```
# Check GPU
!nvidia-smi
# install XGBoost for GPU support
!pip install xgboost
```

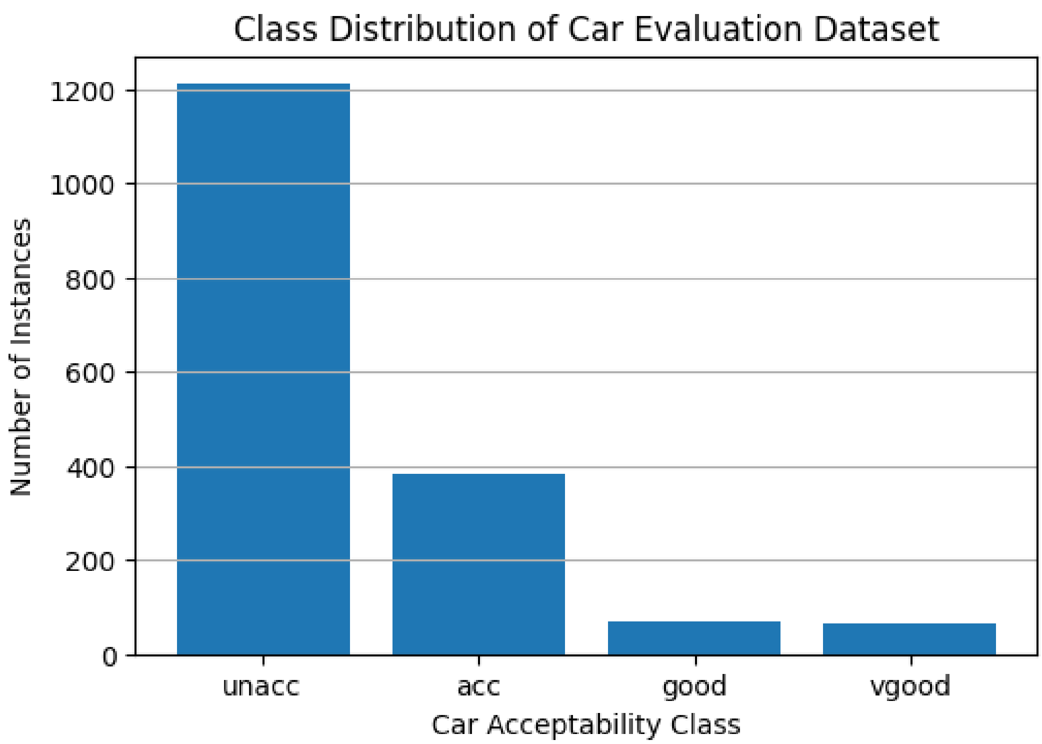
```
Thu Jan  1 16:26:03 2026
+-----------------------------------------------------------------------
--------------------+
| NVIDIA-SMI 550.54.15              Driver Version: 550.54.15
CUDA Version: 12.4     |
|-----------------------------------------+------------------------
+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A |
Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage |
GPU-Util  Compute M. |
|                                         |                        |
MIG M. |
|
=========================================+========================+===
===================|
|   0  Tesla T4                       Off |   00000000:00:04.0 Off |
0 |
| N/A   70C    P0             31W /   70W |     102MiB /  15360MiB |
0%      Default |
|                                         |                        |
N/A |
+-----------------------------------------+------------------------
+----------------------+


+-----------------------------------------------------------------------
--------------------+
| Processes:
|
|  GPU   GI   CI        PID   Type   Process name
GPU Memory |
|        ID   ID
Usage      |
|
=======================================================================
===================|
+-----------------------------------------------------------------------
--------------------+
Requirement already satisfied: xgboost in
/usr/local/lib/python3.12/dist-packages (3.1.2)
Requirement already satisfied: numpy in
/usr/local/lib/python3.12/dist-packages (from xgboost) (2.0.2)
Requirement already satisfied: nvidia-nccl-cu12 in
/usr/local/lib/python3.12/dist-packages (from xgboost) (2.27.5)
```

```
Requirement already satisfied: scipy in
/usr/local/lib/python3.12/dist-packages (from xgboost) (1.16.3)
```

```python
import pandas as pd
import numpy as np
import time

from sklearn.model_selection import train_test_split
from sklearn.preprocessing import OneHotEncoder
from sklearn.metrics import accuracy_score

import xgboost as xgb
import matplotlib.pyplot as plt

