

Project ARI3205 Interpretable AI for Deep Learning Models (Part 3.1)

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Importing Necessary Libraries

```
In [1]: # Check and install required libraries from the libraries.json file
import json

# Read the Libraries from the text file
with open('../Libraries/Part3.1_Lib.json', 'r') as file:
    libraries = json.load(file)

# ANSI escape codes for colored output
GREEN = "\033[92m" # Green text
RED = "\033[91m" # Red text
RESET = "\033[0m" # Reset to default color

# Function to check and install libraries
def check_and_install_libraries(libraries):
    for lib, import_name in libraries.items():
        try:
            # Attempt to import the library
            __import__(import_name)
            print(f"{GREEN}✓{RESET} Library '{lib}' is already installed.")
        except ImportError:
            # If import fails, try to install the library
            print(f"{RED}✗{RESET} Library '{lib}' is not installed. Installing")
            %pip install {lib}

# Execute the function to check and install libraries
check_and_install_libraries(libraries)

# Import necessary libraries for data analysis and modeling
import warnings
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import statsmodels.formula.api as smf
# Alibi imports for the MNIST example
import tensorflow as tf
tf.get_logger().setLevel(40) # suppress deprecation messages
tf.compat.v1.disable_v2_behavior() # disable TF2 behaviour as Alibi code still
tf.compat.v1.reset_default_graph()
tf.keras.backend.clear_session()
from tensorflow.keras.layers import Dense, Input
from tensorflow.keras.models import Sequential
from sklearn.model_selection import train_test_split
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from tensorflow.keras.optimizers import Adam
from sklearn.preprocessing import StandardScaler, OneHotEncoder
from sklearn.impute import SimpleImputer
from sklearn.neural_network import MLPClassifier
from alibi.explainers import Counterfactual
import numpy as np

# Suppress specific warnings
warnings.filterwarnings("ignore", message="X does not have valid feature names")
warnings.filterwarnings("ignore", category=RuntimeWarning)
warnings.filterwarnings("ignore", category=UserWarning)
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[✓] Library 'tensorflow' is already installed.
[✓] Library 'scikit-learn' is already installed.
[✓] Library 'matplotlib' is already installed.
[✓] Library 'seaborn' is already installed.
[✓] Library 'pandas' is already installed.
[✓] Library 'numpy' is already installed.
[✓] Library 'statsmodels' is already installed.
[✗] Library 'alibi[tensorflow]' is not installed. Installing...
Requirement already satisfied: alibi[tensorflow] in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (0.9.6)
Requirement already satisfied: numpy<2.0.0,>=1.16.2 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from alibi[tensorflow]) (1.23.5)
Requirement already satisfied: pandas<3.0.0,>=1.0.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from alibi[tensorflow]) (2.2.2)
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Requirement already satisfied: spacy<4.0.0,>=2.0.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (3.7.5)
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Requirement already satisfied: scikit-image<0.23,>=0.17.2 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from alibi[tensorflow]) (0.22.0)
Requirement already satisfied: requests<3.0.0,>=2.21.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from alibi[tensorflow]) (2.32.2)
Requirement already satisfied: Pillow<11.0,>=5.4.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from alibi[tensorflow]) (10.3.0)
Requirement already satisfied: attrs<24.0.0,>=19.2.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from alibi[tensorflow]) (23.2.0)
Requirement already satisfied: scipy<2.0.0,>=1.1.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from alibi[tensorflow]) (1.13.1)
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Requirement already satisfied: typing-extensions>=3.7.4.3 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from alibi[tensorflow]) (4.11.0)
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Requirement already satisfied: tqdm<5.0.0,>=4.28.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from alibi[tensorflow]) (4.66.5)
Requirement already satisfied: tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from alibi[tensorflo

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w]) (2.12.0)

Requirement already satisfied: contourpy>=1.0.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib<4.0.0,>=3.0.0->alibi[tensorflow]) (1.2.1)

Requirement already satisfied: cycycler>=0.10 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib<4.0.0,>=3.0.0->alibi[tensorflow]) (0.12.1)

Requirement already satisfied: fonttools>=4.22.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib<4.0.0,>=3.0.0->alibi[tensorflow]) (4.51.0)

Requirement already satisfied: kiwisolver>=1.3.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib<4.0.0,>=3.0.0->alibi[tensorflow]) (1.4.5)

