- Code for CSSE415: Group 3, "Bird Species Prediction"
- Imports
- Download bird data from Google Drive

```
!pip install -U gdown
import gdown
url = "https://drive.google.com/uc?id=1hZr6QwZHtj3jYwLzgJrcMi8k11_6lLnq"
gdown.download(url, output="family included full data.csv", quiet=False)
Requirement already satisfied: gdown in /usr/local/lib/python3.11/dist-packages (5.2.0)
     Requirement already satisfied: beautifulsoup4 in /usr/local/lib/python3.11/dist-packages (from gdown
     Requirement already satisfied: filelock in /usr/local/lib/python3.11/dist-packages (from gdown) (3.1
     Requirement already satisfied: requests[socks] in /usr/local/lib/python3.11/dist-packages (from gdow
     Requirement already satisfied: tqdm in /usr/local/lib/python3.11/dist-packages (from gdown) (4.67.1)
     Requirement already satisfied: soupsieve>1.2 in /usr/local/lib/python3.11/dist-packages (from beauti
     Requirement already satisfied: typing-extensions>=4.0.0 in /usr/local/lib/python3.11/dist-packages (
     Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.11/dist-packages (
     Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.11/dist-packages (from request
     Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.11/dist-packages (from r
     Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.11/dist-packages (from r
     Requirement already satisfied: PySocks!=1.5.7,>=1.5.6 in /usr/local/lib/python3.11/dist-packages (fr
     Downloading...
     From: <a href="https://drive.google.com/uc?id=1hZr6QwZHtj3jYwLzgJrcMi8k11_61Lnq">https://drive.google.com/uc?id=1hZr6QwZHtj3jYwLzgJrcMi8k11_61Lnq</a>
     To: /content/family_included_full_data.csv
     100%| 16.7M/16.7M [00:00<00:00, 213MB/s]
     'family included full data.csv'
# Core libraries
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from time import time
# Scikit-learn
from sklearn.model_selection import train_test_split, GridSearchCV, cross_validate
from sklearn.preprocessing import StandardScaler, LabelEncoder, OrdinalEncoder, PolynomialFeatures
from sklearn.metrics import mean absolute error, mean squared error, r2 score
from sklearn.linear model import LinearRegression, Ridge, LogisticRegression
from sklearn.neighbors import KNeighborsRegressor, KNeighborsClassifier
from sklearn.tree import DecisionTreeClassifier, plot_tree
from sklearn.ensemble import RandomForestRegressor, RandomForestClassifier, GradientBoostingRegressor
from sklearn.pipeline import Pipeline
df = pd.read_csv('family_included_full_data.csv', encoding='latin-1') # had to use latin-1 encoding, other
```

```
df.drop(["Unnamed: 0", "Species3 BirdTree", "Species1 BirdLife", "Species2 eBird", "eBird.species.group",
dff = df.dropna(axis=0)
print(dff.shape)
X = dff.drop(['Family3'], axis=1)
y = dff['Family3']
→ (45632, 12)
# See how dropping NA for remaining features impacts number of remaining records
features = df.columns
before size = [ ]
after_size = [ ]
na_feature = [ ]
for f in features:
    before_size.append(df.shape[0])
    data = df.dropna(subset = [f])
    after size.append(data.shape[0])
    na_feature.append(f)
dropNA_results = pd.DataFrame()
dropNA results['before size'] = before size
dropNA_results['after_size'] = after_size
dropNA results['NA feature'] = na feature
dropNA_results['change_size'] = dropNA_results['before_size']-dropNA_results['after_size']
dropNA_results_Ordered = dropNA_results.sort_values(by='change_size',ascending=False)
dropNA_results_Ordered.head(10)
# plt.plot(dropNA results['NA feature'],dropNA results['change size'])
\overline{\rightarrow}
```

	before_size	after_size	NA_feature	change_size
2	90303	55692	Beak.Length_Nares	34611
9	90303	62645	Hand-wing.Index	27658
7	90303	62678	Kipps.Distance	27625
8	90303	64169	Secondary1	26134
3	90303	70277	Beak.Width	20026
1	90303	74172	Beak.Length_Culmen	16131
4	90303	75318	Beak.Depth	14985
5	90303	80460	Tarsus.Length	9843
10	90303	83551	Tail.Length	6752
6	90303	89219	Wing.Length	1084

Preprocess Data

```
cat_cols = X.select_dtypes(include='object').columns
num_cols = X.select_dtypes(exclude='object').columns

X_cat = X[cat_cols].fillna("missing").astype(str)
encoder = OrdinalEncoder()
X_cat_encoded = encoder.fit_transform(X_cat)
```

```
X cat encoded df = pd.DataFrame(X cat encoded, columns=cat cols, index=X.index)
X_num = X[num_cols].fillna(0)
X_processed = pd.concat([X_num, X_cat_encoded_df], axis=1)
stnd = StandardScaler().set_output(transform="pandas")
X_processed = stnd.fit_transform(X_processed)
le = LabelEncoder()
y_encoded = le.fit_transform(y)
X_train, X_test, y_train, y_test = train_test_split(
   X processed, y encoded, test size=0.20, random state=42
print("Rows: ", len(X_train) + len(X_test))
print("Features: ", len(X.iloc[0]))
→ Rows: 45632
     Features: 11

    Feature Selection

def SelectFeature(current_model, remaining_features, X, y):
    scores = []
    for feature in remaining features:
        trial_features = current_model + [feature]
        r2 = cross_validate(
           LinearRegression(fit_intercept=True),
            X[trial features],
            у,
            cv=5,
            scoring='r2'
        )['test_score'].mean()
        scores.append(r2)
    best feature index = np.argmax(scores)
    return remaining_features[best_feature_index], scores
model = []
candidates = X_train.columns.tolist()
selected features = []
r2_progress = []
while len(candidates) > 0:
    next_feature, all_scores = SelectFeature(model, candidates, X_train, y_train)
    model.append(next_feature)
    selected_features.append(next_feature)
    r2_progress.append(max(all_scores))
    candidates.remove(next_feature)
    print("Added feature:", next_feature, "| Validation R^2:", round(max(all_scores), 4))
best_index = int(np.argmax(r2_progress))
model best = model[:best index + 2] # +2 accounts for 'bias' and best index offset
lr_final = LinearRegression(fit_intercept=True)
lr_final.fit(X_train[model_best], y_train)
```

r2 test = lr final.score(X test[model best], y test)

```
print("Final model test R^2:", round(r2_test, 4))
print("Selected features:", model_best)

Added feature: Wing.Length | Validation R^2: 0.0918
   Added feature: Beak.Length_Nares | Validation R^2: 0.0982
   Added feature: Beak.Width | Validation R^2: 0.1034
   Added feature: Beak.Depth | Validation R^2: 0.1088
   Added feature: Sex | Validation R^2: 0.1122
   Added feature: Tail.Length | Validation R^2: 0.1141
   Added feature: Tarsus.Length | Validation R^2: 0.1151
   Added feature: Beak.Length_Culmen | Validation R^2: 0.1158
   Added feature: Hand-wing.Index | Validation R^2: 0.116
   Added feature: Kipps.Distance | Validation R^2: 0.1161
   Added feature: Secondary1 | Validation R^2: 0.1161
   Final model test R^2: 0.1223
   Selected features: ['Wing.Length', 'Beak.Length_Nares', 'Beak.Width', 'Beak.Depth', 'Sex', 'Tail.Length')
```

X train.head()

