cnn_tabular_single_task_combination

April 13, 2025

Original Data source https://nihcc.app.box.com/v/ChestXray-NIHCC

Google Healthcare APIs https://cloud.google.com/healthcare-api/docs/resources/public-datasets/nih-chest

[319]:
```
!apt-get update && apt-get install -y libgl1
```

```
Hit:1 https://developer.download.nvidia.com/compute/cuda/repos/ubuntu2204/x86_64
InRelease
Hit:2 http://archive.ubuntu.com/ubuntu jammy InRelease
Hit:3 http://security.ubuntu.com/ubuntu jammy-security InRelease
Hit:4 http://archive.ubuntu.com/ubuntu jammy-updates InRelease
Hit:5 http://archive.ubuntu.com/ubuntu jammy-backports InRelease
Reading package lists… Done
Reading package lists… Done
Building dependency tree… Done
Reading state information… Done
libgl1 is already the newest version (1.4.0-1).
0 upgraded, 0 newly installed, 0 to remove and 104 not upgraded.
```

[320]:
```
!pip install kagglehub
!pip install kagglehub[pandas-datasets]
!pip install wget
!pip install keras-tuner
!pip install seaborn
!pip install opencv-python
!pip install scikit-learn
!pip install fastparquet
```

```
Requirement already satisfied: kagglehub in /usr/local/lib/python3.11/dist-
packages (0.3.11)
Requirement already satisfied: packaging in /usr/local/lib/python3.11/dist-
packages (from kagglehub) (23.2)
Requirement already satisfied: pyyaml in /usr/local/lib/python3.11/dist-packages
(from kagglehub) (6.0.2)
Requirement already satisfied: requests in /usr/local/lib/python3.11/dist-
packages (from kagglehub) (2.31.0)
Requirement already satisfied: tqdm in /usr/local/lib/python3.11/dist-packages
(from kagglehub) (4.67.1)
Requirement already satisfied: charset-normalizer<4,>=2 in
```

```
/usr/local/lib/python3.11/dist-packages (from requests->kagglehub) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.11/dist-
packages (from requests->kagglehub) (3.6)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.11/dist-packages (from requests->kagglehub) (2.2.1)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.11/dist-packages (from requests->kagglehub) (2024.2.2)
WARNING: Running pip as the 'root' user can result in broken permissions
and conflicting behaviour with the system package manager. It is recommended to
use a virtual environment instead: https://pip.pypa.io/warnings/venv

[notice] A new release of pip is
available: 24.0 -> 25.0.1
[notice] To update, run:
python3 -m pip install --upgrade pip
Requirement already satisfied: kagglehub[pandas-datasets] in
/usr/local/lib/python3.11/dist-packages (0.3.11)
Requirement already satisfied: packaging in /usr/local/lib/python3.11/dist-
packages (from kagglehub[pandas-datasets]) (23.2)
Requirement already satisfied: pyyaml in /usr/local/lib/python3.11/dist-packages
(from kagglehub[pandas-datasets]) (6.0.2)
Requirement already satisfied: requests in /usr/local/lib/python3.11/dist-
packages (from kagglehub[pandas-datasets]) (2.31.0)
Requirement already satisfied: tqdm in /usr/local/lib/python3.11/dist-packages
(from kagglehub[pandas-datasets]) (4.67.1)
Requirement already satisfied: pandas in /usr/local/lib/python3.11/dist-packages
(from kagglehub[pandas-datasets]) (2.2.3)
Requirement already satisfied: numpy>=1.23.2 in /usr/local/lib/python3.11/dist-
packages (from pandas->kagglehub[pandas-datasets]) (1.26.4)
Requirement already satisfied: python-dateutil>=2.8.2 in
/usr/local/lib/python3.11/dist-packages (from pandas->kagglehub[pandas-
datasets]) (2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.11/dist-
packages (from pandas->kagglehub[pandas-datasets]) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in /usr/local/lib/python3.11/dist-
packages (from pandas->kagglehub[pandas-datasets]) (2025.2)
Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/lib/python3.11/dist-packages (from requests->kagglehub[pandas-
datasets]) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.11/dist-
packages (from requests->kagglehub[pandas-datasets]) (3.6)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.11/dist-packages (from requests->kagglehub[pandas-
datasets]) (2.2.1)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.11/dist-packages (from requests->kagglehub[pandas-
```

```
datasets]) (2024.2.2)
Requirement already satisfied: six>=1.5 in /usr/lib/python3/dist-packages (from
python-dateutil>=2.8.2->pandas->kagglehub[pandas-datasets]) (1.16.0)
WARNING: Running pip as the 'root' user can result in broken permissions
and conflicting behaviour with the system package manager. It is recommended to
use a virtual environment instead: https://pip.pypa.io/warnings/venv

[notice] A new release of pip is
available: 24.0 -> 25.0.1
[notice] To update, run:
python3 -m pip install --upgrade pip
Requirement already satisfied: wget in /usr/local/lib/python3.11/dist-packages
(3.2)
WARNING: Running pip as the 'root' user can result in broken permissions
and conflicting behaviour with the system package manager. It is recommended to
use a virtual environment instead: https://pip.pypa.io/warnings/venv

[notice] A new release of pip is
available: 24.0 -> 25.0.1
[notice] To update, run:
python3 -m pip install --upgrade pip
Requirement already satisfied: keras-tuner in /usr/local/lib/python3.11/dist-
packages (1.4.7)
Requirement already satisfied: keras in /usr/local/lib/python3.11/dist-packages
(from keras-tuner) (3.0.5)
Requirement already satisfied: packaging in /usr/local/lib/python3.11/dist-
packages (from keras-tuner) (23.2)
Requirement already satisfied: requests in /usr/local/lib/python3.11/dist-
packages (from keras-tuner) (2.31.0)
Requirement already satisfied: kt-legacy in /usr/local/lib/python3.11/dist-
packages (from keras-tuner) (1.0.5)
Requirement already satisfied: absl-py in /usr/local/lib/python3.11/dist-
packages (from keras->keras-tuner) (2.1.0)
Requirement already satisfied: numpy in /usr/local/lib/python3.11/dist-packages
(from keras->keras-tuner) (1.26.4)
Requirement already satisfied: rich in /usr/local/lib/python3.11/dist-packages
(from keras->keras-tuner) (13.7.1)
Requirement already satisfied: namex in /usr/local/lib/python3.11/dist-packages
(from keras->keras-tuner) (0.0.7)
Requirement already satisfied: h5py in /usr/local/lib/python3.11/dist-packages
(from keras->keras-tuner) (3.10.0)
Requirement already satisfied: dm-tree in /usr/local/lib/python3.11/dist-
packages (from keras->keras-tuner) (0.1.8)
Requirement already satisfied: ml-dtypes in /usr/local/lib/python3.11/dist-
```

```
packages (from keras->keras-tuner) (0.3.2)
Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/lib/python3.11/dist-packages (from requests->keras-tuner) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.11/dist-
packages (from requests->keras-tuner) (3.6)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.11/dist-packages (from requests->keras-tuner) (2.2.1)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.11/dist-packages (from requests->keras-tuner) (2024.2.2)
Requirement already satisfied: markdown-it-py>=2.2.0 in
/usr/local/lib/python3.11/dist-packages (from rich->keras->keras-tuner) (3.0.0)
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in
/usr/local/lib/python3.11/dist-packages (from rich->keras->keras-tuner) (2.17.2)
Requirement already satisfied: mdurl~=0.1 in /usr/local/lib/python3.11/dist-
packages (from markdown-it-py>=2.2.0->rich->keras->keras-tuner) (0.1.2)
WARNING: Running pip as the 'root' user can result in broken permissions
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[notice] A new release of pip is
available: 24.0 -> 25.0.1
[notice] To update, run:
python3 -m pip install --upgrade pip
Requirement already satisfied: seaborn in /usr/local/lib/python3.11/dist-
packages (0.13.2)
Requirement already satisfied: numpy!=1.24.0,>=1.20 in
/usr/local/lib/python3.11/dist-packages (from seaborn) (1.26.4)
Requirement already satisfied: pandas>=1.2 in /usr/local/lib/python3.11/dist-
packages (from seaborn) (2.2.3)
Requirement already satisfied: matplotlib!=3.6.1,>=3.4 in
/usr/local/lib/python3.11/dist-packages (from seaborn) (3.10.1)
Requirement already satisfied: contourpy>=1.0.1 in
/usr/local/lib/python3.11/dist-packages (from matplotlib!=3.6.1,>=3.4->seaborn)
(1.3.1)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.11/dist-
packages (from matplotlib!=3.6.1,>=3.4->seaborn) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in
/usr/local/lib/python3.11/dist-packages (from matplotlib!=3.6.1,>=3.4->seaborn)
(4.57.0)
Requirement already satisfied: kiwisolver>=1.3.1 in
/usr/local/lib/python3.11/dist-packages (from matplotlib!=3.6.1,>=3.4->seaborn)
(1.4.8)
Requirement already satisfied: packaging>=20.0 in
/usr/local/lib/python3.11/dist-packages (from matplotlib!=3.6.1,>=3.4->seaborn)
(23.2)
Requirement already satisfied: pillow>=8 in /usr/local/lib/python3.11/dist-
```

```
packages (from matplotlib!=3.6.1,>=3.4->seaborn) (11.1.0)
Requirement already satisfied: pyparsing>=2.3.1 in /usr/lib/python3/dist-
packages (from matplotlib!=3.6.1,>=3.4->seaborn) (2.4.7)
Requirement already satisfied: python-dateutil>=2.7 in
/usr/local/lib/python3.11/dist-packages (from matplotlib!=3.6.1,>=3.4->seaborn)
(2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.11/dist-
packages (from pandas>=1.2->seaborn) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in /usr/local/lib/python3.11/dist-
packages (from pandas>=1.2->seaborn) (2025.2)
Requirement already satisfied: six>=1.5 in /usr/lib/python3/dist-packages (from
python-dateutil>=2.7->matplotlib!=3.6.1,>=3.4->seaborn) (1.16.0)
WARNING: Running pip as the 'root' user can result in broken permissions

and conflicting behaviour with the system package manager. It is recommended to

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[notice] A new release of pip is
available: 24.0 -> 25.0.1
[notice] To update, run:
python3 -m pip install --upgrade pip
Requirement already satisfied: opencv-python in /usr/local/lib/python3.11/dist-
packages (4.11.0.86)
Requirement already satisfied: numpy>=1.21.2 in /usr/local/lib/python3.11/dist-
packages (from opencv-python) (1.26.4)
WARNING: Running pip as the 'root' user can result in broken permissions

and conflicting behaviour with the system package manager. It is recommended to

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[notice] A new release of pip is
available: 24.0 -> 25.0.1
[notice] To update, run:
python3 -m pip install --upgrade pip
Requirement already satisfied: scikit-learn in /usr/local/lib/python3.11/dist-
packages (1.6.1)
Requirement already satisfied: numpy>=1.19.5 in /usr/local/lib/python3.11/dist-
packages (from scikit-learn) (1.26.4)
Requirement already satisfied: scipy>=1.6.0 in /usr/local/lib/python3.11/dist-
packages (from scikit-learn) (1.15.2)
Requirement already satisfied: joblib>=1.2.0 in /usr/local/lib/python3.11/dist-
packages (from scikit-learn) (1.4.2)
Requirement already satisfied: threadpoolctl>=3.1.0 in
/usr/local/lib/python3.11/dist-packages (from scikit-learn) (3.6.0)
```

```
WARNING: Running pip as the 'root' user can result in broken permissions
and conflicting behaviour with the system package manager. It is recommended to
use a virtual environment instead: https://pip.pypa.io/warnings/venv

[notice] A new release of pip is
available: 24.0 -> 25.0.1
[notice] To update, run:
python3 -m pip install --upgrade pip
Requirement already satisfied: fastparquet in /usr/local/lib/python3.11/dist-
packages (2024.11.0)
Requirement already satisfied: pandas>=1.5.0 in /usr/local/lib/python3.11/dist-
packages (from fastparquet) (2.2.3)
Requirement already satisfied: numpy in /usr/local/lib/python3.11/dist-packages
(from fastparquet) (1.26.4)
Requirement already satisfied: cramjam>=2.3 in /usr/local/lib/python3.11/dist-
packages (from fastparquet) (2.10.0)
Requirement already satisfied: fsspec in /usr/local/lib/python3.11/dist-packages
(from fastparquet) (2025.3.2)
Requirement already satisfied: packaging in /usr/local/lib/python3.11/dist-
packages (from fastparquet) (23.2)
Requirement already satisfied: python-dateutil>=2.8.2 in
/usr/local/lib/python3.11/dist-packages (from pandas>=1.5.0->fastparquet)
(2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.11/dist-
packages (from pandas>=1.5.0->fastparquet) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in /usr/local/lib/python3.11/dist-
packages (from pandas>=1.5.0->fastparquet) (2025.2)
Requirement already satisfied: six>=1.5 in /usr/lib/python3/dist-packages (from
python-dateutil>=2.8.2->pandas>=1.5.0->fastparquet) (1.16.0)
WARNING: Running pip as the 'root' user can result in broken permissions
and conflicting behaviour with the system package manager. It is recommended to
use a virtual environment instead: https://pip.pypa.io/warnings/venv

[notice] A new release of pip is
available: 24.0 -> 25.0.1
[notice] To update, run:
python3 -m pip install --upgrade pip
```