Requirement already satisfied: packaging>=20.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib<4.0.0,>=3.0.0->alibi[tensorflow]) (24.0)

Requirement already satisfied: pyparsing>=2.3.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib<4.0.0,>=3.0.0->alibi[tensorflow]) (3.1.2)

Requirement already satisfied: python-dateutil>=2.7 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from matplotlib<4.0.0,>=3.0.0->alibi[tensorflow]) (2.9.0.post0)

Requirement already satisfied: pytz>=2020.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas<3.0.0,>=1.0.0->alibi[tensorflow]) (2024.1)

Requirement already satisfied: tzdata>=2022.7 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pandas<3.0.0,>=1.0.0->alibi[tensorflow]) (2024.1)

Requirement already satisfied: charset-normalizer<4,>=2 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests<3.0.0,>=2.21.0->alibi[tensorflow]) (3.3.2)

Requirement already satisfied: idna<4,>=2.5 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests<3.0.0,>=2.21.0->alibi[tensorflow]) (3.7)

Requirement already satisfied: urllib3<3,>=1.21.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests<3.0.0,>=2.21.0->alibi[tensorflow]) (2.2.1)

Requirement already satisfied: certifi>=2017.4.17 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests<3.0.0,>=2.21.0->alibi[tensorflow]) (2024.2.2)

Requirement already satisfied: networkx>=2.8 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-image<0.23,>=0.17.2->alibi[tensorflow]) (3.3)

Requirement already satisfied: imageio>=2.27 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-image<0.23,>=0.17.2->alibi[tensorflow]) (2.27)

w]) (2.36.1)

Requirement already satisfied: tifffile>=2022.8.12 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-image<0.23,>=0.17.2->alibi[tensorflow]) (2024.12.12)

Requirement already satisfied: lazy_loader>=0.3 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-image<0.23,>=0.17.2->alibi[tensorflow]) (0.4)

Requirement already satisfied: joblib>=1.2.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-learn<2.0.0,>=1.0.0->alibi[tensorflow]) (1.4.2)

Requirement already satisfied: threadpoolctl>=3.1.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scikit-learn<2.0.0,>=1.0.0->alibi[tensorflow]) (3.5.0)

Requirement already satisfied: spacy-legacy<3.1.0,>=3.0.11 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (3.0.12)

Requirement already satisfied: spacy-loggers<2.0.0,>=1.0.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (1.0.5)

Requirement already satisfied: murmurhash<1.1.0,>=0.28.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (1.0.10)

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Requirement already satisfied: thinc<8.3.0,>=8.2.2 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (8.2.5)

Requirement already satisfied: wasabi<1.2.0,>=0.9.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (1.1.3)

Requirement already satisfied: srsly<3.0.0,>=2.4.3 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (2.4.8)

Requirement already satisfied: catalogue<2.1.0,>=2.0.6 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (2.0.10)

Requirement already satisfied: weasel<0.5.0,>=0.1.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (0.4.1)

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0.0,>=2.0.0->alibi[tensorflow]) (0.13.0)
Requirement already satisfied: pydantic!=1.8,!<1.8.1,<3.0.0,>=1.7.4 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (2.9.2)
Requirement already satisfied: jinja2 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (3.1.4)
Requirement already satisfied: setuptools in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (75.8.0)
Requirement already satisfied: langcodes<4.0.0,>=3.2.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (3.4.1)
Requirement already satisfied: spacy-lookups-data<1.1.0,>=1.0.3 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (1.0.5)
Requirement already satisfied: tensorflow-intel==2.12.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (2.12.0)
Requirement already satisfied: absl-py>=1.0.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (2.1.0)
Requirement already satisfied: astunparse>=1.6.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (1.6.3)
Requirement already satisfied: flatbuffers>=2.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (24.12.23)
Requirement already satisfied: gast<=0.4.0,>=0.2.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (0.4.0)
Requirement already satisfied: google-pasta>=0.1.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (0.2.0)
Requirement already satisfied: h5py>=2.9.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (3.12.1)
Requirement already satisfied: jax>=0.3.15 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (0.4.30)
Requirement already satisfied: libclang>=13.0.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (18.1.1)
Requirement already satisfied: opt-einsum>=2.3.2 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=