₹		Beak.Length_Culmen	Beak.Length_Nares	Beak.Width	Beak.Depth	Tarsus.Length	Wing.Length	Κi
	32795	0.093177	-0.195732	-0.176084	-0.183358	0.270495	-0.305171	
	13810	6.986371	6.247147	7.402524	5.435082	0.905493	3.013555	
	87598	-0.456790	-0.395666	-0.487800	-0.420201	-0.306776	-0.602451	
	60353	-0.142523	-0.125755	0.330455	0.079801	0.200398	0.192098	
	8136	2.379881	2.878256	3.194351	2.198229	0.456046	0.138047	

Calculate the BaseLine Regressor Error Rate

```
Baseline_Error = (1 - (df['Family3'].value_counts().max())/df.shape[0])*100
print('The Baseline Error Rate is ', Baseline_Error, '%')
```

The Baseline Error Rate is 94.72885729156285 %

Models

The following section has a series of models which are used to determine what the best approach to classifying the family of the birds.

```
import numpy as np
import pandas as pd
from xgboost import XGBClassifier
from sklearn.model_selection import GridSearchCV
from sklearn.metrics import accuracy_score
from time import time

X_train = X_train.astype(np.float32)
X_test = X_test.astype(np.float32)
y_train = y_train.astype(np.int32)
y test = y test.astype(np.int32)
```

```
start = time()
xgb_grid = {
    'learning_rate': [0.1, 0.01],
    'n_estimators': [100, 200],
    'max_depth': [3],
    'tree_method': ['gpu_hist'],
    'predictor': ['gpu_predictor']
}
xgb = XGBClassifier(use label encoder=False, eval metric='logloss', verbosity=3)
xgbCV = GridSearchCV(xgb, param_grid=xgb_grid, cv=5, return_train_score=True, n_jobs=-1, verbose=3) # o
xgbCV.fit(X_train, y_train)
print('XGBoost Classifier:')
print(' Optimal Parameters:', xgbCV.best_params_)
print(' Optimal CV accuracy =', round(xgbCV.best_score_, 3))
print(f"Computer runtime: {time()-start:.2f} seconds")
eval_start = time()
xgb_best = xgbCV.best_estimator_
acc_train = xgb_best.score(X_train, y_train)
acc_test = xgb_best.score(X_test, y_test)
print('XGBoost Evaluation')
print(f"\tTrain accuracy = {round(acc_train,4)}, Test accuracy = {round(acc_test,4)}")
print(f"\tRuntime: {time()-eval_start:.2f} seconds")
     NameError
                                               Traceback (most recent call last)
     <ipython-input-6-2b5c49431465> in <cell line: 0>()
          6 from time import time
          7
     ---> 8 X_train = X_train.astype(np.float32)
          9 X_test = X_test.astype(np.float32)
          10 y_train = y_train.astype(np.int32)
     NameError: name 'X_train' is not defined
```

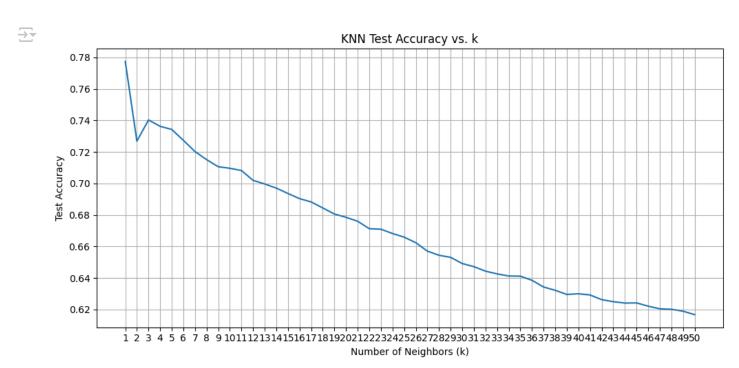
KNN

```
from cuml.neighbors import KNeighborsClassifier
from cuml.model_selection import train_test_split
from cuml.metrics import accuracy_score
import cudf
import numpy as np
import itertools

# Convert your data to cuDF format
X_train_gpu = cudf.DataFrame.from_pandas(X_train)
y_train_gpu = cudf.Series(y_train)
X_test_gpu = cudf.Series(y_test)

# Define parameter grid
```

```
param_grid = {
    'n_neighbors': [1, 2, 3, 4, 5],
    'weights': ['uniform', 'distance'],
    'metric': ['euclidean', 'manhattan']
}
# Manual grid search
best_score = 0
best_params = None
for n, w, m in itertools.product(param_grid['n_neighbors'],
                                 param_grid['weights'],
                                 param_grid['metric']):
    try:
        model = KNeighborsClassifier(n_neighbors=n, weights=w, metric=m)
        model.fit(X_train_gpu, y_train_gpu)
        preds = model.predict(X_train_gpu)
        acc = accuracy_score(y_train_gpu, preds)
        print(f"Params: n={n}, weights={w}, metric={m} => CV Accuracy: {acc:.4f}")
        if acc > best_score:
            best_score = acc
            best_params = {'n_neighbors': n, 'weights': w, 'metric': m}
            best_model = model
    except Exception as e:
        print(f"Skipping combo n={n}, weights={w}, metric={m} due to error: {e}")
# Test set performance
y_test_pred = best_model.predict(X_test_gpu)
test_acc = accuracy_score(y_test_gpu, y_test_pred)
print("\nBest Parameters:", best_params)
print(f"Best Cross-Validation Accuracy: {best_score:.4f}")
print(f"Test Set Accuracy: {test_acc:.4f}")
```



✓ Logistic Regressor

```
from cuml.linear_model import LogisticRegression
from cuml.metrics import accuracy score
import cudf
# Convert datasets to cuDF
X train gpu = cudf.DataFrame.from pandas(X train)
y_train_gpu = cudf.Series(y_train)
X_test_gpu = cudf.DataFrame.from_pandas(X_test)
y_test_gpu = cudf.Series(y_test)
# Initialize and fit Logistic Regression (cuML)
model1 = LogisticRegression(
    penalty='l1',
    solver='qn',
    max_iter=100,
    fit intercept=True
model2 = LogisticRegression(
    penalty='12',
    solver='qn',
    max iter=100,
    fit intercept=True
)
model1.fit(X_train_gpu, y_train_gpu)
model2.fit(X train gpu, y train gpu)
# Predict and evaluate
y_pred = model1.predict(X_test_gpu)
acc = accuracy_score(y_test_gpu, y_pred)
print(f"Test Accuracy 1 (GPU Logistic Regression): {acc:.4f}")
y_pred = model2.predict(X_test_gpu)
acc = accuracy_score(y_test_gpu, y_pred)
print(f"Test Accuracy 2 (GPU Logistic Regression): {acc:.4f}")
Fraction [2025-05-14 21:15:50.325] [CUML] [warning] QWL-QN: max iterations reached
     [2025-05-14 21:15:50.327] [CUML] [warning] Maximum iterations reached before solver is converged. To
     [2025-05-14 21:15:51.552] [CUML] [warning] L-BFGS: max iterations reached
     [2025-05-14 21:15:51.553] [CUML] [warning] Maximum iterations reached before solver is converged. To
     Test Accuracy 1 (GPU Logistic Regression): 0.6126
     Test Accuracy 2 (GPU Logistic Regression): 0.5948
```

→ Decision Tree

```
import xgboost as xgb
import numpy as np
import itertools
from sklearn.metrics import accuracy score
```