0.0.1 Load Libraries

[321]:
```
import os
import json
import zipfile
import seaborn as sns
```

```
import numpy as np
import kagglehub
from kagglehub import KaggleDatasetAdapter
import pandas as pd
import matplotlib.pyplot as plt
import cv2
import urllib.request

import tensorflow as tf
from sklearn.preprocessing import StandardScaler, LabelEncoder
from sklearn.model_selection import train_test_split
from sklearn.utils.class_weight import compute_class_weight
from tensorflow.keras import layers, models, Input, Model, Sequential
from tensorflow.keras.applications import DenseNet121
from tensorflow.keras.optimizers import Adam
from kerastuner import HyperModel
from kerastuner.tuners import RandomSearch
from tensorflow.keras.regularizers import l2  # <-- MISSING IMPORT
```

[322]:
```
# from google.colab import drive
# drive.mount('/content/drive')
```

[323]:
```
!cd /workspace/chest
!mkdir -p /workspace/chest/drive/MyDrive/AAI-590_Collabs
```

[324]:
```
# Global flags
SKIP_BOUNDING_BOX = True
SKIP_DOWNLOAD = False
SKIP_UNZIP = False

ROOT_PATH = "/workspace/chest"
# ROOT_PATH = "/content"

DRIVE_PATH = ROOT_PATH + "/drive/MyDrive/AAI-590_Collabs"
RESIZED_IMAGES_ZIP_PATH = ROOT_PATH + "/drive/MyDrive/AAI-590_Collabs"
RESIZED_IMAGES_ZIP_PATH = ROOT_PATH
RESIZED_IMAGES_PATH = ROOT_PATH + "/images_resized/images_resized";
```

[325]:
```
SKIP_DOWNLOAD = os.path.exists(RESIZED_IMAGES_ZIP_PATH)
SKIP_UNZIP = os.path.exists(RESIZED_IMAGES_PATH)
```

[326]:
```
# print current variables
print("SKIP_DOWNLOAD: ", SKIP_DOWNLOAD)
print("SKIP_UNZIP: ", SKIP_UNZIP)
```

```
SKIP_DOWNLOAD:  True
SKIP_UNZIP:  True
```

0.0.2 Load Dataset

[327]:
```
# Set the dataset path
dataset_name = "nih-chest-xrays/data"
version = 3
# Set the path to the file you'd like to load
file_path = "Data_Entry_2017.csv"
file_path_bbox = "BBox_List_2017.csv"

gcloud_url_base = 'https://storage.googleapis.com/
 ↪gcs-public-data--healthcare-nih-chest-xray/png/'
```

[328]:
```
# Load the latest version
df = kagglehub.load_dataset(
  KaggleDatasetAdapter.PANDAS,
  dataset_name,
  file_path,
  # Provide any additional arguments like
  # sql_query or pandas_kwargs. See the
  # documenation for more information:
  # https://github.com/Kaggle/kagglehub/blob/main/README.
 ↪md#kaggledatasetadapterpandas
)

df_box_list = kagglehub.load_dataset(
  KaggleDatasetAdapter.PANDAS,
  dataset_name,
  file_path_bbox
)
```

```
/tmp/ipykernel_617090/2090411782.py:2: DeprecationWarning: load_dataset is
deprecated and will be removed in future version.
  df = kagglehub.load_dataset(
/tmp/ipykernel_617090/2090411782.py:12: DeprecationWarning: load_dataset is
deprecated and will be removed in future version.
  df_box_list = kagglehub.load_dataset(
```

[329]:
```
print(df['View Position'].value_counts())
```

```
View Position
PA    67310
AP    44810
Name: count, dtype: int64
```

[330]:
```
# keep orignal dataframe for reference
df_locked = df.copy()
```

[331]:
```
links = [
    "https://nihcc.box.com/shared/static/vfk49d74nhbxq3nqjg0900w5nvkorp5c.gz",
    "https://nihcc.box.com/shared/static/i28rlmbvmfjbl8p2n3ril0pptcmcu9d1.gz",
    "https://nihcc.box.com/shared/static/f1t00wrtdk94satdfb9olcolqx20z2jp.gz",
    "https://nihcc.box.com/shared/static/0aowwzs5lhjrceb3qp67ahp0rd1l1etg.gz",
    "https://nihcc.box.com/shared/static/v5e3goj22zr6h8tzualxfsqlqaygfbsn.gz",
    "https://nihcc.box.com/shared/static/asi7ikud9jwnkrnkj99jnpfkjdes7l6l.gz",
    "https://nihcc.box.com/shared/static/jn1b4mw4n6lnh74ovmcjb8y48h8xj07n.gz",
    "https://nihcc.box.com/shared/static/tvpxmn7qyrgl0w8wfh9kqfjskv6nmm1j.gz",
    "https://nihcc.box.com/shared/static/upyy3ml7qdumlgk2rfcvlb9k6gvqq2pj.gz",
    "https://nihcc.box.com/shared/static/l6nilvfa9cg3s28tqv1qc1olm3gnz54p.gz",
    "https://nihcc.box.com/shared/static/hhq8fkdgvcari67vfhs7ppg2w6ni4jze.gz",
    "https://nihcc.box.com/shared/static/ioqwiy20ihqwyr8pf4c24eazhh281pbu.gz",
]
```

