	0.222824	0.062376
6	0.892890	0.015687	0.864706	0.033524
7	0.845797	0.036909	0.856863	0.057409
8	0.271990	0.068701	0.202824	0.056601
9	0.892890	0.015687	0.864706	0.033524
10	0.860346	0.038528	0.848941	0.055981
11	0.248411	0.040387	0.194902	0.044321
12	0.892890	0.015687	0.864706	0.033524
13	0.867463	0.035243	0.852863	0.050346
14	0.250589	0.066594	0.194902	0.058347
15	0.892890	0.015687	0.864706	0.033524
16	0.870748	0.036116	0.852863	0.050346
17	0.254957	0.070552	0.202745	0.065262
18	0.892890	0.015687	0.864706	0.033524
19	0.867887	0.033389	0.852863	0.059116
20	0.256143	0.054487	0.202902	0.047978
21	0.892890	0.015687	0.864706	0.033524
22	0.867526	0.037263	0.848863	0.060512
23	0.269699	0.072525	0.218902	0.064754
24	0.892890	0.015687	0.864706	0.033524

```
25      0.860888          0.042892   0.848863       0.060512
26      0.260097          0.053232   0.202980       0.048518
27      0.892890          0.015687   0.864706       0.033524
28      0.860260          0.043169   0.844863       0.060304
29      0.250260          0.074608   0.190824       0.060724
30      0.892890          0.015687   0.864706       0.033524
31      0.860260          0.043169   0.844863       0.060304
32      0.251916          0.055901   0.210902       0.067761
33      0.892890          0.015687   0.864706       0.033524
34      0.860518          0.039841   0.844863       0.060304
35      0.249599          0.045375   0.206902       0.062791
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & C,kernel & accuracy D4 & accuracy D4 std & f1 D4 & f1 D4 std & precision D4 &
precision D4 std & recall D4 & recall D4 std \\
\midrule
0 & 0.1,rbf & 0.846 & 0.009 & 0.632 & 0.025 & 0.519 & 0.017 & 0.809 & 0.057 \\
1 & 0.1,poly & 0.781 & 0.041 & 0.533 & 0.036 & 0.417 & 0.040 & 0.762 & 0.111 \\
2 & 0.1,sigmoid & 0.832 & 0.016 & 0.530 & 0.045 & 0.489 & 0.041 & 0.582 & 0.059
\\
3 & 10,rbf & \textbf{0.964} & 0.010 & \textbf{0.886} & 0.030 & \textbf{0.901} &
0.028 & \textbf{0.873} & 0.037 \\
4 & 10,poly & 0.951 & 0.013 & 0.843 & 0.046 & 0.869 & 0.022 & 0.821 & 0.076 \\
5 & 10,sigmoid & 0.794 & 0.020 & 0.260 & 0.071 & 0.315 & 0.086 & 0.223 & 0.062
\\
6 & 100,rbf & 0.961 & \textbf{0.007} & 0.878 & \textbf{0.023} & 0.893 &
\textbf{0.016} & 0.865 & \textbf{0.034} \\
7 & 100,poly & 0.951 & \textbf{0.007} & 0.849 & 0.025 & 0.846 & 0.037 & 0.857 &
0.057 \\
8 & 100,sigmoid & 0.781 & 0.016 & 0.232 & 0.060 & 0.272 & 0.069 & 0.203 & 0.057
\\
9 & 200,rbf & 0.961 & \textbf{0.007} & 0.878 & \textbf{0.023} & 0.893 &
\textbf{0.016} & 0.865 & \textbf{0.034} \\
10 & 200,poly & 0.952 & 0.011 & 0.853 & 0.035 & 0.860 & 0.039 & 0.849 & 0.056 \\
11 & 200,sigmoid & 0.773 & 0.010 & 0.218 & 0.042 & 0.248 & 0.040 & 0.195 & 0.044
\\
12 & 300,rbf & 0.961 & \textbf{0.007} & 0.878 & \textbf{0.023} & 0.893 &
\textbf{0.016} & 0.865 & \textbf{0.034} \\
13 & 300,poly & 0.954 & 0.010 & 0.859 & 0.033 & 0.867 & 0.035 & 0.853 & 0.050 \\
