```
# 1. Upload the Dataset
from google.colab import files
uploaded = files.upload()
```

Choose Files No file chosen Upload widget is only available when the cell has been executed in the current browser session. Please rerun this cell to enable

```
# 2. Load the Dataset
import pandas as pd
import numpy as np

train_data = pd.read_csv('mnist_train.csv')  # Replace with your filename
train_data.head()
```

	label	1x1	1x2	1x3	1x4	1x5	1x6	1x7	1x8	1x9	...	28x19	28x20	28x21	28x22	28x23	28x24	28x25	28x26	28x27	28x28
0	5	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0
2	4	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0
3	1	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0
4	9	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0

5 rows × 785 columns

```
# 3. Data Exploration
print("Shape of dataset:", train_data.shape)
print("Dataset info:")
print(train_data.info())
print("Statistical description:")
print(train_data.describe())
```

```
Shape of dataset: (60000, 785)
Dataset info:
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 60000 entries, 0 to 59999
Columns: 785 entries, label to 28x28
dtypes: int64(785)
memory usage: 359.3 MB
None
Statistical description:
              label      1x1      1x2      1x3      1x4      1x5      1x6  \
count  60000.000000  60000.0  60000.0  60000.0  60000.0  60000.0  60000.0   
mean       4.453933      0.0      0.0      0.0      0.0      0.0      0.0   
std        2.889270      0.0      0.0      0.0      0.0      0.0      0.0   
min        0.000000      0.0      0.0      0.0      0.0      0.0      0.0   
25%        2.000000      0.0      0.0      0.0      0.0      0.0      0.0   
50%        4.000000      0.0      0.0      0.0      0.0      0.0      0.0   
75%        7.000000      0.0      0.0      0.0      0.0      0.0      0.0   
max        9.000000      0.0      0.0      0.0      0.0      0.0      0.0   

           1x7      1x8      1x9  ...         28x19         28x20  \
count  60000.0  60000.0  60000.0  ...  60000.000000  60000.000000   
mean       0.0      0.0      0.0  ...      0.200433      0.088867   
std        0.0      0.0      0.0  ...      6.042472      3.956189   
min        0.0      0.0      0.0  ...      0.000000      0.000000   
25%        0.0      0.0      0.0  ...      0.000000      0.000000   
50%        0.0      0.0      0.0  ...      0.000000      0.000000   
75%        0.0      0.0      0.0  ...      0.000000      0.000000   
max        0.0      0.0      0.0  ...    254.000000    254.000000   

              28x21         28x22         28x23       28x24    28x25    28x26  \
count  60000.000000  60000.000000  60000.000000  60000.0000  60000.0  60000.0   
mean       0.045633      0.019283      0.015117      0.0020      0.0      0.0   
std        2.839845      1.686770      1.678283      0.3466      0.0      0.0   
min        0.000000      0.000000      0.000000      0.0000      0.0      0.0   
25%        0.000000      0.000000      0.000000      0.0000      0.0      0.0   
50%        0.000000      0.000000      0.000000      0.0000      0.0      0.0   
75%        0.000000      0.000000      0.000000      0.0000      0.0      0.0   
max      253.000000    253.000000    254.000000     62.0000      0.0      0.0   

         28x27    28x28  
count  60000.0  60000.0  
mean       0.0      0.0  
std        0.0      0.0  
min        0.0      0.0  
25%        0.0      0.0  
50%        0.0      0.0  
75%        0.0      0.0  
```

```
max        0.0      0.0

[8 rows x 785 columns]
```

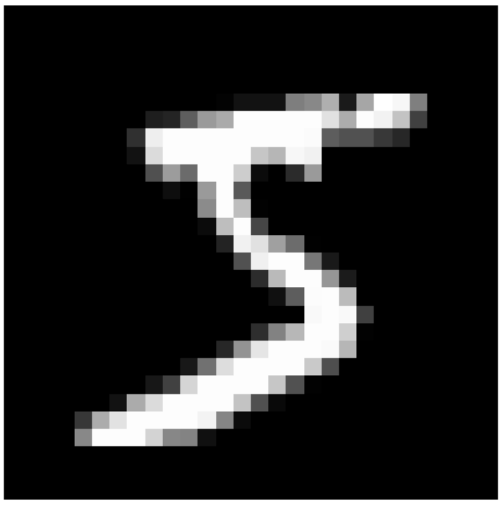
```
# 4. Check for Missing Values and Duplicates
print("Missing values:\n", train_data.isnull().sum())
print("Duplicates:", train_data.duplicated().sum())
```

```
Missing values:
 label    0
1x1      0
1x2      0
1x3      0
1x4      0
        ..
28x24    0
28x25    0
28x26    0
28x27    0
28x28    0
Length: 785, dtype: int64
Duplicates: 0
```