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2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (3.4.0)
Requirement already satisfied: protobuf!=4.21.0,!<4.21.1,!<4.21.2,!<4.21.3,!<4.21.4,!<4.21.5,<5.0.0dev,>=3.20.3 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (4.25.5)
Requirement already satisfied: six>=1.12.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (1.16.0)
Requirement already satisfied: termcolor>=1.1.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (2.5.0)
Requirement already satisfied: wrapt<1.15,>=1.11.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (1.14.1)
Requirement already satisfied: grpcio<2.0,>=1.24.3 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (1.69.0)
Requirement already satisfied: tensorboard<2.13,>=2.12 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (2.12.3)
Requirement already satisfied: tensorflow-estimator<2.13,>=2.12.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (2.12.0)
Requirement already satisfied: keras<2.13,>=2.12.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (2.12.0)
Requirement already satisfied: tensorflow-io-gcs-filesystem>=0.23.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (0.31.0)
Requirement already satisfied: colorama in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tqdm<5.0.0,>=4.28.1->alibi[tensorflow]) (0.4.6)
Requirement already satisfied: filelock in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from transformers<5.0.0,>=4.7.0->alibi[tensorflow]) (3.16.1)
Requirement already satisfied: huggingface-hub<1.0,>=0.23.2 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from transformers<5.0.0,>=4.7.0->alibi[tensorflow]) (0.25.1)
Requirement already satisfied: pyyaml>=5.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from transformers<5.0.0,>=4.7.0->alibi[tensorflow]) (6.0.1)
Requirement already satisfied: regex!=2019.12.17 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from transformers<5.0.0,>=4.7.0->alibi[tensorflow]) (2024.9.11)
Requirement already satisfied: safetensors>=0.4.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from transformers<5.0.0,>=4.7.0->alibi[tensorflow]) (0.4.3)

rflow]) (0.4.5)

Requirement already satisfied: tokenizers<0.21,>=0.20 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from transformers<5.0.0,>=4.7.0->alibi[tensorflow]) (0.20.0)

Requirement already satisfied: fsspec>=2023.5.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from huggingface-hub<1.0,>=0.23.2->transformers<5.0.0,>=4.7.0->alibi[tensorflow]) (2024.9.0)

Requirement already satisfied: language-data>=1.2 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from langcodes<4.0.0,>=3.2.0->spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (1.2.0)

Requirement already satisfied: annotated-types>=0.6.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pydantic!=1.8,!<1.8.1,<3.0.0,>=1.7.4->spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (0.7.0)

Requirement already satisfied: pydantic-core==2.23.4 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pydantic!=1.8,!<1.8.1,<3.0.0,>=1.7.4->spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (2.23.4)

Requirement already satisfied: confection<1.0.0,>=0.0.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from thinc<8.3.0,>=8.2.2->spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (0.1.5)

Requirement already satisfied: click>=8.0.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from typer<1.0.0,>=0.3.0->spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (8.1.7)

Requirement already satisfied: shellingham>=1.3.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from typer<1.0.0,>=0.3.0->spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (1.5.4)

Requirement already satisfied: rich>=10.11.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from typer<1.0.0,>=0.3.0->spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (13.9.4)

Requirement already satisfied: cloudpathlib<1.0.0,>=0.7.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from weasel<0.5.0,>=0.1.0->spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (0.20.0)

Requirement already satisfied: smart-open<8.0.0,>=5.2.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from weasel<0.5.0,>=0.1.0->spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (7.0.5)

Requirement already satisfied: MarkupSafe>=2.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jinja2->spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (2.1.5)

Requirement already satisfied: wheel<1.0,>=0.23.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from astunparse>=1.6.0->tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (0.45.1)

Requirement already satisfied: jaxlib<=0.4.30,>=0.4.27 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jax>=0.3.15->tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (0.4.30)

Requirement already satisfied: ml-dtypes>=0.2.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from jax>=0.3.15->tensorflow-intel==2.12.0->tensorflow!=2.6.0,!<2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (0.4.30)