14 & 300,sigmoid & 0.774 & 0.015 & 0.219 & 0.062 & 0.251 & 0.067 & 0.195 & 0.058
\\
15 & 400,rbf & 0.961 & \textbf{0.007} & 0.878 & \textbf{0.023} & 0.893 &
\textbf{0.016} & 0.865 & \textbf{0.034} \\
16 & 400,poly & 0.955 & 0.011 & 0.861 & 0.035 & 0.871 & 0.036 & 0.853 & 0.050 \\
```

```
17 & 400,sigmoid & 0.774 & 0.016 & 0.225 & 0.068 & 0.255 & 0.071 & 0.203 & 0.065
\\
18 & 500,rbf & 0.961 & \textbf{0.007} & 0.878 & \textbf{0.023} & 0.893 &
\textbf{0.016} & 0.865 & \textbf{0.034} \\
19 & 500,poly & 0.954 & 0.010 & 0.859 & 0.032 & 0.868 & 0.033 & 0.853 & 0.059 \\
20 & 500,sigmoid & 0.773 & 0.015 & 0.226 & 0.049 & 0.256 & 0.054 & 0.203 & 0.048
\\
21 & 600,rbf & 0.961 & \textbf{0.007} & 0.878 & \textbf{0.023} & 0.893 &
\textbf{0.016} & 0.865 & \textbf{0.034} \\
22 & 600,poly & 0.954 & 0.011 & 0.857 & 0.035 & 0.868 & 0.037 & 0.849 & 0.061 \\
23 & 600,sigmoid & 0.776 & 0.018 & 0.241 & 0.067 & 0.270 & 0.073 & 0.219 & 0.065
\\
24 & 700,rbf & 0.961 & \textbf{0.007} & 0.878 & \textbf{0.023} & 0.893 &
\textbf{0.016} & 0.865 & \textbf{0.034} \\
25 & 700,poly & 0.952 & 0.012 & 0.853 & 0.037 & 0.861 & 0.043 & 0.849 & 0.061 \\
26 & 700,sigmoid & 0.776 & 0.012 & 0.228 & 0.050 & 0.260 & 0.053 & 0.203 & 0.049
\\
27 & 800,rbf & 0.961 & \textbf{0.007} & 0.878 & \textbf{0.023} & 0.893 &
\textbf{0.016} & 0.865 & \textbf{0.034} \\
28 & 800,poly & 0.952 & 0.012 & 0.851 & 0.038 & 0.860 & 0.043 & 0.845 & 0.060 \\
29 & 800,sigmoid & 0.775 & 0.018 & 0.216 & 0.067 & 0.250 & 0.075 & 0.191 & 0.061
\\
30 & 900,rbf & 0.961 & \textbf{0.007} & 0.878 & \textbf{0.023} & 0.893 &
\textbf{0.016} & 0.865 & \textbf{0.034} \\
31 & 900,poly & 0.952 & 0.012 & 0.851 & 0.038 & 0.860 & 0.043 & 0.845 & 0.060 \\
32 & 900,sigmoid & 0.771 & 0.010 & 0.229 & 0.062 & 0.252 & 0.056 & 0.211 & 0.068
\\
33 & 1000,rbf & 0.961 & \textbf{0.007} & 0.878 & \textbf{0.023} & 0.893 &
\textbf{0.016} & 0.865 & \textbf{0.034} \\
34 & 1000,poly & 0.952 & 0.010 & 0.851 & 0.033 & 0.861 & 0.040 & 0.845 & 0.060
\\
35 & 1000,sigmoid & 0.771 & 0.009 & 0.225 & 0.057 & 0.250 & 0.045 & 0.207 &
0.063 \\
\bottomrule
\end{tabular}
\end{table}
```

```
        C,kernel  accuracy_D5  accuracy_D5_std     f1_D5  f1_D5_std  \
0        0.1,rbf     0.948581         0.012524  0.823900   0.035679
1       0.1,poly     0.904971         0.028322  0.733516   0.052342
2    0.1,sigmoid     0.882821         0.021058  0.666807   0.040835
3         10,rbf     0.979176         0.011177  0.926373   0.038960
4        10,poly     0.973971         0.017809  0.910312   0.059545
5     10,sigmoid     0.881505         0.022366  0.581821   0.068823
6        100,rbf     0.979830         0.012894  0.927355   0.046330
7       100,poly     0.970056         0.016134  0.895555   0.052505
8    100,sigmoid     0.870443         0.016658  0.531172   0.043513
```

9	200,rbf	0.979830	0.012894	0.927355	0.046330
10	200,poly	0.968099	0.016142	0.889667	0.050117
11	200,sigmoid	0.863922	0.017479	0.523693	0.035470
12	300,rbf	0.979830	0.012894	0.927355	0.046330