df = pd.read_csv('/content/car_evaluation.csv', header=None)

df.columns = [
    "buying", "maint", "doors",
    "persons", "lug_boot", "safety", "target"
]

display(df.head())
```


```
{"summary":"{\n  \"name\": \"display(df\",\n  \"rows\": 5,\n
\"fields\": [\n    {\n      \"column\": \"buying\",\n
\"properties\": {\n        \"dtype\": \"category\",\n
\"num_unique_values\": 1,\n        \"samples\": [\n
\"vhigh\"\n        ],\n        \"semantic_type\": \"\",\n
\"description\": \"\"\n      }\n    },\n    {\n      \"column\":
\"maint\",\n      \"properties\": {\n        \"dtype\": \"category\",\
n        \"num_unique_values\": 1,\n        \"samples\": [\n
\"vhigh\"\n        ],\n        \"semantic_type\": \"\",\n
\"description\": \"\"\n      }\n    },\n    {\n      \"column\":
\"doors\",\n      \"properties\": {\n        \"dtype\": \"category\",\
n        \"num_unique_values\": 1,\n        \"samples\": [\n
\"2\"\n        ],\n        \"semantic_type\": \"\",\n
\"description\": \"\"\n      }\n    },\n    {\n      \"column\":
\"persons\",\n      \"properties\": {\n        \"dtype\":
\"category\",\n        \"num_unique_values\": 1,\n        \"samples\":
[\n          \"2\"\n        ],\n        \"semantic_type\": \"\",\n
\"description\": \"\"\n      }\n    },\n    {\n      \"column\":
\"lug_boot\",\n      \"properties\": {\n        \"dtype\":
\"category\",\n        \"num_unique_values\": 2,\n        \"samples\":
[\n          \"med\"\n        ],\n        \"semantic_type\": \"\",\n
\"description\": \"\"\n      }\n    },\n    {\n      \"column\":
\"safety\",\n      \"properties\": {\n        \"dtype\": \"string\",\n
\"num_unique_values\": 3,\n        \"samples\": [\n          \"low\"\n
],\n        \"semantic_type\": \"\",\n        \"description\": \"\"\n
}\n    },\n    {\n      \"column\": \"target\",\n      \"properties\":
{\n        \"dtype\": \"category\",\n        \"num_unique_values\":
```

```
1,\n        \"samples\": [\n          \"unacc\"\n        ],\n        \"semantic_type\": \"\",\n        \"description\": \"\"\n      }\n    }\n  ]\n}","type":"dataframe"}

# Count instances of each class
label_counts = df["target"].value_counts()