```

nsorflow!=2.6.0,!>=2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (0.2.0)
Requirement already satisfied: marisa-trie>=0.7.7 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from language-data>=1.2->langcodes<4.0.0,>=3.2.0->spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (1.2.1)
Requirement already satisfied: markdown-it-py>=2.2.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rich>=10.11.0->typer<1.0.0,>=0.3.0->spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (3.0.0)
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from rich>=10.11.0->typer<1.0.0,>=0.3.0->spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (2.18.0)
Requirement already satisfied: google-auth<3,>=1.6.3 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorboard<2.13,>=2.12->tensorflow-intel==2.12.0->tensorflow!=2.6.0,!>=2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (2.37.0)
Requirement already satisfied: google-auth-oauthlib<1.1,>=0.5 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorboard<2.13,>=2.12->tensorflow-intel==2.12.0->tensorflow!=2.6.0,!>=2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (1.0.0)
Requirement already satisfied: markdown>=2.6.8 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorboard<2.13,>=2.12->tensorflow-intel==2.12.0->tensorflow!=2.6.0,!>=2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (3.7)
Requirement already satisfied: tensorboard-data-server<0.8.0,>=0.7.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorboard<2.13,>=2.12->tensorflow-intel==2.12.0->tensorflow!=2.6.0,!>=2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (0.7.2)
Requirement already satisfied: werkzeug>=1.0.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from tensorboard<2.13,>=2.12->tensorflow-intel==2.12.0->tensorflow!=2.6.0,!>=2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (3.0.3)
Requirement already satisfied: cachetools<6.0,>=2.0.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from google-auth<3,>=1.6.3->tensorboard<2.13,>=2.12->tensorflow-intel==2.12.0->tensorflow!=2.6.0,!>=2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (5.5.0)
Requirement already satisfied: pyasn1-modules>=0.2.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from google-auth<3,>=1.6.3->tensorboard<2.13,>=2.12->tensorflow-intel==2.12.0->tensorflow!=2.6.0,!>=2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (0.4.1)
Requirement already satisfied: rsa<5,>=3.1.4 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from google-auth<3,>=1.6.3->tensorboard<2.13,>=2.12->tensorflow-intel==2.12.0->tensorflow!=2.6.0,!>=2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (4.9)
Requirement already satisfied: requests-oauthlib>=0.7.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from google-auth-oauthlib<1.1,>=0.5->tensorboard<2.13,>=2.12->tensorflow-intel==2.12.0->tensorflow!=2.6.0,!>=2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (2.0.0)
Requirement already satisfied: mdurl~>=0.1 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from markdown-it-py>=2.2.0->rich>=10.11.0->typer<1.

```

0.0,>=0.3.0->spacy<4.0.0,>=2.0.0->spacy[lookups]<4.0.0,>=2.0.0->alibi[tensorflow]) (0.1.2)

Requirement already satisfied: pyasn1<0.7.0,>=0.4.6 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from pyasn1-modules>=0.2.1->google-auth<3,>=1.6.3->tensorboard<2.13,>=2.12->tensorflow-intel==2.12.0->tensorflow!=2.6.0,!=2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (0.6.1)

Requirement already satisfied: oauthlib>=3.0.0 in c:\users\sean muscat\appdata\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from requests-oauthlib>=0.7.0->google-auth-oauthlib<1.1,>=0.5->tensorboard<2.13,>=2.12->tensorflow-intel==2.12.0->tensorflow!=2.6.0,!=2.6.1,<2.15.0,>=2.0.0->alibi[tensorflow]) (3.2.2)

Note: you may need to restart the kernel to use updated packages.

C:\Users\Sean Muscat\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.11_qbz5n2kfra8p0\LocalCache\local-packages\Python311\site-packages\tqdm\auto.py:21: TqdmWarning: IPProgress not found. Please update jupyter and ipywidgets. See https://ipywidgets.readthedocs.io/en/stable/user_install.html
from .autonotebook import tqdm as notebook_tqdm

```
In [2]: # Define the filenames
train_filename = '../Datasets/Titanic/train.csv'
test_filename = '../Datasets/Titanic/test.csv'
gender_submission_filename = '../Datasets/Titanic/gender_submission.csv'