13	300,poly	0.969396	0.016565	0.895192	0.050720
14	300,sigmoid	0.867181	0.016705	0.527230	0.035898
15	400,rbf	0.979830	0.012894	0.927355	0.046330
16	400,poly	0.968095	0.017535	0.891345	0.053136
17	400,sigmoid	0.869785	0.020536	0.535221	0.051496
18	500,rbf	0.979830	0.012894	0.927355	0.046330
19	500,poly	0.968095	0.017535	0.891345	0.053136
20	500,sigmoid	0.868486	0.016961	0.529638	0.043662
21	600,rbf	0.979830	0.012894	0.927355	0.046330
22	600,poly	0.968095	0.017535	0.891345	0.053136
23	600,sigmoid	0.869134	0.017697	0.529027	0.041995
24	700,rbf	0.979830	0.012894	0.927355	0.046330
25	700,poly	0.968095	0.017535	0.891345	0.053136
26	700,sigmoid	0.867841	0.017891	0.526276	0.049111
27	800,rbf	0.979830	0.012894	0.927355	0.046330
28	800,poly	0.968095	0.017535	0.891345	0.053136
29	800,sigmoid	0.868482	0.017843	0.523238	0.042326
30	900,rbf	0.979830	0.012894	0.927355	0.046330
31	900,poly	0.968095	0.017535	0.891345	0.053136
32	900,sigmoid	0.870439	0.016942	0.528737	0.046522
33	1000,rbf	0.979830	0.012894	0.927355	0.046330
34	1000,poly	0.968095	0.017535	0.891345	0.053136
35	1000,sigmoid	0.867833	0.014988	0.523375	0.039524

	precision_D5	precision_D5_std	recall_D5	recall_D5_std
0	0.786645	0.071539	0.871429	0.044160
1	0.617100	0.097323	0.928571	0.056344
2	0.553147	0.062845	0.847619	0.028571
3	0.902072	0.048234	0.952381	0.030117
4	0.877534	0.079911	0.947619	0.040963
5	0.566201	0.076596	0.600000	0.066326
6	0.917511	0.053786	0.938095	0.044160
7	0.868291	0.071384	0.928571	0.054294
8	0.530837	0.065465	0.533333	0.024281
9	0.917511	0.053786	0.938095	0.044160
10	0.861474	0.076767	0.923810	0.038095
11	0.509003	0.063035	0.542857	0.009524
12	0.917511	0.053786	0.938095	0.044160
13	0.863293	0.081142	0.933333	0.023328
14	0.520699	0.064976	0.538095	0.024281
15	0.917511	0.053786	0.938095	0.044160
16	0.856224	0.082963	0.933333	0.023328
17	0.530993	0.080113	0.542857	0.027766
18	0.917511	0.053786	0.938095	0.044160

```
19      0.856224          0.082963   0.933333       0.023328
20      0.523997          0.067358   0.538095       0.028571
21      0.917511          0.053786   0.938095       0.044160
22      0.856224          0.082963   0.933333       0.023328
23      0.527497          0.068691   0.533333       0.019048
24      0.917511          0.053786   0.938095       0.044160
25      0.856224          0.082963   0.933333       0.023328
26      0.521232          0.070160   0.533333       0.032297
27      0.917511          0.053786   0.938095       0.044160
28      0.856224          0.082963   0.933333       0.023328
29      0.526436          0.072411   0.523810       0.026082
30      0.917511          0.053786   0.938095       0.044160
31      0.856224          0.082963   0.933333       0.023328
32      0.530006          0.062300   0.528571       0.031587
33      0.917511          0.053786   0.938095       0.044160
34      0.856224          0.082963   0.933333       0.023328