[332]:
```
# Create a dictionary for folder locations
folder_ranges = {
    "images_001": (0, 4998),  # Adjusted to 0-based index
    "images_002": (4999, 14998),
    "images_003": (14999, 24998),
    "images_004": (24999, 34998),
    "images_005": (34999, 44998),
    "images_006": (44999, 54998),
    "images_007": (54999, 64998),
    "images_008": (64999, 74998),
    "images_009": (74999, 84998),
    "images_010": (84999, 94998),
    "images_011": (94999, 104998),
    "images_012": (104999, 112120)
}

def get_image_folder(df, image_name):
    if image_name in df["Image Index"].values:
        image_index = df[df["Image Index"] == image_name].index[0]  # Get row␣
 ↪index
        # print(f"Image {image_name} is at index {image_index}")  # Debugging␣
 ↪output

        for folder, (start, end) in folder_ranges.items():
            if start <= image_index <= end:
                return folder

    return None  # If not found
```

0.1 Data Cleaning

0.2 Remove all where "View Position" column value is "AP"

AP means "anteroposterior dimension" which is an X-ray from front-to-back This wil affect the training with both back-to-front and front-to-back images of MRIs

[333]:
```
# Entries before removal
print(f"Before 'AP' removal: {df['View Position'].value_counts()}")

# Entries after removal
df = df[df['View Position'] != 'AP']

# Remaining data is 66.57% of total initial data
print(f"After 'AP' removal: {df['View Position'].value_counts()}")
```

```
Before 'AP' removal: View Position
PA    67310
AP    44810
Name: count, dtype: int64
After 'AP' removal: View Position
PA    67310
Name: count, dtype: int64
```

[334]:
```
display(df.head())
display(df.tail())
display(df.columns)
```

```
        Image Index          Finding Labels  Follow-up #  Patient ID  \
0  00000001_000.png            Cardiomegaly            0           1
1  00000001_001.png  Cardiomegaly|Emphysema            1           1
2  00000001_002.png   Cardiomegaly|Effusion            2           1
3  00000002_000.png              No Finding            0           2
4  00000003_000.png                  Hernia            0           3

   Patient Age Patient Gender View Position  OriginalImage[Width  Height]  \
0           58              M            PA                 2682     2749
1           58              M            PA                 2894     2729
2           58              M            PA                 2500     2048
3           81              M            PA                 2500     2048
4           81              F            PA                 2582     2991

   OriginalImagePixelSpacing[x     y]  Unnamed: 11
0                        0.143  0.143          NaN
1                        0.143  0.143          NaN
2                        0.168  0.168          NaN
3                        0.171  0.171          NaN
4                        0.143  0.143          NaN

             Image Index  Finding Labels  Follow-up #  Patient ID  \
```

```
112115  00030801_001.png  Mass|Pneumonia            1       30801
112116  00030802_000.png       No Finding           0       30802
112117  00030803_000.png       No Finding           0       30803
112118  00030804_000.png       No Finding           0       30804
112119  00030805_000.png       No Finding           0       30805

        Patient Age Patient Gender View Position  OriginalImage[Width  \
112115           39              M            PA                 2048
112116           29              M            PA                 2048
112117           42              F            PA                 2048
112118           30              F            PA                 2048
112119           27              M            PA                 2048

        Height]  OriginalImagePixelSpacing[x     y]  Unnamed: 11
112115     2500                         0.168  0.168          NaN
112116     2500                         0.168  0.168          NaN
112117     2500                         0.168  0.168          NaN
112118     2500                         0.168  0.168          NaN
112119     2500                         0.171  0.171          NaN
```

```
Index(['Image Index', 'Finding Labels', 'Follow-up #', 'Patient ID',
       'Patient Age', 'Patient Gender', 'View Position', 'OriginalImage[Width',
       'Height]', 'OriginalImagePixelSpacing[x', 'y]', 'Unnamed: 11'],
      dtype='object')
```

0.2.1 We want to have 7 generalized classes from the original 15

Take values from "Finding Labels" and convert them into more generalized labels

[335]:
```python
# Create a list to store all unique labels
all_labels = []

# Iterate over the 'Finding Labels' column
for index, row in df.iterrows():
    labels = row['Finding Labels'].split('|')
    for label in labels:
        all_labels.append(label)

# Get unique labels and print them
all_labels = list(set(all_labels))
print(f"All possible options in 'Finding Labels': {all_labels}")
```

```
All possible options in 'Finding Labels': ['Pneumonia', 'Hernia',
'Cardiomegaly', 'Atelectasis', 'Nodule', 'Fibrosis', 'Consolidation', 'Mass',
'Pneumothorax', 'Pleural_Thickening', 'Edema', 'Emphysema', 'Effusion', 'No
Finding', 'Infiltration']
```

[336]:
```python
category_map = {
```

```
    'Infection/Infiltration': ['has_Pneumonia', 'has_Consolidation',␣
 ↪'has_Infiltration'],
    'Fluid Related Issues': ['has_Edema', 'has_Effusion',␣
 ↪'has_Pleural_Thickening'],
    'Lung Structure Issues': ['has_Atelectasis', 'has_Pneumothorax',␣
 ↪'has_Fibrosis', 'has_Emphysema'],
    'Nodule/Mass': ['has_Nodule', 'has_Mass'],
    'Cardiac Issues': ['has_Cardiomegaly'],
    'Hernia': ['has_Hernia'],
    'No Finding': ['has_No Finding']
}

def generalize_labels(label):
    if label in ['Pneumonia', 'Consolidation', 'Infiltration']:
        return 'Infection/Infiltration'
    elif label in ['Edema', 'Effusion', 'Pleural_Thickening']:
        return 'Fluid Related Issues'
    elif label in ['Atelectasis', 'Pneumothorax', 'Fibrosis', 'Emphysema']:
        return 'Lung Structure Issues'
    elif label in ['Nodule', 'Mass']:
        return 'Nodule/Mass'
    elif label == 'Cardiomegaly':
        return 'Cardiac Issues'
    elif label == 'Hernia':
        return 'Hernia'
    else:
        return label  # If we don't detect an issue 'No Finding'


categories = category_map.keys()
df['Finding Labels'] = df['Finding Labels'].apply(lambda x: '|'.
 ↪join([generalize_labels(label) for label in x.split('|')]))

# Example:
display(df.head()) # View the updated DataFrame
```

```
       Image Index                         Finding Labels  Follow-up #  \
0  00000001_000.png                         Cardiac Issues            0
1  00000001_001.png  Cardiac Issues|Lung Structure Issues            1
2  00000001_002.png   Cardiac Issues|Fluid Related Issues            2
3  00000002_000.png                             No Finding            0
4  00000003_000.png                                 Hernia            0

   Patient ID  Patient Age Patient Gender View Position  OriginalImage[Width  \
0           1           58              M            PA                 2682
1           1           58              M            PA                 2894
2           1           58              M            PA                 2500
```

```
3           2           81              M            PA                  2500
4           3           81              F            PA                  2582

   Height]  OriginalImagePixelSpacing[x     y]  Unnamed: 11
0     2749                         0.143  0.143          NaN
1     2729                         0.143  0.143          NaN
2     2048                         0.168  0.168          NaN
3     2048                         0.171  0.171          NaN
4     2991                         0.143  0.143          NaN
```

[337]:
```
display(df.head())
display(df.tail())
display(df.columns)
```

```
       Image Index                         Finding Labels  Follow-up #  \
0  00000001_000.png                         Cardiac Issues            0
1  00000001_001.png  Cardiac Issues|Lung Structure Issues            1
2  00000001_002.png   Cardiac Issues|Fluid Related Issues            2
3  00000002_000.png                           No Finding            0
4  00000003_000.png                               Hernia            0

   Patient ID  Patient Age Patient Gender View Position  OriginalImage[Width  \
0           1           58              M            PA                 2682
1           1           58              M            PA                 2894
2           1           58              M            PA                 2500
3           2           81              M            PA                 2500
4           3           81              F            PA                 2582

   Height]  OriginalImagePixelSpacing[x     y]  Unnamed: 11
0     2749                         0.143  0.143          NaN
1     2729                         0.143  0.143          NaN
2     2048                         0.168  0.168          NaN
3     2048                         0.171  0.171          NaN
4     2991                         0.143  0.143          NaN

            Image Index                       Finding Labels  Follow-up #  \
112115  00030801_001.png  Nodule/Mass|Infection/Infiltration            1
112116  00030802_000.png                           No Finding            0
112117  00030803_000.png                           No Finding            0
112118  00030804_000.png                           No Finding            0
112119  00030805_000.png                           No Finding            0

        Patient ID  Patient Age Patient Gender View Position  \
112115       30801           39              M            PA
112116       30802           29              M            PA
112117       30803           42              F            PA
112118       30804           30              F            PA
112119       30805           27              M            PA
```

```
        OriginalImage[Width  Height]  OriginalImagePixelSpacing[x     y]  \
112115                 2048     2500                         0.168  0.168
112116                 2048     2500                         0.168  0.168
112117                 2048     2500                         0.168  0.168
112118                 2048     2500                         0.168  0.168
112119                 2048     2500                         0.171  0.171

        Unnamed: 11
112115          NaN
112116          NaN
112117          NaN
112118          NaN
112119          NaN
```

```
Index(['Image Index', 'Finding Labels', 'Follow-up #', 'Patient ID',
       'Patient Age', 'Patient Gender', 'View Position', 'OriginalImage[Width',
       'Height]', 'OriginalImagePixelSpacing[x', 'y]', 'Unnamed: 11'],
      dtype='object')
```