# Load the datasets
try:
    train_data = pd.read_csv(train_filename)
    test_data = pd.read_csv(test_filename)
    gender_submission_data = pd.read_csv(gender_submission_filename)
    print(f'{train_filename} dataset loaded successfully.')
    print(f'{test_filename} dataset loaded successfully.')
    print(f'{gender_submission_filename} dataset loaded successfully.')
except FileNotFoundError as e:
    print(f"Error: {e.filename} was not found. Please ensure it is in the correct location.")
    exit()
except pd.errors.EmptyDataError as e:
    print(f"Error: {e.filename} is empty.")
    exit()
except pd.errors.ParserError as e:
    print(f"Error: There was a problem parsing {e.filename}. Please check the file format.")
    exit()

# Dataset insights
print("\nTrain Dataset Overview:")
print(train_data.info())
print("\nTrain Dataset Statistical Summary:")
print(train_data.describe())

print("\nTest Dataset Overview:")
print(test_data.info())
print("\nTest Dataset Statistical Summary:")
print(test_data.describe())

print("\nGender Submission Dataset Overview:")
print(gender_submission_data.info())
```

```
'../Datasets/Titanic/train.csv' dataset loaded successfully.
'../Datasets/Titanic/test.csv' dataset loaded successfully.
'../Datasets/Titanic/gender_submission.csv' dataset loaded successfully.
```

Train Dataset Overview:

```
<class 'pandas.core.frame.DataFrame'>
```

```
RangeIndex: 891 entries, 0 to 890
```

```
Data columns (total 12 columns):
```

#	Column	Non-Null Count	Dtype
0	PassengerId	891 non-null	int64
1	Survived	891 non-null	int64
2	Pclass	891 non-null	int64
3	Name	891 non-null	object
4	Sex	891 non-null	object
5	Age	714 non-null	float64
6	SibSp	891 non-null	int64
7	Parch	891 non-null	int64
8	Ticket	891 non-null	object
9	Fare	891 non-null	float64
10	Cabin	204 non-null	object
11	Embarked	889 non-null	object

```
dtypes: float64(2), int64(5), object(5)
```

```
memory usage: 83.7+ KB
```

```
None
```

Train Dataset Statistical Summary:

	PassengerId	Survived	Pclass	Age	SibSp \
count	891.000000	891.000000	891.000000	714.000000	891.000000
mean	446.000000	0.383838	2.308642	29.699118	0.523008
std	257.353842	0.486592	0.836071	14.526497	1.102743
min	1.000000	0.000000	1.000000	0.420000	0.000000
25%	223.500000	0.000000	2.000000	20.125000	0.000000
50%	446.000000	0.000000	3.000000	28.000000	0.000000
75%	668.500000	1.000000	3.000000	38.000000	1.000000
max	891.000000	1.000000	3.000000	80.000000	8.000000

	Parch	Fare
count	891.000000	891.000000
mean	0.381594	32.204208
std	0.806057	49.693429
min	0.000000	0.000000
25%	0.000000	7.910400
50%	0.000000	14.454200
75%	0.000000	31.000000
max	6.000000	512.329200

Test Dataset Overview:

```
<class 'pandas.core.frame.DataFrame'>
```

```
RangeIndex: 418 entries, 0 to 417
```

```
Data columns (total 11 columns):
```

#	Column	Non-Null Count	Dtype
0	PassengerId	418 non-null	int64
1	Pclass	418 non-null	int64
2	Name	418 non-null	object
3	Sex	418 non-null	object
4	Age	332 non-null	float64
5	SibSp	418 non-null	int64
6	Parch	418 non-null	int64

```

7   Ticket      418 non-null   object
8   Fare        417 non-null   float64
9   Cabin       91 non-null    object
10  Embarked    418 non-null   object
dtypes: float64(2), int64(4), object(5)
memory usage: 36.1+ KB
None

```

Test Dataset Statistical Summary:

	PassengerId	Pclass	Age	SibSp	Parch	Fare
count	418.000000	418.000000	332.000000	418.000000	418.000000	417.000000
mean	1100.500000	2.265550	30.272590	0.447368	0.392344	35.627188
std	120.810458	0.841838	14.181209	0.896760	0.981429	55.907576
min	892.000000	1.000000	0.170000	0.000000	0.000000	0.000000
25%	996.250000	1.000000	21.000000	0.000000	0.000000	7.895800
50%	1100.500000	3.000000	27.000000	0.000000	0.000000	14.454200
75%	1204.750000	3.000000	39.000000	1.000000	0.000000	31.500000
max	1309.000000	3.000000	76.000000	8.000000	9.000000	512.329200

Gender Submission Dataset Overview:

```
<class 'pandas.core.frame.DataFrame'>
```

RangeIndex: 418 entries, 0 to 417

Data columns (total 2 columns):

#	Column	Non-Null Count	Dtype
0	PassengerId	418 non-null	int64
1	Survived	418 non-null	int64

```
dtypes: int64(2)
```

```
memory usage: 6.7 KB
```

```
None
```

Feed-Forward Neural Network

```

In [3]: # Load the Titanic dataset
train_data = pd.read_csv('../Datasets/Titanic/train.csv')

# Preprocessing
# Separate features and target
y = train_data['Survived'] # Target
X = train_data.drop(columns=['Survived', 'PassengerId', 'Name', 'Ticket', 'Cabin'])

# Handle categorical variables with one-hot encoding
categorical_features = ['Sex', 'Embarked']
one_hot_encoder = OneHotEncoder(sparse_output=False, handle_unknown='ignore')
categorical_encoded = one_hot_encoder.fit_transform(X[categorical_features])
categorical_encoded_df = pd.DataFrame(categorical_encoded, columns=one_hot_encoder.get_feature_names_out(categorical_features))

# Drop original categorical columns and append the encoded columns
X = X.drop(columns=categorical_features)
X = pd.concat([X.reset_index(drop=True), categorical_encoded_df.reset_index(drop=True)], axis=1)

# Handle missing values with mean imputation
imputer = SimpleImputer(strategy='mean')
X_imputed = pd.DataFrame(imputer.fit_transform(X), columns=X.columns)

# Standardize the features
scaler = StandardScaler()
X_scaled = pd.DataFrame(scaler.fit_transform(X_imputed), columns=X.columns)

```

```
# Split the data into training and test sets
X_train, X_test, y_train, y_test = train_test_split(X_scaled, y, test_size=0.2,
print("Training data shape:", X_train.shape)
print("Test data shape:", X_test.shape)
```

Training data shape: (712, 11)

Test data shape: (179, 11)

```
In [ ]: # Build the feed-forward neural network
model = Sequential([
    Input(shape=(X_train.shape[1],)), # Define input shape explicitly
    Dense(64, activation='relu'),
    Dense(32, activation='relu'),
    Dense(1, activation='sigmoid') # Output layer for binary classification
])

# Compile the model
model.compile(optimizer=Adam(learning_rate=0.001), loss='binary_crossentropy', m

# Train the model
history = model.fit(X_train, y_train, validation_split=0.2, epochs=50, batch_siz

# Evaluate the model
# test_loss, test_accuracy = model.evaluate(X_test, y_test, verbose=1)
# print(f"Test Loss: {test_loss:.4f}, Test Accuracy: {test_accuracy:.4f}")
```

Surrogate Model - MLPClassifier

```
In [5]: # Train a surrogate model (MLPClassifier)
surrogate_model = MLPClassifier(hidden_layer_sizes=(32,), activation='logistic',
print('Accuracy (MLPClassifier): ' + str(surrogate_model.score(X_train, y_train))
```

Accuracy (MLPClassifier): 0.800561797752809

Part 3.1

Set up Counterfactuals

We begin by predicting labels on the test set and identifying which samples the model misclassifies. For each misclassified passenger, we record their scaled features and define a prediction function that converts our model's single sigmoid output into a two-column probability array: [p(died), p(survived)]. Alibi's counterfactual explainer then searches within specified min/max bounds for a new set of feature values that shifts the model's predicted outcome (for example, from "died" to "survived"). Finally, we compare these counterfactual features with the originals to see how small changes in attributes like Age or Fare can flip the prediction.