35      0.520040          0.055460   0.528571       0.031587
```

```
\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & C,kernel & accuracy D5 & accuracy D5 std & f1 D5 & f1 D5 std & precision D5 &
precision D5 std & recall D5 & recall D5 std \\
\midrule
0 & 0.1,rbf & 0.949 & 0.013 & 0.824 & 0.036 & 0.787 & 0.072 & 0.871 & 0.044 \\
1 & 0.1,poly & 0.905 & 0.028 & 0.734 & 0.052 & 0.617 & 0.097 & 0.929 & 0.056 \\
2 & 0.1,sigmoid & 0.883 & 0.021 & 0.667 & 0.041 & 0.553 & 0.063 & 0.848 & 0.029
\\
3 & 10,rbf & 0.979 & \textbf{0.011} & 0.926 & 0.039 & 0.902 & \textbf{0.048} &
\textbf{0.952} & 0.030 \\
4 & 10,poly & 0.974 & 0.018 & 0.910 & 0.060 & 0.878 & 0.080 & 0.948 & 0.041 \\
5 & 10,sigmoid & 0.882 & 0.022 & 0.582 & 0.069 & 0.566 & 0.077 & 0.600 & 0.066
\\
6 & 100,rbf & \textbf{0.98} & 0.013 & \textbf{0.927} & 0.046 & \textbf{0.918} &
0.054 & 0.938 & 0.044 \\
7 & 100,poly & 0.970 & 0.016 & 0.896 & 0.053 & 0.868 & 0.071 & 0.929 & 0.054 \\
8 & 100,sigmoid & 0.870 & 0.017 & 0.531 & 0.044 & 0.531 & 0.065 & 0.533 & 0.024
\\
9 & 200,rbf & \textbf{0.98} & 0.013 & \textbf{0.927} & 0.046 & \textbf{0.918} &
0.054 & 0.938 & 0.044 \\
10 & 200,poly & 0.968 & 0.016 & 0.890 & 0.050 & 0.861 & 0.077 & 0.924 & 0.038 \\
11 & 200,sigmoid & 0.864 & 0.017 & 0.524 & \textbf{0.035} & 0.509 & 0.063 &
0.543 & \textbf{0.01} \\
12 & 300,rbf & \textbf{0.98} & 0.013 & \textbf{0.927} & 0.046 & \textbf{0.918} &
0.054 & 0.938 & 0.044 \\
13 & 300,poly & 0.969 & 0.017 & 0.895 & 0.051 & 0.863 & 0.081 & 0.933 & 0.023 \\
```

```
14 & 300,sigmoid & 0.867 & 0.017 & 0.527 & 0.036 & 0.521 & 0.065 & 0.538 & 0.024
\\
15 & 400,rbf & \textbf{0.98} & 0.013 & \textbf{0.927} & 0.046 & \textbf{0.918} &
0.054 & 0.938 & 0.044 \\
16 & 400,poly & 0.968 & 0.018 & 0.891 & 0.053 & 0.856 & 0.083 & 0.933 & 0.023 \\
17 & 400,sigmoid & 0.870 & 0.021 & 0.535 & 0.051 & 0.531 & 0.080 & 0.543 & 0.028
\\
18 & 500,rbf & \textbf{0.98} & 0.013 & \textbf{0.927} & 0.046 & \textbf{0.918} &
0.054 & 0.938 & 0.044 \\
19 & 500,poly & 0.968 & 0.018 & 0.891 & 0.053 & 0.856 & 0.083 & 0.933 & 0.023 \\
20 & 500,sigmoid & 0.868 & 0.017 & 0.530 & 0.044 & 0.524 & 0.067 & 0.538 & 0.029
\\
21 & 600,rbf & \textbf{0.98} & 0.013 & \textbf{0.927} & 0.046 & \textbf{0.918} &
0.054 & 0.938 & 0.044 \\
22 & 600,poly & 0.968 & 0.018 & 0.891 & 0.053 & 0.856 & 0.083 & 0.933 & 0.023 \\
23 & 600,sigmoid & 0.869 & 0.018 & 0.529 & 0.042 & 0.527 & 0.069 & 0.533 & 0.019
\\
24 & 700,rbf & \textbf{0.98} & 0.013 & \textbf{0.927} & 0.046 & \textbf{0.918} &
0.054 & 0.938 & 0.044 \\
25 & 700,poly & 0.968 & 0.018 & 0.891 & 0.053 & 0.856 & 0.083 & 0.933 & 0.023 \\
26 & 700,sigmoid & 0.868 & 0.018 & 0.526 & 0.049 & 0.521 & 0.070 & 0.533 & 0.032
\\
27 & 800,rbf & \textbf{0.98} & 0.013 & \textbf{0.927} & 0.046 & \textbf{0.918} &
0.054 & 0.938 & 0.044 \\
28 & 800,poly & 0.968 & 0.018 & 0.891 & 0.053 & 0.856 & 0.083 & 0.933 & 0.023 \\
29 & 800,sigmoid & 0.868 & 0.018 & 0.523 & 0.042 & 0.526 & 0.072 & 0.524 & 0.026
\\