[338]:
```
display(df.describe())
display(df.info())
```

```
        Follow-up #    Patient ID   Patient Age  OriginalImage[Width  \
count  67310.000000  67310.000000  67310.000000         67310.000000
mean       4.786317  14396.542802     47.352979          2632.590016
std        9.403191   8559.885944     16.289550           374.573816
min        0.000000      1.000000      1.000000          1143.000000
25%        0.000000   7157.250000     36.000000          2500.000000
50%        1.000000  14112.000000     49.000000          2678.000000
75%        5.000000  21117.750000     59.000000          2992.000000
max      156.000000  30805.000000    412.000000          3056.000000

            Height]  OriginalImagePixelSpacing[x            y]  Unnamed: 11
count  67310.000000                  67310.000000  67310.000000          0.0
mean    2652.208468                      0.153868      0.153868          NaN
std      396.607849                      0.017179      0.017179          NaN
min     1001.000000                      0.115000      0.115000          NaN
25%     2411.000000                      0.143000      0.143000          NaN
50%     2885.000000                      0.143000      0.143000          NaN
75%     2991.000000                      0.168000      0.168000          NaN
max     3056.000000                      0.194336      0.194336          NaN
```

```
<class 'pandas.core.frame.DataFrame'>
Index: 67310 entries, 0 to 112119
Data columns (total 12 columns):
 #   Column                      Non-Null Count  Dtype
---  ------                      --------------  -----
 0   Image Index                 67310 non-null  object
 1   Finding Labels              67310 non-null  object
```

```
 2   Follow-up #                  67310 non-null  int64
 3   Patient ID                   67310 non-null  int64
 4   Patient Age                  67310 non-null  int64
 5   Patient Gender               67310 non-null  object
 6   View Position                67310 non-null  object
 7   OriginalImage[Width          67310 non-null  int64
 8   Height]                      67310 non-null  int64
 9   OriginalImagePixelSpacing[x  67310 non-null  float64
 10  y]                           67310 non-null  float64
 11  Unnamed: 11                  0 non-null      float64
dtypes: float64(3), int64(5), object(4)
memory usage: 6.7+ MB
```

None

0.3 Pre-processing

---

[339]:
```
# Reduce rows with 'No Finding' label to a maximum of 10,000
no_finding_df = df[df['Finding Labels'] == 'No Finding']
if len(no_finding_df) > 10000:
    no_finding_df = no_finding_df.sample(n=10000, random_state=42)  # Randomly␣
 ↪sample 10,000 rows

# Concatenate the reduced 'No Finding' rows with other rows
other_findings_df = df[df['Finding Labels'] != 'No Finding']
df = pd.concat([no_finding_df, other_findings_df], ignore_index=True)

display(len(df))
```

38008

[340]:
```
# Rename columns
df = df.rename(columns={
    "OriginalImage[Width": "width",
    "Height]": "height",
    "OriginalImagePixelSpacing[x": "pixel_spacing x",
    "y]": "pixel_spacing y"
})

display(df.head())
```

```
        Image Index Finding Labels  Follow-up #  Patient ID  Patient Age  \
0  00019856_000.png     No Finding            0       19856           57
1  00001020_000.png     No Finding            0        1020           52
2  00008187_001.png     No Finding            1        8187           59
3  00003360_003.png     No Finding            3        3360            8
4  00014364_000.png     No Finding            0       14364           26
```

```
  Patient Gender View Position  width  height  pixel_spacing x  \
0              M            PA   2992    2991            0.143
1              M            PA   2500    2048            0.171
2              M            PA   2500    2048            0.168
3              M            PA   2048    2500            0.168
4              F            PA   2454    2991            0.143

   pixel_spacing y  Unnamed: 11
0            0.143          NaN
1            0.171          NaN
2            0.168          NaN
3            0.168          NaN
4            0.143          NaN
```

[341]:
```
# drop columns that will not be used for traning, except Patient ID that will␣
 ↪be used for patient-level split
df = df.drop(columns=['Unnamed: 11', 'width', 'height', 'View Position',␣
 ↪'pixel_spacing x', 'pixel_spacing y'], errors='ignore')
```

Encode Tabular Labels

[342]:
```
# Extract each label to a separate boolean column
for label in categories:
  df[f'has_{label}'] = df['Finding Labels'].str.contains(label)
  # encode to 0 and 1
  df[f'has_{label}'] = df[f'has_{label}'].astype(int)

df = df.drop(columns=['Finding Labels'], errors='ignore')
display(df.head())
```

```
        Image Index  Follow-up #  Patient ID  Patient Age Patient Gender  \
0  00019856_000.png            0       19856           57              M
1  00001020_000.png            0        1020           52              M
2  00008187_001.png            1        8187           59              M
3  00003360_003.png            3        3360            8              M
4  00014364_000.png            0       14364           26              F

   has_Infection/Infiltration  has_Fluid Related Issues  \
0                           0                         0
1                           0                         0
2                           0                         0
3                           0                         0
4                           0                         0

   has_Lung Structure Issues  has_Nodule/Mass  has_Cardiac Issues  has_Hernia  \
0                          0                0                   0           0
1                          0                0                   0           0
2                          0                0                   0           0
```

```
3                          0                 0                    0           0
4                          0                 0                    0           0

   has_No Finding
0               1
1               1
2               1
3               1
4               1
```

[343]:
```
# Encode gender (e.g., Male/Female -> 0/1)
df['Patient Gender'] = LabelEncoder().fit_transform(df['Patient Gender'])

# Standardize numerical features
scaler = StandardScaler()
df['Patient Age'] = scaler.fit_transform(df[['Patient Age']])
df['Follow-up #'] = scaler.fit_transform(df[['Follow-up #']])

display(df.head())
```

```
        Image Index  Follow-up #  Patient ID  Patient Age  Patient Gender  \
0  00019856_000.png    -0.552742       19856     0.525833               1
1  00001020_000.png    -0.552742        1020     0.215450               1
2  00008187_001.png    -0.457542        8187     0.649986               1
3  00003360_003.png    -0.267142        3360    -2.515918               1
4  00014364_000.png    -0.552742       14364    -1.398540               0

   has_Infection/Infiltration  has_Fluid Related Issues  \
0                           0                         0
1                           0                         0
2                           0                         0
3                           0                         0
4                           0                         0

   has_Lung Structure Issues  has_Nodule/Mass  has_Cardiac Issues  has_Hernia  \
0                          0                0                   0           0
1                          0                0                   0           0
2                          0                0                   0           0
3                          0                0                   0           0
4                          0                0                   0           0

   has_No Finding
0               1
1               1
2               1
3               1
4               1
```

0.3.1 Retrieive Images

[344]:
```
import os
import tarfile
import urllib.request

def download_and_extract(links, folder_ranges, df_locked):
    """Downloads image archives, extracts them, and organizes images."""

    if not os.path.exists("images"):
        os.makedirs("images")

    for i, link in enumerate(links):
        folder_name = f"images_{i+1:03d}"
        archive_name = f"{folder_name}.tar.gz"

        if not os.path.exists(os.path.join("images", archive_name)): #check if␣
↪the archive already exists to prevent unnecessary downloads
          print(f"Downloading {archive_name}...")
          urllib.request.urlretrieve(link, archive_name)
        else:
          print(f"Skipping download for {archive_name} as file already exists")


        try:
            print(f"Extracting {archive_name}...")
            with tarfile.open(archive_name, "r:gz") as tar:
                tar.extractall()
            print("Extraction complete.")
        except Exception as e:
            print(f"Error extracting {archive_name}: {e}")
            continue  # Skip to the next archive if extraction fails

        # Move extracted images to the 'images' folder
        source_folder = folder_name
        if os.path.exists(source_folder):
          extracted_files = os.listdir(source_folder)
          for file in extracted_files:
            source_file = os.path.join(source_folder, file)
            destination_file = os.path.join("images", file)
            try:
              os.rename(source_file, destination_file)
            except FileExistsError:
              print(f"File {file} already exists in images folder, skipping")

          os.rmdir(source_folder)
        else:
```

```
            print(f"Folder {source_folder} doesn't exist")


        # Remove the archive file
        try:
            os.remove(archive_name)
            print(f"Removed {archive_name}")
        except OSError as e:
            print(f"Error removing {archive_name}: {e}")

if SKIP_DOWNLOAD == False:
  download_and_extract(links, folder_ranges, df_locked)
```