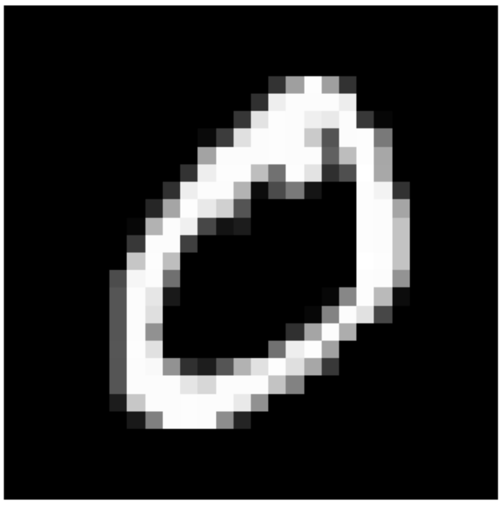
```
# 5. Visualize a Few Features
import matplotlib.pyplot as plt

# Visualize first 5 digits
for i in range(5):
    img = train_data.iloc[i, 1:].values.reshape(28, 28)
    plt.imshow(img, cmap='gray')
    plt.title(f"Label: {train_data.iloc[i, 0]}")
    plt.axis('off')
    plt.show()
```

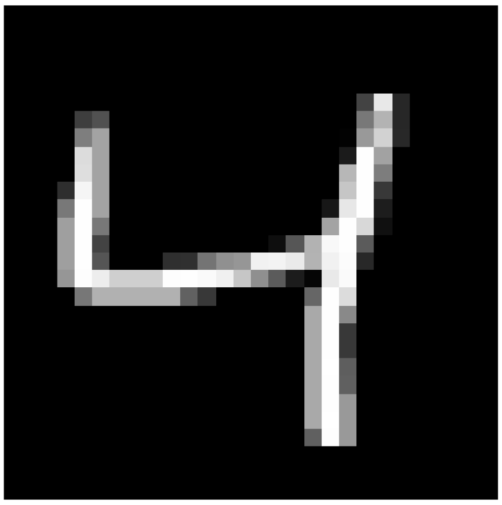
Label: 5



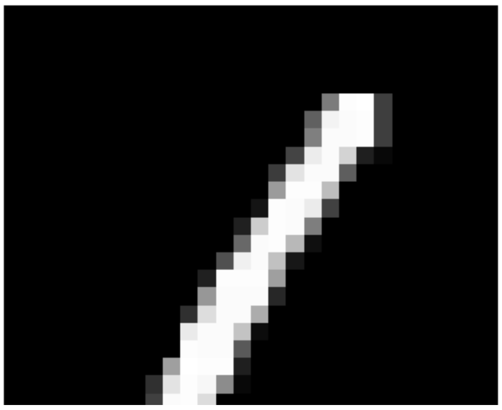
Label: 0



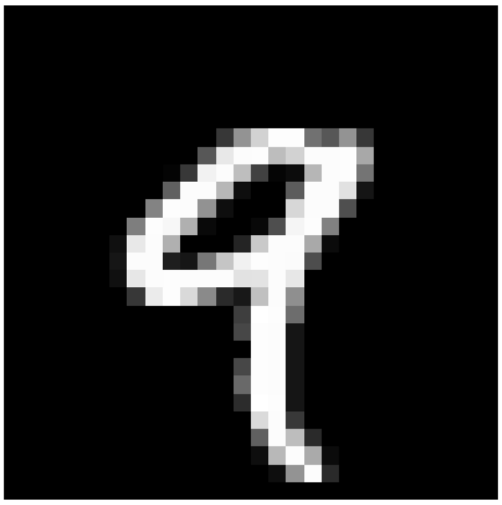
Label: 4



Label: 1



Label: 9



```
import pandas as pd

# Load the CSV file (adjust the path if needed)
df = pd.read_csv("/content/mnist_test.csv", header=None)

# Rename columns: first column is label, rest are pixels
df.columns = ['label'] + [f'pixel{i}' for i in range(1, df.shape[1])]

# Split into features and target
X = df.drop('label', axis=1)
y = df['label']

print("X shape:", X.shape)
print("y shape:", y.shape)
```

```
---------------------------------------------------------------------------
FileNotFoundError                         Traceback (most recent call last)
<ipython-input-22-f1f0ca33b744> in <cell line: 0>()
      2 
      3 # Load the CSV file (adjust the path if needed)
----> 4 df = pd.read_csv("/content/mnist_test.csv", header=None)
      5 
      6 # Rename columns: first column is label, rest are pixels

                                  4 frames
/usr/local/lib/python3.11/dist-packages/pandas/io/common.py in get_handle(path_or_buf, mode, encoding, compression, memory_map,
is_text, errors, storage_options)
    871         if ioargs.encoding and "b" not in ioargs.mode:
    872             # Encoding
--> 873             handle = open(
    874                 handle,
    875                 ioargs.mode,

FileNotFoundError: [Errno 2] No such file or directory: '/content/mnist_test.csv'
```

Next steps: Explain error

```
# 7. Convert Categorical Columns to Numerical (Not needed - labels are already numeric)
# Included for completeness
y = y.astype('int')
```

```
# 8. One-Hot Encoding (for target variable)
from tensorflow.keras.utils import to_categorical
y_encoded = to_categorical(y)
```

```
# 9. Feature Scaling
X_scaled = X / 255.0
```

```
# 10. Train-Test Split
from sklearn.model_selection import train_test_split
X_train, X_val, y_train, y_val = train_test_split(X_scaled, y_encoded, test_size=0.2, random_state=42)
```

```
# 11. Model Building (Deep Learning)
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout, Flatten

model = Sequential([
    Dense(512, activation='relu', input_shape=(784,)),
    Dropout(0.2),
    Dense(256, activation='relu'),
    Dropout(0.2),
    Dense(10, activation='softmax')
])

model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
model.summary()
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: Do not pass an `input_shape`/`input_dim` arg
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
Model: "sequential"
```