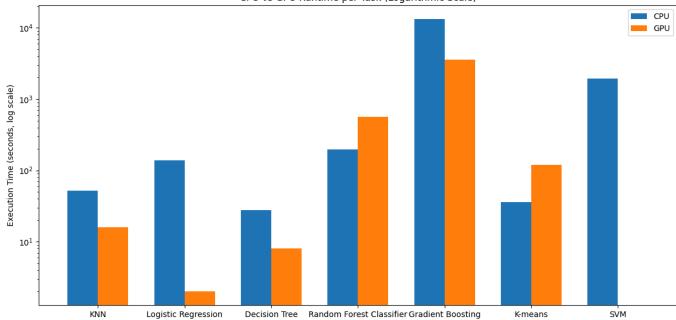
```
# Prepare DMatrix format for XGBoost
dtrain = xgb.DMatrix(X_train, label=y_train)
dtest = xgb.DMatrix(X_test, label=y_test)
# Define parameter grid (mimicking a decision tree)
param grid = {
    'max_depth': [5, 10, 20, 30],
    'min_child_weight': [1, 2, 4],
    'gamma': [0, 1],
# Manual grid search
best_score = 0
best_params = None
for depth, child weight, gamma in itertools.product(
    param_grid['max_depth'],
    param grid['min child weight'],
   param_grid['gamma']
):
    params = {
        'tree_method': 'gpu_hist',
        'objective': 'multi:softmax',
        'num_class': len(np.unique(y_train)),
        'eval_metric': 'mlogloss',
        'max_depth': depth,
        'min_child_weight': child_weight,
        'gamma': gamma
    }
    model = xgb.train(params, dtrain, num_boost_round=1, verbose_eval=False)
    preds = model.predict(dtest)
    acc = accuracy_score(y_test, preds)
    print(f"Params: max depth={depth}, min child weight={child weight}, gamma={gamma} => Test Acc: {acc:
    if acc > best_score:
       best score = acc
       best model = model
       best_params = params
# Final results
print("\nBest Parameters:", best_params)
print(f"Best Test Set Accuracy (single GPU tree): {best_score:.4f}")
/usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [21:12:26] WARNING: /wor
         E.g. tree_method = "hist", device = "cuda"
       warnings.warn(smsg, UserWarning)
     Params: max_depth=5, min_child_weight=1, gamma=0 => Test Acc: 0.4868
     /usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [21:12:26] WARNING: /wor
         E.g. tree_method = "hist", device = "cuda"
       warnings.warn(smsg, UserWarning)
     /usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [21:12:27] WARNING: /wor
```

```
E.g. tree method = "hist", device = "cuda"
    warnings.warn(smsg, UserWarning)
  /usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [21:12:27] WARNING: /wor
      E.g. tree method = "hist", device = "cuda"
    warnings.warn(smsg, UserWarning)
  Params: max_depth=5, min_child_weight=1, gamma=1 => Test Acc: 0.4868
  Params: max_depth=5, min_child_weight=2, gamma=0 => Test Acc: 0.4654
  /usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [21:12:27] WARNING: /wor
      E.g. tree method = "hist", device = "cuda"
    warnings.warn(smsg, UserWarning)
  Params: max_depth=5, min_child_weight=2, gamma=1 => Test Acc: 0.4654
  /usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [21:12:27] WARNING: /wor
      E.g. tree_method = "hist", device = "cuda"
    warnings.warn(smsg, UserWarning)
  /usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [21:12:28] WARNING: /wor
      E.g. tree_method = "hist", device = "cuda"
    warnings.warn(smsg, UserWarning)
  /usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [21:12:28] WARNING: /wor
      E.g. tree_method = "hist", device = "cuda"
    warnings.warn(smsg, UserWarning)
  Params: max_depth=5, min_child_weight=4, gamma=0 => Test Acc: 0.4167
  Params: max depth=5, min child weight=4, gamma=1 => Test Acc: 0.4167
  /usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [21:12:28] WARNING: /wor
      E.g. tree_method = "hist", device = "cuda"
    warnings.warn(smsg, UserWarning)
  Params: max_depth=10, min_child_weight=1, gamma=0 => Test Acc: 0.5232
  /usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [21:12:28] WARNING: /wor
      E.g. tree_method = "hist", device = "cuda"
    warnings.warn(smsg, UserWarning)
Random Forest Classifier
```

```
# cross-validate to determine optimal number of estimators and depth
time_start = time()
grid = {'max_depth': [10, 15, 20], 'n_estimators': [100, 200, 300]}
rf = RandomForestClassifier(max_features = 'sqrt', n_jobs=-1) # sqrt(P) for classifier
rfCV = GridSearchCV(rf,param_grid=grid,return_train_score=True,n_jobs=-1)
rfCV.fit(X_train,y_train)
print('Random Forest Classifier:')
print(' Optimal Parameters: ', rfCV.best_params_)
print(' Optimal Valid R2 =',(rfCV.best_score_).round(3))
time_end = time()
```

```
print(f"Computer runtime: {time end-time start} seconds")
time_s = time()
print('Random Forest Regressor')
rf_best = rfCV.best_estimator_
R2_train = rf_best.score(X_train,y_train)
R2_test = rf_best.score(X_test,y_test)
print(f"\ttrain R2 = {round(R2_train,4)}, test R2 = {round(R2_test,4)}")
time_e = time()
print(f"\tRuntime: {time_e-time_s} seconds")
→ /work/cssema415/202530/03/.venv/lib/python3.11/site-packages/sklearn/model selection/ split.py:805:
      warnings.warn(
     Random Forest Classifier:
     Optimal Parameters: {'max_depth': 20, 'n_estimators': 300}
     Optimal Valid R2 = 0.809
     Computer runtime: 42.81080222129822 seconds
     Random Forest Regressor
             train R2 = 0.9977, test R2 = 0.822
             Runtime: 3.7895705699920654 seconds
labels = [
    'KNN', 'Logistic Regression', 'Decision Tree', 'Random Forest Classifier',
    'Gradient Boosting', 'K-means', 'SVM'
1
import matplotlib.pyplot as plt
import numpy as np
# Your data
cpu_performance = [52.1, 137.3, 27.8, 197.67, 13234.11, 36, 1958.73]
gpu_performance = [16, 2, 8, 560.85, 3571.21, 120, 0]
# X-axis labels
x = np.arange(len(labels))
width = 0.35 # Bar width
# Create bar chart
plt.figure(figsize=(12, 6))
plt.bar(x - width/2, cpu_performance, width, label='CPU')
plt.bar(x + width/2, gpu_performance, width, label='GPU')
plt.xticks(x, labels)
plt.yscale('log')
plt.ylabel('Execution Time (seconds, log scale)')
plt.title('CPU vs GPU Runtime per Task (Logarithmic Scale)')
plt.legend()
plt.grid(True, which='both', axis='y', linestyle='', linewidth=0.5)
plt.tight_layout()
plt.show()
```