[345]:
```
if SKIP_DOWNLOAD == False:
  image_folder = 'images'
  num_images = len([f for f in os.listdir(image_folder) if os.path.isfile(os.
 ↪path.join(image_folder, f))])
  print(f"Number of images in '{image_folder}' folder: {num_images}")
```

[346]:
```
if SKIP_DOWNLOAD == False:
  image_folder = 'images'

  # Get a set of image names from the 'Image Index' column of the DataFrame
  image_names_in_df = set(df['Image Index'].unique())

  print(len(image_names_in_df))

  # Iterate through all files in the image folder
  for filename in os.listdir(image_folder):
      filepath = os.path.join(image_folder, filename)

      # Check if it's a file and not in the DataFrame's 'Image Index' column
      if os.path.isfile(filepath) and filename not in image_names_in_df:
          try:
              os.remove(filepath)
              print(f"Removed file: {filename}")
          except OSError as e:
              print(f"Error deleting file {filename}: {e}")
```

[347]:
```
image_folder = 'images'
def get_num_images(image_folder):
  num_images = len([f for f in os.listdir(image_folder) if os.path.isfile(os.
 ↪path.join(image_folder, f))])
  return num_images

if SKIP_DOWNLOAD == False:
```

```
  print(f"Number of images in '{image_folder}' folder:␣
 ↪{get_num_images(image_folder)}")
```

[348]:
```
if SKIP_DOWNLOAD == False:
  !python image_scale.py
```

[349]:
```
if SKIP_DOWNLOAD == False:
  !zip -r images_resized.zip images_resized
```

[350]:
```
if SKIP_DOWNLOAD == False:
  print(f"Number of images in 'images_resized' folder:␣
 ↪{get_num_images('images_resized')}")
```

[351]:
```
def zip_folder(folder_path, zip_filename):
  """Zips a folder.
  Args:
    folder_path: The path to the folder to zip.
    zip_filename: The name of the zip file to create.
  """

  # Create a zip archive
  with zipfile.ZipFile(zip_filename, 'w', zipfile.ZIP_DEFLATED) as zipf:
    for root, _, files in os.walk(folder_path):
      for file in files:
        zipf.write(os.path.join(root, file),
                   os.path.relpath(os.path.join(root, file),
                                   os.path.join(folder_path, '..')))
if SKIP_DOWNLOAD == False:
  zip_folder('images_resized', 'images_resized.zip')
```

[352]:
```
if SKIP_DOWNLOAD == False:
  !cp images_resized.zip {RESIZED_IMAGES_ZIP_PATH}
```

[353]:
```
import zipfile
import os

def unzip_files(zip_path, extract_path):
    """Unzips files from a zip archive to a specified directory.

    Args:
        zip_path: Path to the zip file.
        extract_path: Directory to extract the files to.
    """
    try:
        with zipfile.ZipFile(zip_path, 'r') as zip_ref:
            zip_ref.extractall(extract_path)
        print(f"Successfully unzipped '{zip_path}' to '{extract_path}'")
```

```
    except FileNotFoundError:
        print(f"Error: Zip file not found at '{zip_path}'")
    except zipfile.BadZipFile:
        print(f"Error: Invalid zip file at '{zip_path}'")
    except Exception as e:
        print(f"An unexpected error occurred: {e}")

# Assuming RESIZED_IMAGES_ZIP_PATH is defined and holds the correct path
if SKIP_UNZIP == False:
  unzip_files(RESIZED_IMAGES_ZIP_PATH + "/images_resized.zip", "images_resized")
```

[354]:
```
import glob
import random
from PIL import Image

def show_image_tiles(
        folder: str,
        pattern: str = "*.png",          # glob pattern: "*.jpg", "*.jpeg", etc.
        max_images: int | None = None,   # cap the number shown; None = all
        cols: int = 10,                  # how many tiles per row
        thumb_size: tuple[int, int] = (128, 128),  # resize for speed
        shuffle: bool = True,            # randomise order
        seed: int | None = 42            # reproducible shuffle
    ):
    """
    Display images from *folder* as a tiled grid.

    Parameters
    ----------
    folder : str
        Path to the directory containing images.
    pattern : str, default "*.png"
        Glob pattern to match files.
    max_images : int or None, default None
        Show at most this many images.
    cols : int, default 10
        Number of tiles per row.
    thumb_size : (int, int), default (128, 128)
        Target size for thumbnails (width, height).
    shuffle : bool, default True
        Shuffle file list before displaying.
    seed : int or None, default 42
        Seed for reproducible shuffling.
    """
    # ------------------------------------------------------------------ #
    # 1. Gather files
    # ------------------------------------------------------------------ #
```

```
    paths = glob.glob(os.path.join(folder, pattern))
    if not paths:
        raise FileNotFoundError(f"No files matching {pattern} in {folder}")

    if shuffle:
        rng = random.Random(seed)
        rng.shuffle(paths)

    if max_images:
        paths = paths[:max_images]

    n_imgs = len(paths)
    rows   = math.ceil(n_imgs / cols)

    # ---------------------------------------------------------------------- #
    # 2. Create the figure
    # ---------------------------------------------------------------------- #
    # scale figsize so that each thumbnail has ~thumb_size/64 inches
    w_inch = cols * thumb_size[0] / 64
    h_inch = rows * thumb_size[1] / 64
    fig, axes = plt.subplots(rows, cols,
                             figsize=(w_inch, h_inch),
                             squeeze=False)
    axes = axes.ravel()

    # ---------------------------------------------------------------------- #
    # 3. Plot each image
    # ---------------------------------------------------------------------- #
    for ax, path in zip(axes, paths):
        img = Image.open(path)
        img.thumbnail(thumb_size, Image.Resampling.LANCZOS)
        ax.imshow(img, cmap="gray" if img.mode == "L" else None)
        ax.set_title(os.path.basename(path), fontsize=6)
        ax.axis("off")

    # Hide any leftover axes
    for ax in axes[n_imgs:]:
        ax.axis("off")

    plt.tight_layout()
    plt.show()

# show_image_tiles(
#     folder="images_resized/images_resized",
#     pattern="*.png",
#     max_images=500,        # None = show everything
#     cols=12,               # 12 images per row
```

```
#     thumb_size=(96, 96)    # smaller thumbnails → faster
# )
```

Train / Tests Split

[355]:
```
# Perform train/validation split
def patient_level_split(df, test_val_size=0.2, test_size=0.5, random_state=42):
    patient_ids = df['Patient ID'].unique()

    train_ids, holdout_ids = train_test_split(
        patient_ids,
        test_size=test_val_size,          # 20% of patients will go to val+test
        random_state=random_state,
        shuffle=True
    )

    if test_size < 1.0:
        val_ids, test_ids = train_test_split(
            holdout_ids,
            test_size=test_size,          # half of the hold-out → test, half →␣
 ↪val
            random_state=random_state,
            shuffle=True
        )
    else:
        val_ids  = []
        test_ids = holdout_ids

    train_df = df[df['Patient ID'].isin(train_ids)].reset_index(drop=True)
    val_df   = df[df['Patient ID'].isin(val_ids)].reset_index(drop=True)
    test_df  = df[df['Patient ID'].isin(test_ids)].reset_index(drop=True)

    train_df = train_df.drop(columns=['Patient ID'], errors='ignore')
    val_df   = val_df.drop(columns=['Patient ID'], errors='ignore')
    test_df  = test_df.drop(columns=['Patient ID'], errors='ignore')

    return train_df, val_df, test_df


train_df, val_df, test_df = patient_level_split(df, test_val_size=0.2,␣
 ↪test_size=1.0, random_state=42)
print("Train size:", len(train_df))
print("Val size:", len(val_df))
print("Test size:", len(test_df))

display(train_df.head())
```

```
Train size: 30499
```

```
Val size: 0
Test size: 7509
```

	Image Index	Follow-up #	Patient Age	Patient Gender	has_Infection/Infiltration	has_Fluid Related Issues	has_Lung Structure Issues	has_Nodule/Mass	has_Cardiac Issues	has_Hernia	has_No Finding
0	00019856_000.png	-0.552742	0.525833	1	0	0	0	0	0	0	1
1	00001020_000.png	-0.552742	0.215450	1	0	0	0	0	0	0	1
2	00008187_001.png	-0.457542	0.649986	1	0	0	0	0	0	0	1
3	00014364_000.png	-0.552742	-1.398540	0	0	0	0	0	0	0	1
4	00003706_000.png	-0.552742	-0.032856	0	0	0	0	0	0	0	1