plt.figure(figsize=(6, 4))
plt.bar(label_counts.index, label_counts.values)
plt.title("Class Distribution of Car Evaluation Dataset")
plt.xlabel("Car Acceptability Class")
plt.ylabel("Number of Instances")
plt.grid(axis='y')
plt.show()
```




```
df.info()
df["target"].value_counts()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1728 entries, 0 to 1727
Data columns (total 7 columns):
 #   Column    Non-Null Count  Dtype 
---  ------    --------------  ----- 
 0   buying    1728 non-null   object
 1   maint     1728 non-null   object
 2   doors     1728 non-null   object
```

```
 3   persons   1728 non-null   object
 4   lug_boot  1728 non-null   object
 5   safety    1728 non-null   object
 6   target    1728 non-null   object
dtypes: object(7)
memory usage: 94.6+ KB
```

```
target
unacc    1210
acc       384
good       69
vgood      65
Name: count, dtype: int64
```

```python
from sklearn.preprocessing import LabelEncoder

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

# Encode target labels to numerical values
le = LabelEncoder()
y = le.fit_transform(y)

print("Encoded target labels:", le.classes_)
```

```
Encoded target labels: ['acc' 'good' 'unacc' 'vgood']
```

```python
encoder = OneHotEncoder()

X_encoded = encoder.fit_transform(X).toarray()

print("Encoded feature shape:", X_encoded.shape)
```

```
Encoded feature shape: (1728, 21)
```

```python
X_train, X_test, y_train, y_test = train_test_split(
    X_encoded,
    y,
    test_size=0.2,
    random_state=42,
    stratify=y
)

xgb_cpu = xgb.XGBClassifier(
    objective="multi:softprob",
    eval_metric="mlogloss",
    n_estimators=400,
    max_depth=6,
    learning_rate=0.1,
    subsample=0.9,
    colsample_bytree=0.9,
```

```python
    tree_method="hist",   # CPU
    random_state=42
)

start_cpu = time.time()
xgb_cpu.fit(X_train, y_train)
cpu_time = time.time() - start_cpu

cpu_preds = xgb_cpu.predict(X_test)
cpu_acc = accuracy_score(y_test, cpu_preds)

cpu_time, cpu_acc
```

```
(0.8878271579742432, 0.9971098265895953)
```

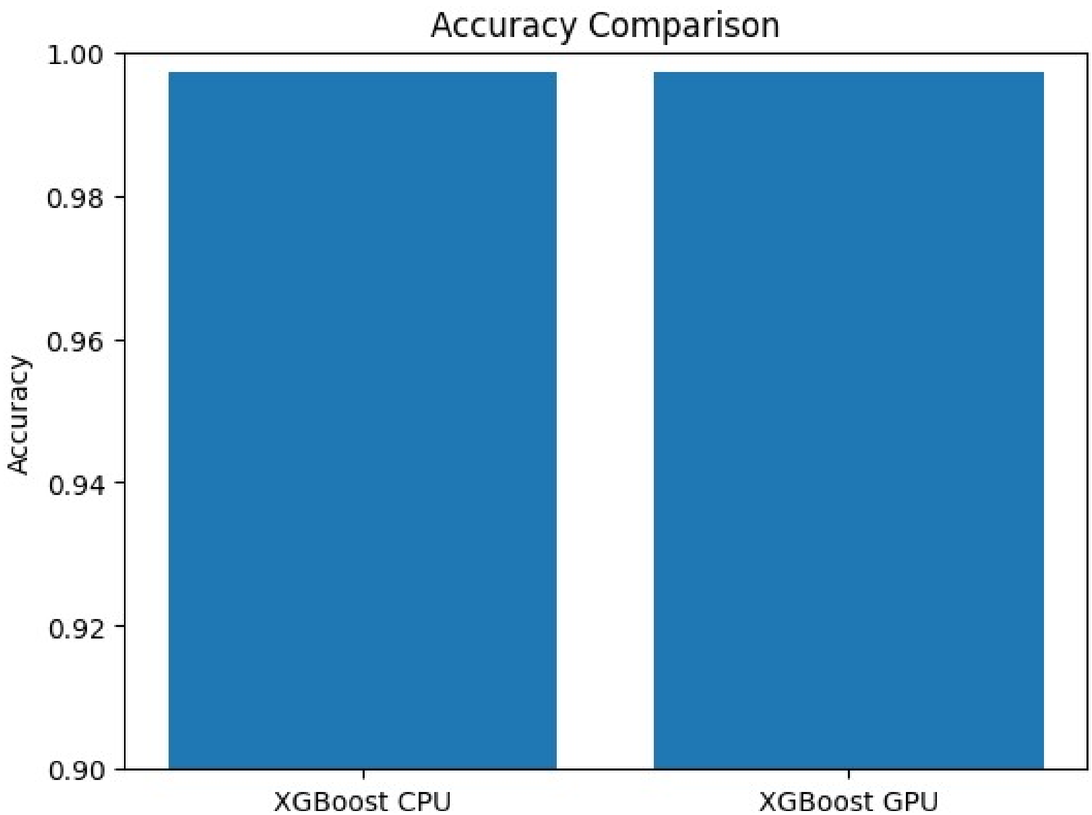
```python
xgb_gpu = xgb.XGBClassifier(