Double-click (or enter) to edit

```
from sklearn.pipeline import Pipeline
from sklearn.preprocessing import StandardScaler, PolynomialFeatures
from sklearn.cluster import KMeans
from sklearn.model selection import GridSearchCV
from sklearn.metrics import silhouette_score
import pandas as pd
pipeline = Pipeline([
    ('scale', StandardScaler()),
    ('poly', PolynomialFeatures(interaction_only=True)),
    ('kmeans', KMeans())
1)
grid = {
    'poly__degree': [1],
    'kmeans__n_clusters': [2, 3, 4, 5, 6],
    'kmeans__init': ['k-means++'],
    'kmeans n init': [10]
}
gridCV = GridSearchCV(pipeline, grid, cv=3, n_jobs=-1, verbose=1, scoring='neg_mean_squared_error')
gridCV.fit(X_processed)
best_kmeans = gridCV.best_estimator_.named_steps['kmeans']
labels = best_kmeans.labels_
sil_score = silhouette_score(X_processed, labels)
print("Best K:", best_kmeans.n_clusters)
print("Silhouette Score:", sil_score)
```

```
Fitting 3 folds for each of 5 candidates, totalling 15 fits
     /usr/local/lib/python3.11/dist-packages/sklearn/model_selection/_search.py:1108: UserWarning: One or
      warnings.warn(
     Best K: 2
     Silhouette Score: 0.5753904254863558
from cuml.preprocessing import StandardScaler
from cuml.cluster import KMeans
from sklearn.preprocessing import PolynomialFeatures
from sklearn.metrics import silhouette score
import pandas as pd
import numpy as np
import cudf
poly = PolynomialFeatures(degree=1, interaction_only=True, include_bias=False)
X_poly = poly.fit_transform(X_processed)
X cudf = cudf.DataFrame.from records(X poly)
scaler = StandardScaler()
X_scaled = scaler.fit_transform(X_cudf)
best_score = -1
best k = None
best model = None
for k in [2, 3, 4, 5, 6]:
    kmeans = KMeans(n_clusters=k, init='k-means++', n_init=10, random_state=42)
    kmeans.fit(X_scaled)
    labels cpu = kmeans.labels .to numpy()
    sil score = silhouette score(X poly, labels cpu)
    print(f"K={k} => Silhouette Score: {sil_score:.4f}")
    if sil_score > best_score:
        best score = sil score
        best k = k
        best model = kmeans
print(f"\nBest number of clusters: {best_k}")
print(f"Best silhouette score: {best_score:.4f}")
```

```
K=2 => Silhouette Score: 0.5754
K=3 => Silhouette Score: 0.4496
K=4 => Silhouette Score: 0.3327
K=5 => Silhouette Score: 0.2677
K=6 => Silhouette Score: 0.2768

Best number of clusters: 2
Best silhouette score: 0.5754
```

Start coding or generate with AI.

```
NameError
                                               Traceback (most recent call last)
     <ipython-input-2-01c5bfff5dc1> in <cell line: 0>()
          13
          14 # Convert to cuDF
     ---> 15 X_train_gpu = cudf.DataFrame.from_pandas(pd.DataFrame(X_train))
          16 y_train_gpu = cudf.Series(y_train)
          17 X_val_gpu = cudf.DataFrame.from_pandas(pd.DataFrame(X_val))
     NameError: name 'X_train' is not defined
import lightgbm as lgb
from sklearn.model selection import GridSearchCV
import time
# Define parameter grid
param_grid = {
    'max depth': [10, 15, 20],
    'n_estimators': [100, 200, 300],
    'learning_rate': [0.1],
                                      # Optional, you can grid this too
    'device_type': ['gpu'],
                                     # Key: tell LightGBM to use GPU
    'boosting_type': ['gbdt'],
                                     # Standard gradient boosting
    'tree_learner': ['serial'],  # 'serial' for single GPU
    'verbosity': [-1],
}
# Initialize LightGBM model with GPU settings
model = lgb.LGBMClassifier(
    objective='multiclass',
    num class=len(np.unique(y train)),
    random_state=42
)
# Time the grid search
time start = time.time()
grid_search = GridSearchCV(model, param_grid, cv=3, scoring='accuracy', n_jobs=1)
grid_search.fit(X_train, y_train)
time_end = time.time()
# Report
print("\nLightGBM (GPU) Results:")
print("Best Params:", grid search.best params )
print("Best CV Accuracy:", round(grid_search.best_score_, 4))
print("Training Time:", round(time_end - time_start, 2), "seconds")
# Evaluate on test set
best model = grid search.best estimator
test_acc = best_model.score(X_test, y_test)
print("Test Accuracy:", round(test_acc, 4))
/usr/local/lib/python3.11/dist-packages/sklearn/model_selection/_split.py:805: UserWarning: The leas
       warnings.warn(
     LightGBM (GPU) Results:
     Best Params: {'boosting_type': 'gbdt', 'device_type': 'gpu', 'learning_rate': 0.1, 'max_depth': 20,
     Best CV Accuracy: 0.1408
```

```
Training Time: 560.85 seconds
Test Accuracy: 0.1274
```

```
# cross-validate to determine optimal number of estimators and depth
time start = time()
grid = {'max_depth': [10, 15, 20], 'n_estimators': [100, 200, 300]}
rf = RandomForestClassifier(max features = 'sqrt', n jobs=-1, random state=42) # sqrt(P) for classifier
rfCV = GridSearchCV(rf,param_grid=grid,return_train_score=True,n_jobs=-1)
rfCV.fit(X_train,y_train)
print('Random Forest Classifier:')
print(' Optimal Parameters: ', rfCV.best params )
print(' Optimal Valid R2 =',(rfCV.best_score_).round(3))
time_end = time()
print(f"Computer runtime: {time end-time start} seconds")
time s = time()
print('Random Forest Regressor')
rf best = rfCV.best_estimator_
R2_train = rf_best.score(X_train,y_train)
R2_test = rf_best.score(X_test,y_test)
print(f"\ttrain R2 = {round(R2_train,4)}, test R2 = {round(R2_test,4)}")
time e = time()
print(f"\tRuntime: {time_e-time_s} seconds")
warnings.warn(
    Random Forest Classifier:
     Optimal Parameters: {'max_depth': 20, 'n_estimators': 300}
     Optimal Valid R2 = 0.809
     Computer runtime: 193.14838981628418 seconds
     Random Forest Regressor
            train R2 = 0.9971, test R2 = 0.8208
            Runtime: 4.518910646438599 seconds
import cudf
import numpy as np
from cuml.svm import SVC
from cuml.metrics import accuracy_score
from itertools import product
from time import time
# Convert your data to GPU-compatible format
X_train_gpu = cudf.DataFrame(X_train.astype(np.float32))
y_train_gpu = cudf.Series(y_train)
X_test_gpu = cudf.DataFrame(X_test.astype(np.float32))
y_test_gpu = cudf.Series(y_test)
# Define SVM parameter grid
svm_grid = {
    'C': [0.1, 1],
    'kernel': ['linear', 'rbf']
}
```

```
# Manual grid search
start = time()
best_acc = 0
best_params = None
best model = None
for C, kernel in product(svm_grid['C'], svm_grid['kernel']):
    model = SVC(C=C, kernel=kernel)
   model.fit(X_train_gpu, y_train_gpu)