0.3.2 Multiple Task Training

[356]:
```
class_columns = [col for col in df.columns if col.startswith("has_")]
# Calculate class distribution for the test dataset (val_df in this case)
class_distribution = train_df[class_columns].sum()
print(class_columns)

# Print the class distribution
print("Class Distribution in the Test Dataset:")
class_distribution
```

```
['has_Infection/Infiltration', 'has_Fluid Related Issues', 'has_Lung Structure
Issues', 'has_Nodule/Mass', 'has_Cardiac Issues', 'has_Hernia', 'has_No
Finding']
Class Distribution in the Test Dataset:
```

[356]:
```
has_Infection/Infiltration    8789
has_Fluid Related Issues      6927
has_Lung Structure Issues     8668
has_Nodule/Mass               5711
has_Cardiac Issues            1246
has_Hernia                     154
has_No Finding                7994
dtype: int64
```

[357]:
```
def prepare_multitask_data(df, class_columns):
    prepared_dict = {}

    for task in class_columns:
        # Sample for positive cases of the current task
        positive_cases = df[df[task] == 1].sample(n=min(5000, df[task].sum()),␣
 ↪random_state=42)

        CONTRAST_TO_HEALTHY = False
        if CONTRAST_TO_HEALTHY:
            # all negative cases are healthy lungs
            negative_cases = df[df['has_No Finding']==1].
 ↪sample(n=len(positive_cases), random_state=42)
        else:
            # negative cases don't have the condition but may have other␣
 ↪conditions
            negative_cases = df[df[task] == 0].
 ↪sample(n=min(len(positive_cases), (df[task] == 0).sum()) , random_state=42)

        # preserve perfect balance
        if len(positive_cases) > len(negative_cases):
            positive_cases = positive_cases.sample(n=len(negative_cases))

        # Combine positive and negative cases
        current_task_data = pd.concat([positive_cases, negative_cases])
        prepared_dict[task] = current_task_data

    return prepared_dict


prepared_datasets = prepare_multitask_data(train_df, class_columns)
```

[358]:
```
display(prepared_datasets.keys())
```

```
dict_keys(['has_Infection/Infiltration', 'has_Fluid Related Issues', 'has_Lung␣
 ↪Structure Issues', 'has_Nodule/Mass', 'has_Cardiac Issues', 'has_Hernia',␣
 ↪'has_No Finding'])
```

[359]:
```
for task, df in prepared_datasets.items():
  display(f"Task: {task}")
  display(df.head())
  display(len(df))
```

'Task: has_Infection/Infiltration'

	Image Index	Follow-up #	Patient Age	Patient Gender	\
13264	00007735_033.png	2.588855	-1.088157	1	
17890	00013520_017.png	1.065656	-1.895152	1	
15011	00010186_000.png	-0.552742	1.270751	1	
27054	00025294_002.png	-0.362342	-2.143459	1	
28957	00028044_003.png	-0.267142	-1.274387	0	

	has_Infection/Infiltration	has_Fluid Related Issues	\
13264	1	0	
17890	1	0	
15011	1	0	
27054	1	1	
28957	1	0	

	has_Lung Structure Issues	has_Nodule/Mass	has_Cardiac Issues	\
13264	0	0	0	
17890	0	0	0	
15011	0	0	0	
27054	0	0	0	
28957	0	0	0	

	has_Hernia	has_No Finding
13264	0	0
17890	0	0
15011	0	0
27054	0	0
28957	0	0

10000

'Task: has_Fluid Related Issues'

	Image Index	Follow-up #	Patient Age	Patient Gender	\
30327	00030393_001.png	-0.457542	-0.405315	0	
19484	00015318_008.png	0.208857	1.829440	0	
25699	00022172_000.png	-0.552742	0.091297	1	
19925	00015895_026.png	1.922456	-1.026081	1	
15521	00010770_000.png	-0.552742	0.836216	0	

	has_Infection/Infiltration	has_Fluid Related Issues	\
30327	0	1	
19484	0	1	
25699	0	1	

```
19925                          0                         1
15521                          0                         1

       has_Lung Structure Issues  has_Nodule/Mass  has_Cardiac Issues  \
30327                          1                1                   0
19484                          1                0                   0
25699                          0                1                   0
19925                          1                0                   0
15521                          1                0                   1

       has_Hernia  has_No Finding
30327           0               0
19484           0               0
25699           0               0
19925           0               0
15521           0               0

10000

'Task: has_Lung Structure Issues'

           Image Index  Follow-up #  Patient Age  Patient Gender  \
17604  00013112_009.png     0.304057     0.153374               0
23876  00020085_006.png     0.018457     0.898292               1
20738  00016757_003.png    -0.267142     0.029220               0
13097  00007557_001.png    -0.457542     0.712062               1
9964   00002604_002.png    -0.362342    -1.646846               1

       has_Infection/Infiltration  has_Fluid Related Issues  \
17604                           0                         0
23876                           0                         1
20738                           0                         0
13097                           1                         0
9964                            0                         0

       has_Lung Structure Issues  has_Nodule/Mass  has_Cardiac Issues  \
17604                          1                0                   0
23876                          1                0                   0
20738                          1                1                   0
13097                          1                0                   0
9964                           1                0                   0

       has_Hernia  has_No Finding
17604           0               0
23876           0               0
20738           0               0
13097           0               0
9964            0               0

10000
```

'Task: has_Nodule/Mass'

	Image Index	Follow-up #	Patient Age	Patient Gender	\
15232	00010516_001.png	-0.457542	0.960369	0	
18152	00013814_003.png	-0.267142	1.332828	1	
10991	00004049_000.png	-0.552742	-0.591545	0	
29439	00028876_021.png	1.446456	-0.467392	1	
28695	00027652_009.png	0.304057	0.029220	1	

	has_Infection/Infiltration	has_Fluid Related Issues	\
15232	0	0	
18152	1	0	
10991	0	0	
29439	0	0	
28695	0	0	

	has_Lung Structure Issues	has_Nodule/Mass	has_Cardiac Issues	\
15232	0	1	0	
18152	0	1	0	
10991	0	1	0	
29439	1	1	0	
28695	0	1	0	

	has_Hernia	has_No Finding
15232	0	0
18152	0	0
10991	0	0
29439	0	0
28695	0	0

10000

'Task: has_Cardiac Issues'

	Image Index	Follow-up #	Patient Age	Patient Gender	\
19456	00015282_000.png	-0.552742	-0.839851	1	
13327	00007858_004.png	-0.171942	0.525833	0	
27795	00026338_003.png	-0.267142	-1.957229	1	
11714	00005266_001.png	-0.457542	-0.343239	0	
11650	00005090_000.png	-0.552742	0.339603	0	

	has_Infection/Infiltration	has_Fluid Related Issues	\
19456	0	0	
13327	0	0	
27795	1	0	
11714	0	0	
11650	0	0	

	has_Lung Structure Issues	has_Nodule/Mass	has_Cardiac Issues	\
19456	0	0	1	

```
13327                          0                0                    1
27795                          0                0                    1
11714                          0                0                    1
11650                          0                0                    1

       has_Hernia  has_No Finding
19456           0               0
13327           0               0
27795           0               0
11714           0               0
11650           0               0
```

2492

'Task: has_Hernia'

```
           Image Index  Follow-up #  Patient Age  Patient Gender  \
8382   00000385_000.png    -0.552742     1.332828               0
18299  00014005_000.png    -0.552742     1.394904               1
30311  00030310_000.png    -0.552742     1.643211               1
21968  00018120_000.png    -0.552742     1.146598               1
22776  00018999_001.png    -0.457542     0.960369               1

       has_Infection/Infiltration  has_Fluid Related Issues  \
8382                            1                         0
18299                           0                         0
30311                           0                         0
21968                           0                         0
22776                           0                         0

       has_Lung Structure Issues  has_Nodule/Mass  has_Cardiac Issues  \
8382                           0                0                   0
18299                          0                0                   0
30311                          0                1                   0
21968                          0                0                   0
22776                          1                1                   0

       has_Hernia  has_No Finding
8382            1               0
18299           1               0
30311           1               0
21968           1               0
22776           1               0
```

308

'Task: has_No Finding'

```
           Image Index  Follow-up #  Patient Age  Patient Gender  \
5487   00004026_000.png    -0.552742     1.643211               1
2577   00023215_000.png    -0.552742    -0.343239               0
```

```
3692  00012364_025.png     1.827256     0.215450              0
5918  00012697_008.png     0.208857     1.332828              1
7561  00000199_000.png    -0.552742     0.401680              0

      has_Infection/Infiltration  has_Fluid Related Issues  \
5487                           0                         0
2577                           0                         0
3692                           0                         0
5918                           0                         0
7561                           0                         0

      has_Lung Structure Issues  has_Nodule/Mass  has_Cardiac Issues  \
5487                          0                0                   0
2577                          0                0                   0
3692                          0                0                   0
5918                          0                0                   0
7561                          0                0                   0

      has_Hernia  has_No Finding
5487           0               1
2577           0               1
3692           0               1
5918           0               1
7561           0               1

10000
```