30 & 900,rbf & \textbf{0.98} & 0.013 & \textbf{0.927} & 0.046 & \textbf{0.918} &
0.054 & 0.938 & 0.044 \\
31 & 900,poly & 0.968 & 0.018 & 0.891 & 0.053 & 0.856 & 0.083 & 0.933 & 0.023 \\
32 & 900,sigmoid & 0.870 & 0.017 & 0.529 & 0.047 & 0.530 & 0.062 & 0.529 & 0.032
\\
33 & 1000,rbf & \textbf{0.98} & 0.013 & \textbf{0.927} & 0.046 & \textbf{0.918}
& 0.054 & 0.938 & 0.044 \\
34 & 1000,poly & 0.968 & 0.018 & 0.891 & 0.053 & 0.856 & 0.083 & 0.933 & 0.023
\\
35 & 1000,sigmoid & 0.868 & 0.015 & 0.523 & 0.040 & 0.520 & 0.055 & 0.529 &
0.032 \\
\bottomrule
\end{tabular}
\end{table}
```

```
        C,kernel  accuracy_D6  accuracy_D6_std     f1_D6  f1_D6_std  \
0        0.1,rbf     0.994139         0.005972  0.981938   0.018304
1       0.1,poly     0.990886         0.007254  0.972225   0.021449
2    0.1,sigmoid     0.969406         0.009097  0.911918   0.024998
3         10,rbf     0.998046         0.002606  0.993857   0.008174
```

4	10,poly	0.993492	0.006177	0.979957	0.018851
5	10,sigmoid	0.983726	0.002899	0.947552	0.010498
6	100,rbf	0.998046	0.002606	0.993857	0.008174
7	100,poly	0.993492	0.006177	0.979957	0.018851
8	100,sigmoid	0.978523	0.006983	0.929259	0.024371
9	200,rbf	0.998046	0.002606	0.993857	0.008174
10	200,poly	0.993492	0.006177	0.979957	0.018851
11	200,sigmoid	0.980477	0.007098	0.934947	0.025041
12	300,rbf	0.998046	0.002606	0.993857	0.008174
13	300,poly	0.993492	0.006177	0.979957	0.018851
14	300,sigmoid	0.981774	0.003302	0.939596	0.011225
15	400,rbf	0.998046	0.002606	0.993857	0.008174
16	400,poly	0.993492	0.006177	0.979957	0.018851
17	400,sigmoid	0.976562	0.003801	0.921688	0.013045
18	500,rbf	0.998046	0.002606	0.993857	0.008174
19	500,poly	0.993492	0.006177	0.979957	0.018851
20	500,sigmoid	0.978529	0.010965	0.927183	0.040311
21	600,rbf	0.998046	0.002606	0.993857	0.008174
22	600,poly	0.993492	0.006177	0.979957	0.018851
23	600,sigmoid	0.977869	0.004759	0.926266	0.016599
24	700,rbf	0.998046	0.002606	0.993857	0.008174
25	700,poly	0.993492	0.006177	0.979957	0.018851
26	700,sigmoid	0.980471	0.002897	0.935013	0.010002
27	800,rbf	0.998046	0.002606	0.993857	0.008174
28	800,poly	0.993492	0.006177	0.979957	0.018851
29	800,sigmoid	0.976566	0.004764	0.921255	0.016635
30	900,rbf	0.998046	0.002606	0.993857	0.008174
31	900,poly	0.993492	0.006177	0.979957	0.018851
32	900,sigmoid	0.975921	0.008090	0.918993	0.028589
33	1000,rbf	0.998046	0.002606	0.993857	0.008174
34	1000,poly	0.993492	0.006177	0.979957	0.018851
35	1000,sigmoid	0.974620	0.009481	0.913328	0.035247

	precision_D6	precision_D6_std	recall_D6	recall_D6_std
0	0.968769	0.031359	0.995918	0.008163
1	0.950699	0.041766	0.995918	0.008163
2	0.841881	0.041279	0.995918	0.008163
3	0.992000	0.016000	0.995918	0.008163
4	0.965286	0.036746	0.995918	0.008163
5	0.963095	0.022955	0.934269	0.037461
6	0.992000	0.016000	0.995918	0.008163
7	0.965286	0.036746	0.995918	0.008163
8	0.965110	0.028537	0.896939	0.035177
9	0.992000	0.016000	0.995918	0.008163