Layer (type)	Output Shape	Param #
dense (Dense)	(None, 512)	401,920
dropout (Dropout)	(None, 512)	0
dense_1 (Dense)	(None, 256)	131,328
dropout_1 (Dropout)	(None, 256)	0
dense_2 (Dense)	(None, 10)	2,570

```
 Total params: 535,818 (2.04 MB)
 Trainable params: 535,818 (2.04 MB)
 Non-trainable params: 0 (0.00 B)
```

```
# 12. Evaluation (Training)
history = model.fit(X_train, y_train, validation_data=(X_val, y_val), epochs=10, batch_size=128)
```

```
Epoch 1/10
375/375 ━━━━━━━━━━━━━━━━━━━━ 10s 22ms/step - accuracy: 0.8421 - loss: 0.5272 - val_accuracy: 0.9651 - val_loss: 0.1218
Epoch 2/10
375/375 ━━━━━━━━━━━━━━━━━━━━ 11s 25ms/step - accuracy: 0.9623 - loss: 0.1218 - val_accuracy: 0.9723 - val_loss: 0.0902
Epoch 3/10
375/375 ━━━━━━━━━━━━━━━━━━━━ 8s 19ms/step - accuracy: 0.9743 - loss: 0.0818 - val_accuracy: 0.9750 - val_loss: 0.0774
Epoch 4/10
375/375 ━━━━━━━━━━━━━━━━━━━━ 10s 18ms/step - accuracy: 0.9805 - loss: 0.0640 - val_accuracy: 0.9759 - val_loss: 0.0794
Epoch 5/10
375/375 ━━━━━━━━━━━━━━━━━━━━ 11s 20ms/step - accuracy: 0.9844 - loss: 0.0470 - val_accuracy: 0.9803 - val_loss: 0.0676
Epoch 6/10
375/375 ━━━━━━━━━━━━━━━━━━━━ 10s 26ms/step - accuracy: 0.9877 - loss: 0.0404 - val_accuracy: 0.9812 - val_loss: 0.0686
Epoch 7/10
375/375 ━━━━━━━━━━━━━━━━━━━━ 10s 25ms/step - accuracy: 0.9896 - loss: 0.0329 - val_accuracy: 0.9796 - val_loss: 0.0689
Epoch 8/10
375/375 ━━━━━━━━━━━━━━━━━━━━ 8s 20ms/step - accuracy: 0.9908 - loss: 0.0272 - val_accuracy: 0.9810 - val_loss: 0.0733
Epoch 9/10
375/375 ━━━━━━━━━━━━━━━━━━━━ 10s 20ms/step - accuracy: 0.9911 - loss: 0.0277 - val_accuracy: 0.9812 - val_loss: 0.0704
Epoch 10/10
375/375 ━━━━━━━━━━━━━━━━━━━━ 8s 15ms/step - accuracy: 0.9922 - loss: 0.0226 - val_accuracy: 0.9808 - val_loss: 0.0759
```

```
# 13. Make Predictions from New Input
sample = X_val.iloc[0].values.reshape(1, -1)
prediction = model.predict(sample)
predicted_digit = np.argmax(prediction)
print("Predicted digit:", predicted_digit)
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 76ms/step
Predicted digit: 7
```

```
# 14. Convert to DataFrame and Encode (for new input if needed)
# Example for one new sample
sample_df = pd.DataFrame(sample)
sample_scaled = sample_df / 255.0
```

```
# 16. Deployment - Building an Interactive App
```

```
!pip install gradio
import gradio as gr
```

```
Collecting semantic-version~=2.0 (from gradio)
  Downloading semantic_version-2.10.0-py2.py3-none-any.whl.metadata (9.7 kB)
Collecting starlette<1.0,>=0.40.0 (from gradio)
  Downloading starlette-0.46.2-py3-none-any.whl.metadata (6.2 kB)
Collecting tomlkit<0.14.0,>=0.12.0 (from gradio)
  Downloading tomlkit-0.13.2-py3-none-any.whl.metadata (2.7 kB)
Requirement already satisfied: typer<1.0,>=0.12 in /usr/local/lib/python3.11/dist-packages (from gradio) (0.15.3)