[360]:
```python
# Iterate through each prepared dataset and print class balances
for task, df in prepared_datasets.items():
    print(f"Class distribution for task {task}:")
    print(df[task].value_counts())
    print("-" * 20)
```

```
Class distribution for task has_Infection/Infiltration:
has_Infection/Infiltration
1    5000
0    5000
Name: count, dtype: int64
--------------------
Class distribution for task has_Fluid Related Issues:
has_Fluid Related Issues
1    5000
0    5000
Name: count, dtype: int64
--------------------
Class distribution for task has_Lung Structure Issues:
has_Lung Structure Issues
1    5000
0    5000
```

```
Name: count, dtype: int64
--------------------
Class distribution for task has_Nodule/Mass:
has_Nodule/Mass
1    5000
0    5000
Name: count, dtype: int64
--------------------
Class distribution for task has_Cardiac Issues:
has_Cardiac Issues
1    1246
0    1246
Name: count, dtype: int64
--------------------
Class distribution for task has_Hernia:
has_Hernia
1    154
0    154
Name: count, dtype: int64
--------------------
Class distribution for task has_No Finding:
has_No Finding
1    5000
0    5000
Name: count, dtype: int64
--------------------
```

[361]:
```python
IMG_SIZE = 512
IMG_SIZE = 480 # for EfficientNetV2L
# IMG_SIZE = 1024
# import tensorflow_addons.image as tfa_image

def preprocess_image(image_path):
    image = tf.io.read_file(image_path)
    image = tf.image.decode_png(image, channels=1)
    image = tf.image.resize(image, [IMG_SIZE, IMG_SIZE])
    # image = tf.cast(image, tf.float32) / 255.0 # EfficientNetV2 models expect␣
 ↪their inputs to be float tensors of pixels with values in the [0, 255]
    contrast_factor = 2.5
    image = tf.image.adjust_contrast(image, contrast_factor)

    return image

def augment(image):
    # return image
    """Data augmentation function for single-channel images."""
    image = tf.image.random_flip_left_right(image)
```

```
    image = tf.image.random_brightness(image, max_delta=0.2)
    image = tf.image.random_contrast(image, lower=0.8, upper=1.2)

    # Random Rotation (within a reasonable range for chest X-rays)
    factor = tf.random.uniform(shape=[], minval=-0.1, maxval=0.1) # Rotates by␣
 ↪+/- 0.1 * 2*pi radians
    # image = tf.image.rotate(image, factor) # error, doesn't exist
    # image = tfa_image.rotate(image, factor) # error, obsolete

    return image
```

[362]:
```
# ~ 128MB per batch (1GB=4 batch size)
BATCH_SIZE = 16 # RTX 4090 24GB 32 for cnn_v0
# BATCH_SIZE = 128 # 32 # H100 80GB 128 fits, 168 too much for cnn_v0 with␣
 ↪IMG_SIZE = 1024
# BATCH_SIZE = 64 # 32 # H100 80GB 64 fits, 96 too much for cnn_v1 with␣
 ↪IMG_SIZE = 1024
def create_tf_datasets(task_df, task, is_training=True):
    print(f"Creating {'training' if is_training else 'validation'} datasets for␣
 ↪task: {task}")

    image_paths = [os.path.join(RESIZED_IMAGES_PATH , image_name) for␣
 ↪image_name in task_df['Image Index']]
    tabular_data = task_df[['Follow-up #', 'Patient Age', 'Patient Gender']].
 ↪values
    target = task_df[task].values
    image_indices = task_df['Image Index'].astype(str).values       # keep as␣
 ↪strings
    image_indices = tf.zeros(
        shape=len(task_df['Image Index'].values),
        dtype=tf.float32  # or tf.float32 if needed
    )

    # DEBUG
    # display(task_df.columns)
    # display(task_df[task].head(5))
    # display(task_df[task].values)

    # Create tf.data.Dataset from image paths, tabular data, and targets
    dataset = tf.data.Dataset.from_tensor_slices((image_paths, tabular_data,␣
 ↪target, image_indices))

    # Load and preprocess images using the provided preprocess_image function
    def _load_and_preprocess(path, tab, label, idx):
        img = preprocess_image(path)          # your existing helper
        return img, tab, label, idx
```

```
    dataset = dataset.map(_load_and_preprocess,
                          num_parallel_calls=tf.data.AUTOTUNE)

    # Pack into the model-ready (inputs, label) tuple
    def _to_model_inputs(img, tab, label, idx):
        inputs = {
            "image_input":  img,
            "tabular_input": tab,
            "input_debug":   idx,    # <-- pass Image Index through
        }
        return inputs, label

    dataset = dataset.map(_to_model_inputs,
                          num_parallel_calls=tf.data.AUTOTUNE)

    # Augment (training only)  - keep input_debug untouched
    if is_training:
        dataset = dataset.shuffle(buffer_size=len(image_paths),
                                  reshuffle_each_iteration=True)

        def _augment(inputs, label):
            inputs = {
                "image_input":  augment(inputs["image_input"]),
                "tabular_input": inputs["tabular_input"],
                "input_debug":   inputs["input_debug"],   # keep as-is
            }
            return inputs, label

        dataset = dataset.map(_augment,
                              num_parallel_calls=tf.data.AUTOTUNE)

    # Batch the dataset
    dataset = dataset.batch(BATCH_SIZE)
    # Prefetch for performance
    dataset = dataset.prefetch(buffer_size=tf.data.AUTOTUNE)

    return dataset

def create_training_datasets(task_df, task):
    """Creates tf.data.Dataset for training and validation."""
    train_df, val_test_df = train_test_split(task_df, test_size=0.2,␣
 ↪random_state=42)
    val_df, test_df = train_test_split(val_test_df, test_size=0.5,␣
 ↪random_state=42)

    train_dataset = create_tf_datasets(train_df, task, is_training=True)
```

```
    val_dataset = create_tf_datasets(val_df, task, is_training=False)
    test_dataset = create_tf_datasets(test_df, task, is_training=False)

    return train_dataset, val_dataset, test_dataset
```

0.4 Model Design/Building

[363]:
```
def create_hybrid_model_v1(num_tabular_features=10, num_classes=1):
    img_size = IMG_SIZE

    # image input
    image_input = layers.Input(shape=(img_size, img_size, 1),␣
 ↪name="image_input")
    # rescale 0-255 → 0-1
    x = layers.Rescaling(1./255., name="rescale")(image_input)

    # convolutions
    x = layers.Conv2D(32, (3, 3), activation='relu',␣
 ↪padding='same')(image_input)
    x = layers.BatchNormalization()(x)
    x = layers.Conv2D(32, (3, 3), activation='relu', padding='same')(x)
    x = layers.BatchNormalization()(x)
    x = layers.MaxPooling2D(2)(x)
    x = layers.Dropout(0.2)(x)

    x = layers.Conv2D(64, (3, 3), activation='relu', padding='same')(x)
    x = layers.BatchNormalization()(x)
    x = layers.Conv2D(64, (3, 3), activation='relu', padding='same')(x)
    x = layers.BatchNormalization()(x)
    x = layers.MaxPooling2D(2)(x)
    x = layers.Dropout(0.3)(x)

    x = layers.Conv2D(128, (3, 3), activation='relu', padding='same')(x)
    x = layers.BatchNormalization()(x)
    x = layers.Conv2D(128, (3, 3), activation='relu', padding='same')(x)
    x = layers.BatchNormalization()(x)
    x = layers.MaxPooling2D(2)(x)
    x = layers.Dropout(0.3)(x)

    x = layers.Conv2D(256, (3, 3), activation='relu', padding='same')(x)
    x = layers.BatchNormalization()(x)
    x = layers.Conv2D(256, (3, 3), activation='relu', padding='same')(x)
    x = layers.BatchNormalization()(x)
    x = layers.MaxPooling2D(2)(x)
    x = layers.Dropout(0.4)(x)

    x = layers.GlobalAveragePooling2D()(x)
```

```
    x = layers.Dense(128, activation='relu', kernel_regularizer=l2(0.01))(x)
    x = layers.Dropout(0.5)(x)

    # tabular branch
    tabular_input = layers.Input(shape=(num_tabular_features,),␣
↪name='tabular_input')
    t = layers.Dense(32, activation="relu")(tabular_input)
    t = layers.BatchNormalization()(t)
    t = layers.Dense(32, activation="relu")(t)

    # fusion
    fused = layers.Concatenate(name="fusion")([x, t])      # (None, 256+32)
    fused = layers.Dense(
        128, activation="relu", kernel_regularizer=l2(1e-2)
    )(fused)
    fused = layers.Dropout(0.5)(fused)

    # output
    output = layers.Dense(num_classes, activation='sigmoid')(fused)

    # Maintain dual input interface for compatibility
    model = Model(inputs={"image_input": image_input, "tabular_input":␣
↪tabular_input },  # Dummy tabular input
                  outputs=output)

    model.compile(
        optimizer=Adam(learning_rate=1e-4),
        loss='binary_crossentropy',
        metrics=['accuracy',
                tf.keras.metrics.BinaryAccuracy(name='bin_accuracy'),
                tf.keras.metrics.AUC(name='auc'),
                tf.keras.metrics.Precision(name='precision'),
                tf.keras.metrics.Recall(name='recall')]
    )

    return model
```