10	0.965286	0.036746	0.995918	0.008163
11	0.981781	0.022353	0.892857	0.033603
12	0.992000	0.016000	0.995918	0.008163
13	0.965286	0.036746	0.995918	0.008163

```
14      0.986566          0.017829   0.897109       0.012949
15      0.992000          0.016000   0.995918       0.008163
16      0.965286          0.036746   0.995918       0.008163
17      0.977158          0.020350   0.872449       0.015280
18      0.992000          0.016000   0.995918       0.008163
19      0.965286          0.036746   0.995918       0.008163
20      0.980745          0.018918   0.880187       0.057199
21      0.992000          0.016000   0.995918       0.008163
22      0.965286          0.036746   0.995918       0.008163
23      0.977162          0.020569   0.880527       0.016383
24      0.992000          0.016000   0.995918       0.008163
25      0.965286          0.036746   0.995918       0.008163
26      0.986460          0.017886   0.888861       0.010336
27      0.992000          0.016000   0.995918       0.008163
28      0.965286          0.036746   0.995918       0.008163
29      0.981285          0.017434   0.868197       0.017258
30      0.992000          0.016000   0.995918       0.008163
31      0.965286          0.036746   0.995918       0.008163
32      0.976508          0.026090   0.868027       0.032118
33      0.992000          0.016000   0.995918       0.008163
34      0.965286          0.036746   0.995918       0.008163
35      0.980421          0.018984   0.855527       0.048480

\begin{table}
\caption{Comparison of ML Model Performance Metrics}
\label{tab:model_comparison}
\begin{tabular}{lllllllllll}
\toprule
 & C,kernel & accuracy D6 & accuracy D6 std & f1 D6 & f1 D6 std & precision D6 &
precision D6 std & recall D6 & recall D6 std \\
\midrule
0 & 0.1,rbf & 0.994 & 0.006 & 0.982 & 0.018 & 0.969 & 0.031 & \textbf{0.996} &
\textbf{0.008} \\
1 & 0.1,poly & 0.991 & 0.007 & 0.972 & 0.021 & 0.951 & 0.042 & \textbf{0.996} &
\textbf{0.008} \\
2 & 0.1,sigmoid & 0.969 & 0.009 & 0.912 & 0.025 & 0.842 & 0.041 & \textbf{0.996}
& \textbf{0.008} \\
3 & 10,rbf & \textbf{0.998} & \textbf{0.003} & \textbf{0.994} & \textbf{0.008} &
\textbf{0.992} & \textbf{0.016} & \textbf{0.996} & \textbf{0.008} \\
4 & 10,poly & 0.993 & 0.006 & 0.980 & 0.019 & 0.965 & 0.037 & \textbf{0.996} &
\textbf{0.008} \\
5 & 10,sigmoid & 0.984 & \textbf{0.003} & 0.948 & 0.010 & 0.963 & 0.023 & 0.934
& 0.037 \\
6 & 100,rbf & \textbf{0.998} & \textbf{0.003} & \textbf{0.994} & \textbf{0.008}
& \textbf{0.992} & \textbf{0.016} & \textbf{0.996} & \textbf{0.008} \\
7 & 100,poly & 0.993 & 0.006 & 0.980 & 0.019 & 0.965 & 0.037 & \textbf{0.996} &
\textbf{0.008} \\
8 & 100,sigmoid & 0.979 & 0.007 & 0.929 & 0.024 & 0.965 & 0.029 & 0.897 & 0.035
```

```
\\
9 & 200,rbf & \textbf{0.998} & \textbf{0.003} & \textbf{0.994} & \textbf{0.008}
& \textbf{0.992} & \textbf{0.016} & \textbf{0.996} & \textbf{0.008} \\
10 & 200,poly & 0.993 & 0.006 & 0.980 & 0.019 & 0.965 & 0.037 & \textbf{0.996} &