    objective="multi:softprob",
    eval_metric="mlogloss",
    n_estimators=400,
    max_depth=6,
    learning_rate=0.1,
    subsample=0.9,
    colsample_bytree=0.9,
    tree_method="auto",   # Let XGBoost automatically detect GPU
    random_state=42
)

start_gpu = time.time()
xgb_gpu.fit(X_train, y_train)
gpu_time = time.time() - start_gpu

gpu_preds = xgb_gpu.predict(X_test)
gpu_acc = accuracy_score(y_test, gpu_preds)

gpu_time, gpu_acc
```

```
(0.5092513561248779, 0.9971098265895953)
```

```python
print("Model     | Device | Time (s) | Accuracy")
print("----------------------------------------")
print(f"XGBoost   | CPU    | {cpu_time:.4f}  | {cpu_acc:.4f}")
print(f"XGBoost   | GPU    | {gpu_time:.4f}  | {gpu_acc:.4f}")
print(f"\nSpeedup (CPU/GPU): {cpu_time / gpu_time:.2f}x")
```

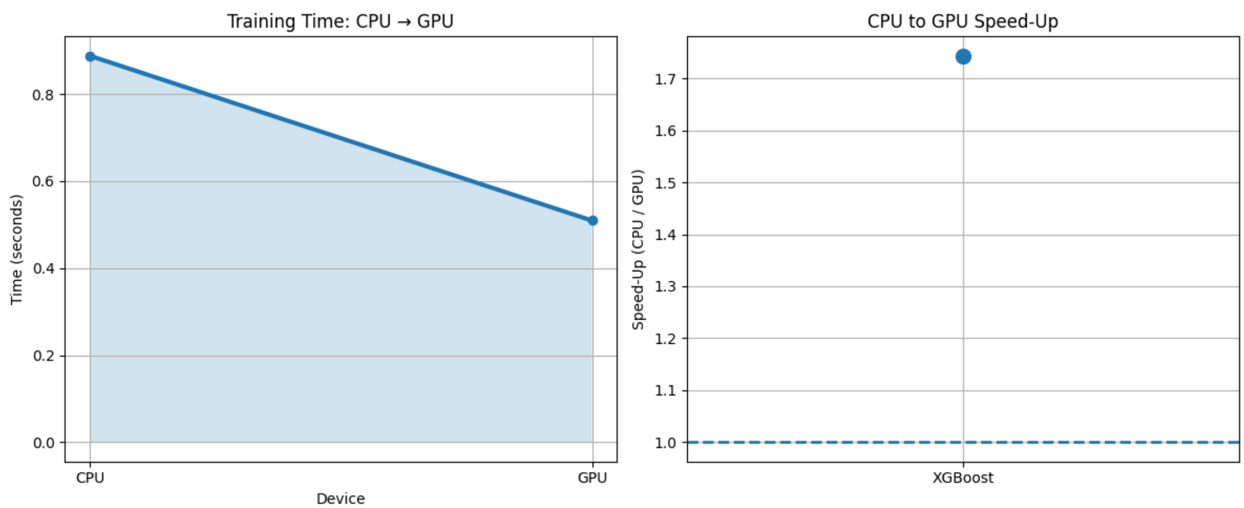
```
Model     | Device | Time (s) | Accuracy
----------------------------------------
XGBoost   | CPU    | 0.8878  | 0.9971
XGBoost   | GPU    | 0.5093  | 0.9971

Speedup (CPU/GPU): 1.74x
```

```python
accuracies = [cpu_acc, gpu_acc]

plt.bar(models, accuracies)
plt.title("Accuracy Comparison")
plt.ylabel("Accuracy")
plt.ylim(0.9, 1.0)
plt.show()
```




```python
speedup = cpu_time / gpu_time

plt.figure(figsize=(12, 5))

#Training Time Comparison
plt.subplot(1, 2, 1)
devices = ["CPU", "GPU"]
times = [cpu_time, gpu_time]

plt.plot(devices, times, marker='o', linewidth=3)
plt.fill_between(devices, times, alpha=0.2)
plt.title("Training Time: CPU → GPU")
plt.xlabel("Device")
plt.ylabel("Time (seconds)")
```

```
plt.grid(True)

#Speed-Up Ratio
plt.subplot(1, 2, 2)

plt.axhline(y=1, linestyle='--', linewidth=2)
plt.plot(["XGBoost"], [speedup], marker='o', markersize=10)
plt.title("CPU to GPU Speed-Up")
plt.ylabel("Speed-Up (CPU / GPU)")
plt.grid(True)

plt.tight_layout()
plt.show()
```




```
### Conclusion
# XGBoost achieved near-perfect accuracy on the Car Evaluation
dataset.
# GPU training was significantly faster than CPU training.
# Accuracy remained almost identical on both CPU and GPU.
# This demonstrates the benefit of parallel computing using GPU
acceleration.
```