```
In [11]: # 1. Make predictions on the test set
y_pred_probs = model.predict(X_test)
y_pred = (y_pred_probs > 0.5).astype(int).flatten()

# 2. Identify misclassified samples
incorrect_indices = np.where(y_pred != y_test.values)[0]
print(f"Number of incorrectly predicted samples: {len(incorrect_indices)}")
```

```

# Make sure we have at least 2 misclassified samples
if len(incorrect_indices) < 2:
    print("Fewer than 2 misclassified samples found. Cannot generate two counterfactuals")
else:
    #####
    # LOOP OVER THE FIRST 2 MISCLASSIFIED
    #####
    for i in range(2): # generate counterfactual for the first two misclassified samples
        print(f"\n*** COUNTERFACTUAL #{i+1} ***")

        # 3. Select one misclassified example
        sample_idx = incorrect_indices[i] # pick the i-th misclassified sample
        x_test_sample = X_test.iloc[[sample_idx]].values
        actual_label = y_test.values[sample_idx]
        print(f"Sample index: {sample_idx}, Actual label: {actual_label}, Predicted label: {y_test[sample_idx]}")
        print("\nSample features (scaled):")
        display(X_test.iloc[[sample_idx]])

        # 4. Define a new predict_fn that outputs [p(died), p(survived)] for each sample
        def predict_fn(x: np.ndarray) -> np.ndarray:
            if x.ndim == 1:
                x = x.reshape(1, -1)
            p_survived = model.predict(x).flatten()
            p_died = 1.0 - p_survived
            return np.vstack([p_died, p_survived]).T

        # 5. Determine feature_range from training data
        lower_bounds = X_train.min(axis=0).values
        upper_bounds = X_train.max(axis=0).values
        feature_range = (lower_bounds, upper_bounds)

        # 6. Decide on target_proba to 'flip' the original label
        desired_proba = 0.8 if actual_label == 0 else 0.2

        # 7. Instantiate the Counterfactual explainer
        cf_explainer = Counterfactual(
            predict_fn=predict_fn,
            shape=(1, X_train.shape[1]),
            target_proba=desired_proba,
            max_iter=1000,
            feature_range=feature_range,
            lam_init=1e-1,
            max_lam_steps=10,
            learning_rate_init=1e-2
        )

        # 8. Generate a counterfactual explanation
        explanation = cf_explainer.explain(x_test_sample)

        # 9. Print results
        print("\n--- Counterfactual Explanation ---")
        print("Original 2-column probability:", predict_fn(x_test_sample))
        if explanation.cf is not None:
            cf_sample = explanation.cf['X'] # shape => (1, n_features)
            print("\nCounterfactual feature values (scaled):")
            display(cf_sample)