\textbf{0.008} \\
11 & 200,sigmoid & 0.980 & 0.007 & 0.935 & 0.025 & 0.982 & 0.022 & 0.893 & 0.034
\\
12 & 300,rbf & \textbf{0.998} & \textbf{0.003} & \textbf{0.994} & \textbf{0.008}
& \textbf{0.992} & \textbf{0.016} & \textbf{0.996} & \textbf{0.008} \\
13 & 300,poly & 0.993 & 0.006 & 0.980 & 0.019 & 0.965 & 0.037 & \textbf{0.996} &
\textbf{0.008} \\
14 & 300,sigmoid & 0.982 & \textbf{0.003} & 0.940 & 0.011 & 0.987 & 0.018 &
0.897 & 0.013 \\
15 & 400,rbf & \textbf{0.998} & \textbf{0.003} & \textbf{0.994} & \textbf{0.008}
& \textbf{0.992} & \textbf{0.016} & \textbf{0.996} & \textbf{0.008} \\
16 & 400,poly & 0.993 & 0.006 & 0.980 & 0.019 & 0.965 & 0.037 & \textbf{0.996} &
\textbf{0.008} \\
17 & 400,sigmoid & 0.977 & 0.004 & 0.922 & 0.013 & 0.977 & 0.020 & 0.872 & 0.015
\\
18 & 500,rbf & \textbf{0.998} & \textbf{0.003} & \textbf{0.994} & \textbf{0.008}
& \textbf{0.992} & \textbf{0.016} & \textbf{0.996} & \textbf{0.008} \\
19 & 500,poly & 0.993 & 0.006 & 0.980 & 0.019 & 0.965 & 0.037 & \textbf{0.996} &
\textbf{0.008} \\
20 & 500,sigmoid & 0.979 & 0.011 & 0.927 & 0.040 & 0.981 & 0.019 & 0.880 & 0.057
\\
21 & 600,rbf & \textbf{0.998} & \textbf{0.003} & \textbf{0.994} & \textbf{0.008}
& \textbf{0.992} & \textbf{0.016} & \textbf{0.996} & \textbf{0.008} \\
22 & 600,poly & 0.993 & 0.006 & 0.980 & 0.019 & 0.965 & 0.037 & \textbf{0.996} &
\textbf{0.008} \\
23 & 600,sigmoid & 0.978 & 0.005 & 0.926 & 0.017 & 0.977 & 0.021 & 0.881 & 0.016
\\
24 & 700,rbf & \textbf{0.998} & \textbf{0.003} & \textbf{0.994} & \textbf{0.008}
& \textbf{0.992} & \textbf{0.016} & \textbf{0.996} & \textbf{0.008} \\
25 & 700,poly & 0.993 & 0.006 & 0.980 & 0.019 & 0.965 & 0.037 & \textbf{0.996} &
\textbf{0.008} \\
26 & 700,sigmoid & 0.980 & \textbf{0.003} & 0.935 & 0.010 & 0.986 & 0.018 &
0.889 & 0.010 \\
27 & 800,rbf & \textbf{0.998} & \textbf{0.003} & \textbf{0.994} & \textbf{0.008}
& \textbf{0.992} & \textbf{0.016} & \textbf{0.996} & \textbf{0.008} \\
28 & 800,poly & 0.993 & 0.006 & 0.980 & 0.019 & 0.965 & 0.037 & \textbf{0.996} &
\textbf{0.008} \\
29 & 800,sigmoid & 0.977 & 0.005 & 0.921 & 0.017 & 0.981 & 0.017 & 0.868 & 0.017
\\
30 & 900,rbf & \textbf{0.998} & \textbf{0.003} & \textbf{0.994} & \textbf{0.008}
& \textbf{0.992} & \textbf{0.016} & \textbf{0.996} & \textbf{0.008} \\
31 & 900,poly & 0.993 & 0.006 & 0.980 & 0.019 & 0.965 & 0.037 & \textbf{0.996} &
\textbf{0.008} \\
32 & 900,sigmoid & 0.976 & 0.008 & 0.919 & 0.029 & 0.977 & 0.026 & 0.868 & 0.032
```

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\\
33 & 1000,rbf & \textbf{0.998} & \textbf{0.003} & \textbf{0.994} &
\textbf{0.008} & \textbf{0.992} & \textbf{0.016} & \textbf{0.996} &
\textbf{0.008} \\
34 & 1000,poly & 0.993 & 0.006 & 0.980 & 0.019 & 0.965 & 0.037 & \textbf{0.996}
& \textbf{0.008} \\
35 & 1000,sigmoid & 0.975 & 0.009 & 0.913 & 0.035 & 0.980 & 0.019 & 0.856 &
0.048 \\
\bottomrule
\end{tabular}
\end{table}
```