    acc = accuracy_score(y_train_gpu, model.predict(X_train_gpu))
    print(f"Params: C={C}, kernel={kernel} => Train Accuracy: {acc:.4f}")
   if acc > best_acc:
       best_acc = acc
       best_params = {'C': C, 'kernel': kernel}
       best model = model
print(f"\nBest Parameters: {best_params}")
print(f"Best Train Accuracy: {best_acc:.4f}")
print(f"Grid Search Runtime: {time() - start:.2f} seconds")
# Evaluate on test set
eval_start = time()
acc_train = accuracy_score(y_train_gpu, best_model.predict(X_train_gpu))
acc_test = accuracy_score(y_test_gpu, best_model.predict(X_test_gpu))
print(f"\nSVM Evaluation:")
print(f"\tTrain Accuracy: {round(acc_train, 4)}, Test Accuracy: {round(acc_test, 4)}")
print(f"\tRuntime: {time() - eval_start:.2f} seconds")
```

```
[2025-05-14 22:05:27.880] [CUML] [warning] Warning: could not fill working set, found only 770 ele
    [2025-05-14 22:05:27.880] [CUML] [warning] Warning: could not fill working set, found only 773 ele
    [2025-05-14 22:05:28.377] [CUML] [warning] Warning: could not fill working set, found only 519 ele
    [2025-05-14 22:05:28.378] [CUML] [warning] Warning: could not fill working set, found only 773 ele
    [2025-05-14 22:05:28.378] [CUML] [warning] Warning: could not fill working set, found only 768 ele
    [2025-05-14 22:05:29.515] [CUML] [warning] Warning: could not fill working set, found only 519 ele
    [2025-05-14 22:05:29.516] [CUML] [warning] Warning: could not fill working set, found only 771 ele
    [2025-05-14 22:05:29.516] [CUML] [warning] Warning: could not fill working set, found only 772 ele
    [2025-05-14 22:05:29.517] [CUML] [warning] Warning: could not fill working set, found only 769 ele
    [2025-05-14 22:05:29.518] [CUML] [warning] Warning: could not fill working set, found only 772 ele
    [2025-05-14 22:05:30.731] [CUML] [warning] Warning: could not fill working set, found only 519 ele
    [2025-05-14 22:05:30.732] [CUML] [warning] Warning: could not fill working set, found only 771 ele
    [2025-05-14 22:05:30.732] [CUML] [warning] Warning: could not fill working set, found only 769 ele
    [2025-05-14 22:05:30.733] [CUML] [warning] Warning: could not fill working set, found only 773 ele
    [2025-05-14 22:05:30.733] [CUML] [warning] Warning: could not fill working set, found only 769 ele
    [2025-05-14 22:05:31.609] [CUML] [warning] Warning: could not fill working set, found only 519 ele
    [2025-05-14 22:05:31.610] [CUML] [warning] Warning: could not fill working set, found only 772 ele
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    [2025-05-14 22:05:31.611] [CUML] [warning] Warning: could not fill working set, found only 770 ele
    [2025-05-14 22:05:31.672] [CUML] [warning] Warning: could not fill working set, found only 519 ele
    [2025-05-14 22:05:31.673] [CUML] [warning] Warning: could not fill working set, found only 772 ele
    [2025-05-14 22:05:31.674] [CUML] [warning] Warning: could not fill working set, found only 770 ele
    [2025-05-14 22:05:31.675] [CUML] [warning] Warning: could not fill working set, found only 771 ele
    [2025-05-14 22:05:31.750] [CUML] [warning] Warning: could not fill working set, found only 519 ele
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    [2025-05-14 22:05:32.141] [CUML] [warning] Warning: could not fill working set, found only 771 ele
    [2025-05-14 22:05:32.141] [CUML] [warning] Warning: could not fill working set, found only 987 ele
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    [2025-05-14 22:05:33.382] [CUML] [warning] Warning: could not fill working set, found only 734 ele
    [2025-05-14 22:05:33.383] [CUML] [warning] Warning: could not fill working set, found only 786 ele
    [2025-05-14 22:05:33.384] [CUML] [warning] Warning: could not fill working set, found only 960 ele
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    [2025-05-14 22:05:36.180] [CUML] [warning] Warning: could not fill working set, found only 734 ele
    [2025-05-14 22:05:36.181] [CUML] [warning] Warning: could not fill working set, found only 774 ele
    [2025-05-14 22:05:36.182] [CUML] [warning] Warning: could not fill working set, found only 977 ele
    [2025-05-14 22:05:36.182] [CUML] [warning] Warning: could not fill working set, found only 779 ele
    [2025-05-14 22:05:36.183] [CUML] [warning] Warning: could not fill working set, found only 976 ele
    [2025-05-14 22:05:36.927] [CUML] [warning] Warning: could not fill working set, found only 734 ele
    [2025-05-14 22:05:36.929] [CUML] [warning] Warning: could not fill working set, found only 907 ele
    [2025-05-14 22:05:36.930] [CUML] [warning] Warning: could not fill working set, found only 840 ele
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| בעבט-טט-14 בבט:טט:טט:טס: | נעשר | LUmil | warning warning could not till working set, tound only און ele
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[2025-05-14 22:05:37.122] [CUML] [warning] Warning: could not fill working set, found only 774 ele
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[2025-05-14 22:05:43.922] [CUML] [warning] Warning: could not fill working set, found only 555 ele
[2025-05-14 22:05:43.923] [CUML] [warning] Warning: could not fill working set, found only 780 ele
[2025-05-14 22:05:43.924] [CUML] [warning] Warning: could not fill working set, found only 791 ele
[2025-05-14 22:05:43.924] [CUML] [warning] Warning: could not fill working set, found only 787 ele
[2025-05-14 22:05:43.925] [CUML] [warning] Warning: could not fill working set, found only 791 ele
[2025-05-14 22:05:44.401] [CUML] [warning] Warning: could not fill working set, found only 555 ele
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[2025-05-14 22:05:45.581] [CUML] [warning] Warning: could not fill working set, found only 555 ele
[2025-05-14 22:05:45.582] [CUML] [warning] Warning: could not fill working set, found only 791 ele
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[2025-05-14 22:05:45.584] [CUML] [warning] Warning: could not fill working set, found only 792 ele
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[2025-05-14 22:05:47.746] [CUML] [warning] Warning: could not fill working set, found only 804 ele
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[2025-05-14 22:05:47.888] [CUML] [warning] Warning: could not fill working set, found only 780 ele
[2025-05-14 22:05:49.268] [CUML] [warning] Warning: could not fill working set, found only 533 ele
```