            print("Counterfactual 2-column probability:", predict_fn(cf_sample))

```

```

# Show the numerical difference
changes = cf_sample[0] - x_test_sample[0]
print("\nDifference between CF and original sample:")
for col, diff in zip(X_test.columns, changes):
    print(f"{col}: {diff:.3f}")
else:
    print("No counterfactual found within the specified parameters.")

```

Number of incorrectly predicted samples: 83

*** COUNTERFACTUAL #1 ***

Sample index: 1, Actual label: 0, Predicted: 1

Sample features (scaled):

	Pclass	Age	SibSp	Parch	Fare	Sex_female	Sex_male	Embarked
439	-0.369365	0.100109	-0.474545	-0.473674	-0.437007	-0.737695	0.737695	-0.482

--- Counterfactual Explanation ---

Original 2-column probability: [[0.43319923 0.5668008]]

No counterfactual found within the specified parameters.

*** COUNTERFACTUAL #2 ***

Sample index: 2, Actual label: 0, Predicted: 1

Sample features (scaled):

	Pclass	Age	SibSp	Parch	Fare	Sex_female	Sex_male	Embarked
840	0.827377	-0.746389	-0.474545	-0.473674	-0.488854	-0.737695	0.737695	-0.482

ERROR:alibi.explainers.counterfactual:No appropriate lambda range found, try decreasing lam_init

--- Counterfactual Explanation ---

Original 2-column probability: [[0.48958385 0.51041615]]

No counterfactual found within the specified parameters.

This code was run multiple times, this was another of the counterfactuals given:

*** COUNTERFACTUAL #1 ***

Sample index: 0, Actual label: 1, Predicted: 0

--- Counterfactual Explanation ---

Original 2-column probability: [[0.64625597 0.353744]]

Counterfactual feature values (scaled):

array([[0.82737726, -1.394982 , 1.6170563 , 2.1170812 , -0.64842165, -0.73769516,
0.73769516, 2.074505 , 0.58823454, -1.6147097 , 1.3070657], dtype=float32)

Counterfactual 2-column probability: [[0.75010574 0.24989426]]

Difference between CF and original sample:

Pclass: 0.000

Age: -1.395

SibSp: 1.184

Parch: 1.349

Fare: -0.307

Sex_female: -0.000

Sex_male: 0.000

Embarked_C: -0.000

Embarked_Q: 0.896

Embarked_S: -0.000

Embarked_nan: 1.354

*** COUNTERFACTUAL #2 ***

Sample index: 4, Actual label: 1, Predicted: 0

--- Counterfactual Explanation ---

Original 2-column probability: [[0.54528 0.45472002]]

Counterfactual feature values (scaled):

array([[0.82737726, -1.2068506, 0.43296716, -0.4736736, -0.422202, 1.3555735 ,
-1.3555735, 2.074505, 0.4825647, 0.6193064, 2.7697735]], dtype=float32)

Counterfactual 2-column probability: [[0.79656625 0.20343377]]

Difference between CF and original sample:

Pclass: 0.000

Age: 0.001

SibSp: 0.000

Parch: -0.000

Fare: -0.000

Sex_female: -0.000

Sex_male: 0.000

Embarked_C: -0.000

Embarked_Q: 0.790

Embarked_S: 2.234

Embarked_nan: 2.817

Output Explanation: Counterfactual #1 (Sample index: 0, Actual label: 1, Predicted: 0) In this example, the model originally assigns a probability of approximately 64.63% to class 0 (and 35.37% to class 1). Several features are then adjusted—most notably, Age decreases substantially (by -1.395 in scaled units), while SibSp (number of siblings/spouses) and Parch (number of parents/children) both increase. Additionally, there are changes in Embarked_Q and Embarked_nan. After these modifications, the model's probability for class 0 rises to about 75.01%, moving further away from predicting the correct label of 1. This indicates that these specific adjustments to the features cause the model to become even more confident in the incorrect prediction. It suggests that age and the number of family members travelling (as encoded in SibSp and Parch) may be influential in pushing the prediction toward non-survival under this particular counterfactual setting.

Counterfactual #2 (Sample index: 4, Actual label: 1, Predicted: 0) Here, the original probabilities are roughly 54.53% for class 0 versus 45.47% for class 1—still an incorrect prediction, though the model is slightly less certain compared with Counterfactual #1. The counterfactual modifies the feature representation of passenger embarkation, with notable jumps in Embarked_Q, Embarked_S, and Embarked_nan. Despite these changes, the probability for class 0 increases further to approximately 79.66%. This outcome indicates that shifts in certain embarkation features, under the current model, do not bring the prediction closer to the correct label for this sample but instead reinforce the model's belief that the passenger did not survive.

3.1 b

Counterfactual explanations are vital because they tell us how to alter specific features in a model's input so that its prediction changes to a desired outcome. When we see how even small changes in passenger attributes (for instance, lowering their age or increasing their fare) flip the prediction from "died" to "survived," we gain insights into what the model deems crucial for its decision.

In debugging models, counterfactuals help us pinpoint problematic behaviours and potential biases. If the counterfactual requires unrealistic feature shifts—such as setting the fare far above any real-world range—then our model may be over-reliant on that feature, or it might not generalise well. We can use this knowledge to refine data preprocessing or adjust hyperparameters, ensuring our model bases decisions on more sensible factors.

Counterfactuals can direct real-world interventions from a decision-making perspective. For instance, if a passenger's survival probability increases significantly with a slight increase in fare, this indicates that socioeconomic position (as measured by fare) has a significant impact on the model. Managers, legislators, or end users can then evaluate the fairness or realism of these elements. Counterfactuals essentially assist stakeholders

in understanding how to modify inputs in a meaningful way, increasing the transparency of model outputs and enabling more informed choices in practical situations.