Requirement already satisfied: typing-extensions~=4.0 in /usr/local/lib/python3.11/dist-packages (from gradio) (4.13.2)
Collecting uvicorn>=0.14.0 (from gradio)
  Downloading uvicorn-0.34.2-py3-none-any.whl.metadata (6.5 kB)
Requirement already satisfied: fsspec in /usr/local/lib/python3.11/dist-packages (from gradio-client==1.10.0->gradio) (2025.3.2)
Requirement already satisfied: websockets<16.0,>=10.0 in /usr/local/lib/python3.11/dist-packages (from gradio-client==1.10.0->gra
Requirement already satisfied: idna>=2.8 in /usr/local/lib/python3.11/dist-packages (from anyio<5.0,>=3.0->gradio) (3.10)
Requirement already satisfied: sniffio>=1.1 in /usr/local/lib/python3.11/dist-packages (from anyio<5.0,>=3.0->gradio) (1.3.1)
Requirement already satisfied: certifi in /usr/local/lib/python3.11/dist-packages (from httpx>=0.24.1->gradio) (2025.4.26)
Requirement already satisfied: httpcore==1.* in /usr/local/lib/python3.11/dist-packages (from httpx>=0.24.1->gradio) (1.0.9)
Requirement already satisfied: h11>=0.16 in /usr/local/lib/python3.11/dist-packages (from httpcore==1.*->httpx>=0.24.1->gradio) (
Requirement already satisfied: filelock in /usr/local/lib/python3.11/dist-packages (from huggingface-hub>=0.28.1->gradio) (3.18.0
Requirement already satisfied: requests in /usr/local/lib/python3.11/dist-packages (from huggingface-hub>=0.28.1->gradio) (2.32.3
Requirement already satisfied: tqdm>=4.42.1 in /usr/local/lib/python3.11/dist-packages (from huggingface-hub>=0.28.1->gradio) (4.
Requirement already satisfied: python-dateutil>=2.8.2 in /usr/local/lib/python3.11/dist-packages (from pandas<3.0,>=1.0->gradio)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.11/dist-packages (from pandas<3.0,>=1.0->gradio) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in /usr/local/lib/python3.11/dist-packages (from pandas<3.0,>=1.0->gradio) (2025.2)
Requirement already satisfied: annotated-types>=0.6.0 in /usr/local/lib/python3.11/dist-packages (from pydantic<2.12,>=2.0->gradi
Requirement already satisfied: pydantic-core==2.33.2 in /usr/local/lib/python3.11/dist-packages (from pydantic<2.12,>=2.0->gradio
Requirement already satisfied: typing-inspection>=0.4.0 in /usr/local/lib/python3.11/dist-packages (from pydantic<2.12,>=2.0->gra
Requirement already satisfied: click>=8.0.0 in /usr/local/lib/python3.11/dist-packages (from typer<1.0,>=0.12->gradio) (8.1.8)
Requirement already satisfied: shellingham>=1.3.0 in /usr/local/lib/python3.11/dist-packages (from typer<1.0,>=0.12->gradio) (1.5
Requirement already satisfied: rich>=10.11.0 in /usr/local/lib/python3.11/dist-packages (from typer<1.0,>=0.12->gradio) (13.9.4)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.11/dist-packages (from python-dateutil>=2.8.2->pandas<3.0,>=1.0