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[2025-05-14 22:05:49.269] [CUML] [warning] Warning: could not fill working set, found only 779 ele
[2025-05-14 22:05:49.269] [CUML] [warning] Warning: could not fill working set, found only 777 ele
[2025-05-14 22:05:49.270] [CUML] [warning] Warning: could not fill working set, found only 779 ele
[2025-05-14 22:05:49.754] [CUML] [warning] Warning: could not fill working set, found only 533 ele
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[2025-05-14 22:05:53.109] [CUML] [warning] Warning: could not fill working set, found only 784 ele
[2025-05-14 22:05:53.251] [CUML] [warning] Warning: could not fill working set, found only 533 ele
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[2025-05-14 22:05:53.253] [CUML] [warning] Warning: could not fill working set, found only 772 ele
[2025-05-14 22:05:53.254] [CUML] [warning] Warning: could not fill working set, found only 781 ele
[2025-05-14 22:05:53.255] [CUML] [warning] Warning: could not fill working set, found only 770 ele
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[2025-05-14 22:05:56.269] [CUML] [warning] Warning: could not fill working set, found only 782 ele
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[2025-05-14 22:05:57.462] [CUML] [warning] Warning: could not fill working set, found only 776 ele
[2025-05-14 22:05:57.463] [CUML] [warning] Warning: could not fill working set, found only 778 ele
[2025-05-14 22:05:58.315] [CUML] [warning] Warning: could not fill working set, found only 533 ele
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[2025-05-14 22:05:58.372] [CUML] [warning] Warning: could not fill working set, found only 779 ele
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[2025-05-14 22:05:58.373] [CUML] [warning] Warning: could not fill working set, found only 779 ele
[2025-05-14 22:05:58.373] [CUML] [warning] Warning: could not fill working set, found only 776 ele
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[2025-05-14 22:06:03.627] [CUML] [warning] Warning: could not fill working set, found only 885 ele
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[2025-05-14 22:06:10.772] [CUML] [warning] Warning: could not fill working set. found only 591 ele
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[2025-05-14 22:06:13.982] [CUML] [warning] Warning: could not fill working set, found only 838 ele
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[2025-05-14 22:06:18.927] [CUML] [warning] Warning: could not fill working set, found only 902 ele
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[2025_05_1/ 22.06.10 000] [CHMI] [warning] Warning, could not fill working set found only 788 alo
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[2025-05-14 22:06:40.078] [CUML] [warning] Warning: could not fill working set, found only 811 ele
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[2025-05-14 22:06:50.710] [CUML] [warning] Warning: could not fill working set, found only 768 ele
[2025-05-14 22:06:50.798] [CUML] [warning] Warning: could not fill working set, found only 514 ele
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[2025-05-14 22:07:25.710] [CUML] [warning] Warning: could not fill working set, found only 792 ele
[2025-05-14 22:07:25.711] [CUML] [warning] Warning: could not fill working set, found only 863 ele
[2025-05-14 22:07:25.712] [CUML] [warning] Warning: could not fill working set, found only 796 ele
```

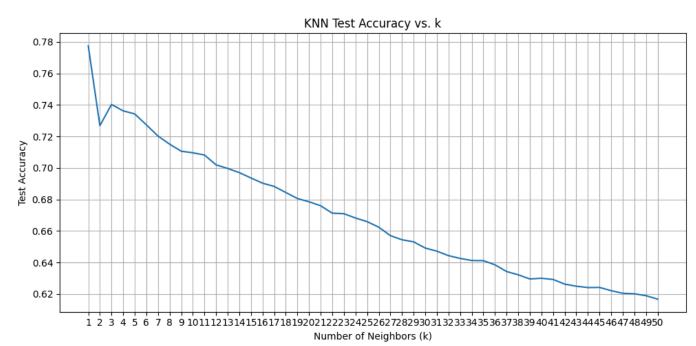
```
[ בטבט-ט5-14 בב:ט/:ב5./בן [CUML] [warning] warning: could not till working set, tound only אום
[2025-05-14 22:07:25.766] [CUML] [warning] Warning: could not fill working set, found only 637 ele
[2025-05-14 22:07:25.767] [CUML] [warning] Warning: could not fill working set, found only 772 ele
[2025-05-14 22:07:25.768] [CUML] [warning] Warning: could not fill working set, found only 885 ele
[2025-05-14 22:07:25.768] [CUML] [warning] Warning: could not fill working set, found only 774 ele
[2025-05-14 22:07:25.769] [CUML] [warning] Warning: could not fill working set, found only 885 ele
[2025-05-14 22:07:25.905] [CUML] [warning] Warning: could not fill working set, found only 637 ele
[2025-05-14 22:07:25.906] [CUML] [warning] Warning: could not fill working set, found only 810 ele
[2025-05-14 22:07:25.907] [CUML] [warning] Warning: could not fill working set, found only 832 ele
[2025-05-14 22:07:25.907] [CUML] [warning] Warning: could not fill working set, found only 827 ele
[2025-05-14 22:07:25.908] [CUML] [warning] Warning: could not fill working set, found only 832 ele
[2025-05-14 22:07:26.736] [CUML] [warning] Warning: could not fill working set, found only 698 ele
[2025-05-14 22:07:26.737] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:26.738] [CUML] [warning] Warning: could not fill working set, found only 949 ele
[2025-05-14 22:07:26.738] [CUML] [warning] Warning: could not fill working set, found only 770 ele
[2025-05-14 22:07:27.209] [CUML] [warning] Warning: could not fill working set, found only 698 ele
[2025-05-14 22:07:27.210] [CUML] [warning] Warning: could not fill working set, found only 770 ele
[2025-05-14 22:07:27.211] [CUML] [warning] Warning: could not fill working set, found only 951 ele
[2025-05-14 22:07:28.345] [CUML] [warning] Warning: could not fill working set, found only 698 ele
[2025-05-14 22:07:28.346] [CUML] [warning] Warning: could not fill working set, found only 768 ele
[2025-05-14 22:07:28.347] [CUML] [warning] Warning: could not fill working set, found only 951 ele
[2025-05-14 22:07:29.176] [CUML] [warning] Warning: could not fill working set, found only 698 ele
[2025-05-14 22:07:29.177] [CUML] [warning] Warning: could not fill working set, found only 772 ele
[2025-05-14 22:07:29.178] [CUML] [warning] Warning: could not fill working set, found only 947 ele
[2025-05-14 22:07:29.179] [CUML] [warning] Warning: could not fill working set, found only 772 ele
[2025-05-14 22:07:29.538] [CUML] [warning] Warning: could not fill working set, found only 698 ele
[2025-05-14 22:07:29.539] [CUML] [warning] Warning: could not fill working set, found only 770 ele
[2025-05-14 22:07:29.540] [CUML] [warning] Warning: could not fill working set, found only 944 ele
[2025-05-14 22:07:29.541] [CUML] [warning] Warning: could not fill working set, found only 774 ele
[2025-05-14 22:07:29.541] [CUML] [warning] Warning: could not fill working set, found only 944 ele
[2025-05-14 22:07:30.290] [CUML] [warning] Warning: could not fill working set, found only 698 ele
[2025-05-14 22:07:30.291] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:30.291] [CUML] [warning] Warning: could not fill working set, found only 951 ele
[2025-05-14 22:07:30.292] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:30.373] [CUML] [warning] Warning: could not fill working set, found only 698 ele
[2025-05-14 22:07:30.374] [CUML] [warning] Warning: could not fill working set, found only 768 ele
[2025-05-14 22:07:30.374] [CUML] [warning] Warning: could not fill working set, found only 951 ele
[2025-05-14 22:07:30.375] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:30.428] [CUML] [warning] Warning: could not fill working set, found only 698 ele
[2025-05-14 22:07:30.429] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:30.430] [CUML] [warning] Warning: could not fill working set, found only 951 ele
[2025-05-14 22:07:30.430] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:30.511] [CUML] [warning] Warning: could not fill working set, found only 698 ele
[2025-05-14 22:07:30.512] [CUML] [warning] Warning: could not fill working set, found only 768 ele
[2025-05-14 22:07:30.512] [CUML] [warning] Warning: could not fill working set, found only 952 ele
[2025-05-14 22:07:30.513] [CUML] [warning] Warning: could not fill working set, found only 768 ele
[2025-05-14 22:07:30.650] [CUML] [warning] Warning: could not fill working set, found only 698 ele
[2025-05-14 22:07:30.651] [CUML] [warning] Warning: could not fill working set, found only 770 ele
[2025-05-14 22:07:30.651] [CUML] [warning] Warning: could not fill working set, found only 949 ele
[2025-05-14 22:07:30.652] [CUML] [warning] Warning: could not fill working set, found only 770 ele
[2025-05-14 22:07:31.496] [CUML] [warning] Warning: could not fill working set, found only 517 ele
[2025-05-14 22:07:31.497] [CUML] [warning] Warning: could not fill working set, found only 768 ele
[2025-05-14 22:07:31.497] [CUML] [warning] Warning: could not fill working set, found only 772 ele
[2025-05-14 22:07:32.065] [CUML] [warning] Warning: could not fill working set, found only 517 ele
[2025-05-14 22:07:32.066] [CUML] [warning] Warning: could not fill working set, found only 768 ele
[2025-05-14 22:07:32.067] [CUML] [warning] Warning: could not fill working set, found only 772 ele
[2025-05-14 22:07:33.479] [CUML] [warning] Warning: could not fill working set, found only 517 ele
[2025-05-14 22:07:33.480] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:33.480] [CUML] [warning] Warning: could not fill working set, found only 772 ele
[2025-05-14 22:07:33.481] [CUML] [warning] Warning: could not fill working set, found only 768 ele
[2025-05-14 22:07:34.944] [CUML] [warning] Warning: could not fill working set, found only 517 ele
[2025-05-14 22:07:34.945] [CUML] [warning] Warning: could not fill working set, found only 768 ele
[2025-05-14 22:07:34.946] [CUML] [warning] Warning: could not fill working set, found only 772 ele
[2025-05-14 22:07:34.946] [CUML] [warning] Warning: could not fill working set, found only 768 ele
```

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[2025-05-14 22:07:36.011] [CUML] [warning] Warning: could not fill working set, found only 517 ele █
[2025-05-14 22:07:36.012] [CUML] [warning] Warning: could not fill working set, found only 768 ele
[2025-05-14 22:07:36.012] [CUML] [warning] Warning: could not fill working set, found only 772 ele
[2025-05-14 22:07:36.013] [CUML] [warning] Warning: could not fill working set, found only 768 ele
[2025-05-14 22:07:36.076] [CUML] [warning] Warning: could not fill working set, found only 517 ele
[2025-05-14 22:07:36.077] [CUML] [warning] Warning: could not fill working set, found only 768 ele
[2025-05-14 22:07:36.077] [CUML] [warning] Warning: could not fill working set, found only 772 ele
[2025-05-14 22:07:36.176] [CUML] [warning] Warning: could not fill working set, found only 517 ele
[2025-05-14 22:07:36.177] [CUML] [warning] Warning: could not fill working set, found only 768 ele
[2025-05-14 22:07:36.336] [CUML] [warning] Warning: could not fill working set, found only 517 ele
[2025-05-14 22:07:36.337] [CUML] [warning] Warning: could not fill working set, found only 768 ele
[2025-05-14 22:07:36.337] [CUML] [warning] Warning: could not fill working set, found only 772 ele
[2025-05-14 22:07:37.278] [CUML] [warning] Warning: could not fill working set, found only 545 ele
[2025-05-14 22:07:37.279] [CUML] [warning] Warning: could not fill working set, found only 770 ele
[2025-05-14 22:07:37.280] [CUML] [warning] Warning: could not fill working set, found only 796 ele
[2025-05-14 22:07:37.280] [CUML] [warning] Warning: could not fill working set, found only 771 ele
[2025-05-14 22:07:37.281] [CUML] [warning] Warning: could not fill working set, found only 795 ele
[2025-05-14 22:07:37.840] [CUML] [warning] Warning: could not fill working set, found only 545 ele
[2025-05-14 22:07:37.841] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:37.842] [CUML] [warning] Warning: could not fill working set, found only 797 ele
[2025-05-14 22:07:37.842] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:37.843] [CUML] [warning] Warning: could not fill working set, found only 797 ele
[2025-05-14 22:07:39.189] [CUML] [warning] Warning: could not fill working set, found only 545 ele
[2025-05-14 22:07:39.190] [CUML] [warning] Warning: could not fill working set, found only 770 ele
[2025-05-14 22:07:39.191] [CUML] [warning] Warning: could not fill working set, found only 798 ele
[2025-05-14 22:07:39.191] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:40.572] [CUML] [warning] Warning: could not fill working set, found only 545 ele
[2025-05-14 22:07:40.573] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:40.574] [CUML] [warning] Warning: could not fill working set, found only 798 ele
[2025-05-14 22:07:40.574] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:41.574] [CUML] [warning] Warning: could not fill working set, found only 545 ele
[2025-05-14 22:07:41.575] [CUML] [warning] Warning: could not fill working set, found only 770 ele
[2025-05-14 22:07:41.575] [CUML] [warning] Warning: could not fill working set, found only 798 ele
[2025-05-14 22:07:41.638] [CUML] [warning] Warning: could not fill working set, found only 545 ele
[2025-05-14 22:07:41.639] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:41.639] [CUML] [warning] Warning: could not fill working set, found only 798 ele
[2025-05-14 22:07:41.736] [CUML] [warning] Warning: could not fill working set, found only 545 ele
[2025-05-14 22:07:41.737] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:41.737] [CUML] [warning] Warning: could not fill working set, found only 798 ele
[2025-05-14 22:07:41.738] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:41.899] [CUML] [warning] Warning: could not fill working set, found only 545 ele
[2025-05-14 22:07:41.900] [CUML] [warning] Warning: could not fill working set, found only 768 ele
[2025-05-14 22:07:41.901] [CUML] [warning] Warning: could not fill working set, found only 798 ele
[2025-05-14 22:07:41.901] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:41.902] [CUML] [warning] Warning: could not fill working set, found only 798 ele
[2025-05-14 22:07:42.823] [CUML] [warning] Warning: could not fill working set, found only 519 ele
[2025-05-14 22:07:42.824] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:42.825] [CUML] [warning] Warning: could not fill working set, found only 771 ele
[2025-05-14 22:07:42.825] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:43.430] [CUML] [warning] Warning: could not fill working set, found only 519 ele
[2025-05-14 22:07:43.431] [CUML] [warning] Warning: could not fill working set, found only 769 ele
[2025-05-14 22:07:43.432] [CUML] [warning] Warning: could not fill working set, found only 770 ele
[2025-05-14 22:07:43.432] [CUML] [warning] Warning: could not fill working set, found only 771 ele
[2025-05-14 22:07:44.850] [CUML] [warning] Warning: could not fill working set, found only 519 ele
[2025-05-14 22:07:44.851] [CUML] [warning] Warning: could not fill working set, found only 770 ele
[2025-05-14 22:07:44.852] [CUML] [warning] Warning: could not fill working set, found only 770 ele
[2025-05-14 22:07:44.852] [CUML] [warning] Warning: could not fill working set, found only 772 ele
MemoryError
                                          Traceback (most recent call last)
<ipython-input-9-8ca384fe9a0a> in <cell line: 0>()
     26 for C, kernel in product(svm_grid['C'], svm_grid['kernel']):
     27
           model = SVC(C=C, kernel=kernel)
---> 28
            model.fit(X_train_gpu, y_train_gpu)
            acc = accuracy_score(y_train_gpu, model.predict(X_train_gpu))
```

```
30
            print(f"Params: C={C}, kernel={kernel} => Train Accuracy: {acc:.4f}")
                                  12 frames
svc.pyx in cuml.svm.svc.SVC.fit()
svc.pyx in cuml.svm.svc.SVC._fit_multiclass()
/usr/local/lib/python3.11/dist-packages/cuml/internals/api_decorators.py in wrapper(*args,
**kwargs)
    191
    192
                            if process_return:
                                ret = func(*args, **kwargs)
--> 193
    194
                                return func(*args, **kwargs)
    195
svc.pyx in cuml.svm.svc.SVC.fit()
svc.pyx in cuml.svm.svc.SVC.fit()
MemoryError: std::bad_alloc: out_of_memory: CUDA error at: /tmp/pip-build-env-
c7imy8iv/normal/lib/python3.11/site-
packages/librmm/include/rmm/mr/device/cuda memory resource.hpp:62: cudaErrorMemoryAllocation out
```

```
from cuml.neighbors import KNeighborsClassifier
from cuml.model_selection import train_test_split
from cuml.metrics import accuracy_score
import cudf
import numpy as np
import itertools
X_train_gpu = cudf.DataFrame.from_pandas(X_train)
y_train_gpu = cudf.Series(y_train)
X test gpu = cudf.DataFrame.from pandas(X test)
y_test_gpu = cudf.Series(y_test)
k_values = list(range(1, 51))
accuracies = []
for k in k_values:
    model = KNeighborsClassifier(n neighbors=k, weights='uniform', metric='euclidean')
    model.fit(X train gpu, y train gpu)
    preds = model.predict(X_test_gpu)
    acc = accuracy_score(y_test_gpu, preds)
    accuracies.append(acc)
plt.figure(figsize=(10, 5))
plt.plot(k_values, accuracies, marker='')
plt.title("KNN Test Accuracy vs. k")
plt.xlabel("Number of Neighbors (k)")
plt.ylabel("Test Accuracy")
plt.grid(True)
plt.xticks(k_values)
plt.tight_layout()
plt.show()
```





```
import cudf
import numpy as np
import matplotlib.pyplot as plt
from cuml.linear model import LogisticRegression
from cuml.metrics import accuracy score
from itertools import product
# Convert to cuDF
X_train_gpu = cudf.DataFrame.from_pandas(X_train.astype('float32'))
y_train_gpu = cudf.Series(y_train)
X test gpu = cudf.DataFrame.from pandas(X test.astype('float32'))
y test gpu = cudf.Series(y test)
# Define hyperparameter grid
penalties = ['l1', 'l2']
max iters = [100, 200, 500, 1000, 2000]
results = []
# Manual grid search
for penalty, max_iter in product(penalties, max_iters):
        model = LogisticRegression(
            penalty=penalty,
            solver='qn', # GPU-optimized quasi-Newton solver
            max iter=max iter,
            fit_intercept=True
        )
        model.fit(X_train_gpu, y_train_gpu)
        y pred = model.predict(X test gpu)
        acc = accuracy_score(y_test_gpu, y_pred)
        results.append({'penalty': penalty, 'max_iter': max_iter, 'accuracy': acc})
        print(f"penalty={penalty}, max_iter={max_iter} → Accuracy: {acc:.4f}")
    except Exception as e:
        print(f"Failed for penalty={penalty}, max_iter={max_iter}: {e}")
# Convert to DataFrame for plotting
import pandas as pd
results df = pd.DataFrame(results)
# Plot
fig, ax = plt.subplots(figsize=(8, 5))
for penalty in penalties:
    subset = results_df[results_df['penalty'] == penalty]
    ax.plot(subset['max_iter'], subset['accuracy'], marker='o', label=f'penalty={penalty}')
ax.set title("Logistic Regression Accuracy by Penalty and Max Iterations")
ax.set_xlabel("max_iter")
ax.set_ylabel("Test Accuracy")
ax.legend()
ax.grid(True)
plt.tight_layout()
plt.show()
```