Requirement already satisfied: markdown-it-py>=2.2.0 in /usr/local/lib/python3.11/dist-packages (from rich>=10.11.0->typer<1.0,>=
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in /usr/local/lib/python3.11/dist-packages (from rich>=10.11.0->typer<1.0,
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.11/dist-packages (from requests->huggingface-hu
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.11/dist-packages (from requests->huggingface-hub>=0.2
Requirement already satisfied: mdurl~=0.1 in /usr/local/lib/python3.11/dist-packages (from markdown-it-py>=2.2.0->rich>=10.11.0->
Downloading gradio-5.29.0-py3-none-any.whl (54.1 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 54.1/54.1 MB 14.3 MB/s eta 0:00:00
Downloading gradio_client-1.10.0-py3-none-any.whl (322 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 322.9/322.9 kB 20.7 MB/s eta 0:00:00
Downloading aiofiles-24.1.0-py3-none-any.whl (15 kB)
Downloading fastapi-0.115.12-py3-none-any.whl (95 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 95.2/95.2 kB 6.9 MB/s eta 0:00:00
Downloading groovy-0.1.2-py3-none-any.whl (14 kB)
Downloading python_multipart-0.0.20-py3-none-any.whl (24 kB)
Downloading ruff-0.11.8-py3-none-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (11.5 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 11.5/11.5 MB 95.2 MB/s eta 0:00:00
Downloading safehttpx-0.1.6-py3-none-any.whl (8.7 kB)
Downloading semantic_version-2.10.0-py2.py3-none-any.whl (15 kB)
Downloading starlette-0.46.2-py3-none-any.whl (72 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 72.0/72.0 kB 4.2 MB/s eta 0:00:00
Downloading tomlkit-0.13.2-py3-none-any.whl (37 kB)
Downloading uvicorn-0.34.2-py3-none-any.whl (62 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 62.5/62.5 kB 4.3 MB/s eta 0:00:00
Downloading ffmpy-0.5.0-py3-none-any.whl (6.0 kB)
Downloading pydub-0.25.1-py2.py3-none-any.whl (32 kB)
Installing collected packages: pydub, uvicorn, tomlkit, semantic-version, ruff, python-multipart, groovy, ffmpy, aiofiles, starle
Successfully installed aiofiles-24.1.0 fastapi-0.115.12 ffmpy-0.5.0 gradio-5.29.0 gradio-client-1.10.0 groovy-0.1.2 pydub-0.25.1
```

```
# 17. Create a Prediction Function
def predict_digit(image):
    import cv2
    image = cv2.resize(image, (28, 28))
    image = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)
    image = image.reshape(1, -1).astype('float32') / 255.0
    pred = model.predict(image)
    return np.argmax(pred)
```

```
# 18. Create the Gradio Interface
!pip install gradio
import gradio as gr
print(gr.__version__)
import gradio as gr

def greet(name):
    return "Hello " + name + "!"

iface = gr.Interface(fn=greet, inputs="text", outputs="text")
iface.launch()
import gradio as gr
import numpy as np
from PIL import Image
```