[2025-05-14 22:30:17.848] [CUML] [warning] Maximum iterations reached before solver is converged. To

penalty=11, max iter=100 → Accuracy: 0.6119

[2025-05-14 22:30:18.006] [CUML] [warning] QWL-QN: max iterations reached

[2025-05-14 22:30:18.006] [CUML] [warning] Maximum iterations reached before solver is converged. To

penalty=11, max iter=200 → Accuracy: 0.6290

penalty=11, max iter=500 → Accuracy: 0.6313

penalty=11, max_iter=1000 → Accuracy: 0.6314

penalty=11, max_iter=2000 → Accuracy: 0.6313

[2025-05-14 22:30:19.130] [CUML] [warning] L-BFGS: max iterations reached

[2025-05-14 22:30:19.131] [CUML] [warning] Maximum iterations reached before solver is converged. To

penalty=12, max_iter=100 → Accuracy: 0.5938

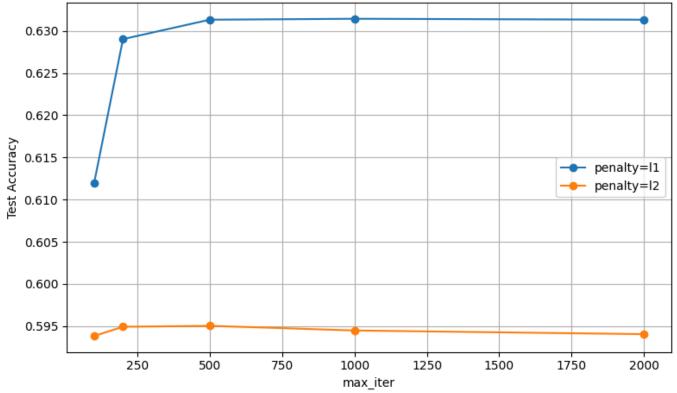
penalty=12, max_iter=200 → Accuracy: 0.5949

penalty=12, max iter=500 → Accuracy: 0.5950

penalty=12, max iter=1000 → Accuracy: 0.5945

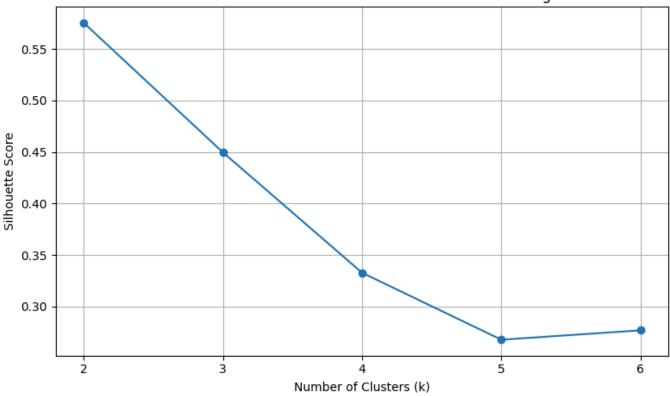
penalty=12, max_iter=2000 → Accuracy: 0.5941

Logistic Regression Accuracy by Penalty and Max Iterations



```
k \text{ values} = [2, 3, 4, 5, 6]
silhouette scores = [0.5754, 0.4496, 0.3327, 0.2677, 0.2768]
plt.figure(figsize=(8, 5))
plt.plot(k_values, silhouette_scores, marker='o')
plt.xticks(k values)
plt.xlabel("Number of Clusters (k)")
plt.ylabel("Silhouette Score")
plt.title("Silhouette Score for Different k in KMeans Clustering")
plt.grid(True)
plt.tight_layout()
plt.show()
```





```
feature_r2_scores = {}

for feature in X.columns:
    model = LinearRegression()
    model.fit(X_train[[feature]], y_train)
    y_pred = model.predict(X_test[[feature]])
    r2 = r2_score(y_test, y_pred)
    feature_r2_scores[feature] = r2
    print(f"{feature}: R^2 = {r2:.4f}")

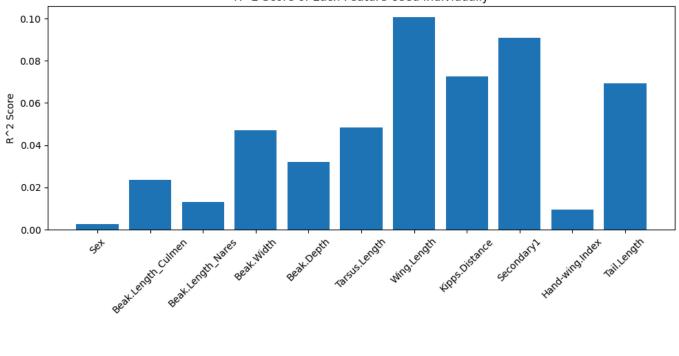
plt.figure(figsize=(10, 5))
plt.bar(feature_r2_scores.keys(), feature_r2_scores.values())
plt.ylabel("R^2 Score")
plt.title("R^2 Score of Each Feature Used Individually")
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```

 \Rightarrow Sex: R^2 = 0.0027

Beak.Length_Culmen: R^2 = 0.0237
Beak.Length_Nares: R^2 = 0.0132
Beak.Width: R^2 = 0.0471

Beak.Depth: R^2 = 0.0322 Tarsus.Length: R^2 = 0.0483 Wing.Length: R^2 = 0.1007 Kipps.Distance: R^2 = 0.0727 Secondary1: R^2 = 0.0909 Hand-wing.Index: R^2 = 0.0096 Tail.Length: R^2 = 0.0691

R^2 Score of Each Feature Used Individually



```
import pandas as pd
import numpy as np
import statsmodels.api as sm
from sklearn.model selection import train test split
import matplotlib.pyplot as plt
coefs = []
ci lowers = []
ci_uppers = []
for feature in X.columns:
   X_feature_train = sm.add_constant(X_train[[feature]])
    model = sm.OLS(y_train, X_feature_train).fit()
    coef = model.params[feature]
    ci = model.conf_int(alpha=0.05).loc[feature].tolist()
    coefs.append(coef)
    ci_lowers.append(ci[0])
    ci_uppers.append(ci[1])
```

```
results_df = pd.DataFrame({
    'Feature': X.columns,
    'Coof': coofs
```