[364]:
```
def create_ds():
    tasks_datasets = []
    for task, task_df in prepared_datasets.items():
        train_ds, val_ds, test_ds = create_training_datasets(task_df, task)
        tasks_datasets.append( (train_ds, val_ds, test_ds) )
    return tasks_datasets

tasks_datasets = create_ds()
```

```
Creating training datasets for task: has_Infection/Infiltration
Creating validation datasets for task: has_Infection/Infiltration
```

```
Creating validation datasets for task: has_Infection/Infiltration
Creating training datasets for task: has_Fluid Related Issues
Creating validation datasets for task: has_Fluid Related Issues
Creating validation datasets for task: has_Fluid Related Issues
Creating training datasets for task: has_Lung Structure Issues
Creating validation datasets for task: has_Lung Structure Issues
Creating validation datasets for task: has_Lung Structure Issues
Creating training datasets for task: has_Nodule/Mass
Creating validation datasets for task: has_Nodule/Mass
Creating validation datasets for task: has_Nodule/Mass
Creating training datasets for task: has_Cardiac Issues
Creating validation datasets for task: has_Cardiac Issues
Creating validation datasets for task: has_Cardiac Issues
Creating training datasets for task: has_Hernia
Creating validation datasets for task: has_Hernia
Creating validation datasets for task: has_Hernia
Creating training datasets for task: has_No Finding
Creating validation datasets for task: has_No Finding
Creating validation datasets for task: has_No Finding
```

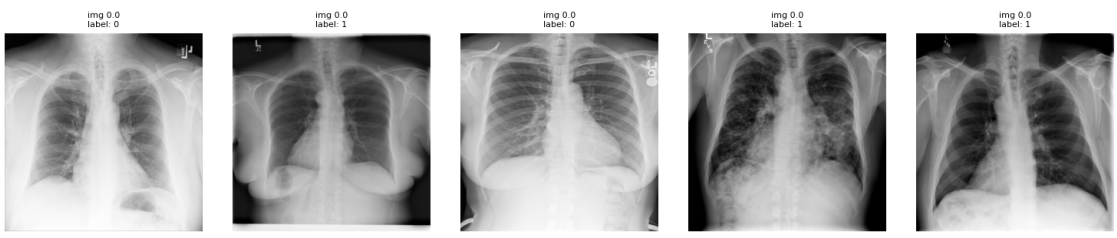
[365]:
```
# sanity check data - peek at first task, train dataset
display(tasks_datasets[0][0])
```

```
<_PrefetchDataset element_spec=({'image_input': TensorSpec(shape=(None, 480,␣
 ↪480, 1), dtype=tf.float32, name=None), 'tabular_input':␣
 ↪TensorSpec(shape=(None, 3), dtype=tf.float64, name=None), 'input_debug':␣
 ↪TensorSpec(shape=(None,), dtype=tf.float32, name=None)},␣
 ↪TensorSpec(shape=(None,), dtype=tf.int64, name=None))>
```

[366]:
```
def show_first_images(ds, n=5):
    """
    Display the first *n* images contained in `image_input`
    of a `tf.data.Dataset` whose elements look like
        ({"image_input": <tensor>, ...}, label)   # or
        {"image_input": <tensor>, ...}            # if unlabeled
    """
    plt.figure(figsize=(3 * n, 3))

    for i, sample in enumerate(ds.unbatch().take(n)):
        # Handle both (inputs, label) and inputs-only cases
        if isinstance(sample, tuple):
            inputs, label = sample
        else:
            inputs, label = sample, None

        img = inputs["image_input"]            # (H, W, C) float or uint8
        debug = inputs["input_debug"]
```

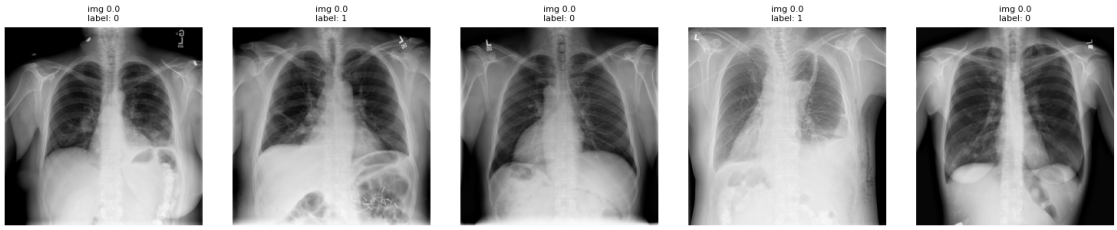
```
        # Tensor → NumPy for matplotlib
        img_np = img.numpy()

        # Squeeze the channel dim if it's single-channel
        if img_np.shape[-1] == 1:
            img_np = img_np.squeeze(-1)
            cmap = "gray"
        else:
            cmap = None                          # default = RGB

        plt.subplot(1, n, i + 1)
        plt.imshow(img_np, cmap=cmap)
        plt.axis("off")

        title = f"img {debug}"
        if label is not None:
            # label could be tensor → convert to Python scalar / list
            label_val = label.numpy()
            # Flatten to plain int/float if possible
            if label_val.size == 1:
                label_val = label_val.item()
            title += f"\nlabel: {label_val}"
        plt.title(title, fontsize=8)

    plt.tight_layout()
    plt.show()

for i, (train_ds, val_ds, _) in enumerate(tasks_datasets):
    show_first_images(train_ds)
```

```
2025-04-13 03:58:50.687047: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7060 of 8000
2025-04-13 03:58:51.727418: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.
2025-04-13 03:58:51.809672: W tensorflow/core/framework/local_rendezvous.cc:404]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
```

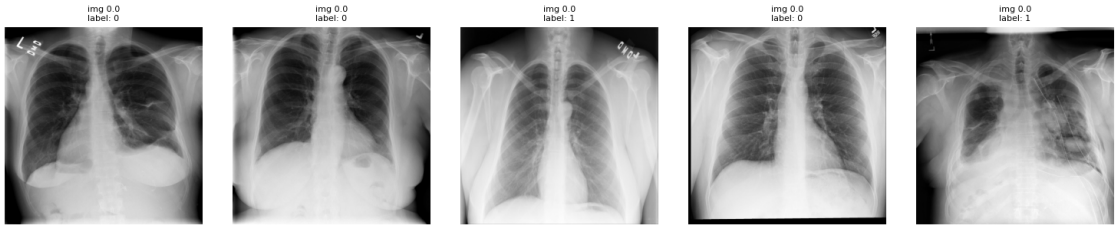


```
2025-04-13 03:59:02.386085: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7674 of 8000
2025-04-13 03:59:02.619888: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.
2025-04-13 03:59:02.667978: W tensorflow/core/framework/local_rendezvous.cc:404]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
```

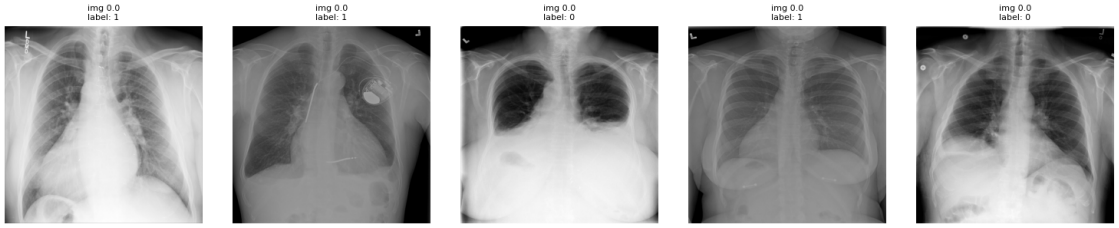

```
2025-04-13 03:59:13.284733: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53392:
Filling up shuffle buffer (this may take a while): 7198 of 8000
2025-04-13 03:59:14.219948: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.
2025-04-13 03:59:14.273627: W tensorflow/core/framework/local_rendezvous.cc:404]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
```



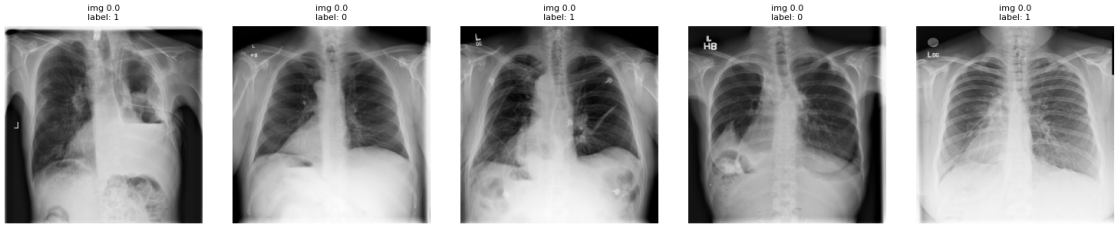

```
2025-04-13 03:59:24.884849: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53409:
Filling up shuffle buffer (this may take a while): 7650 of 8000
2025-04-13 03:59:25.224586: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.
2025-04-13 03:59:25.318430: W tensorflow/core/framework/local_rendezvous.cc:404]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
```



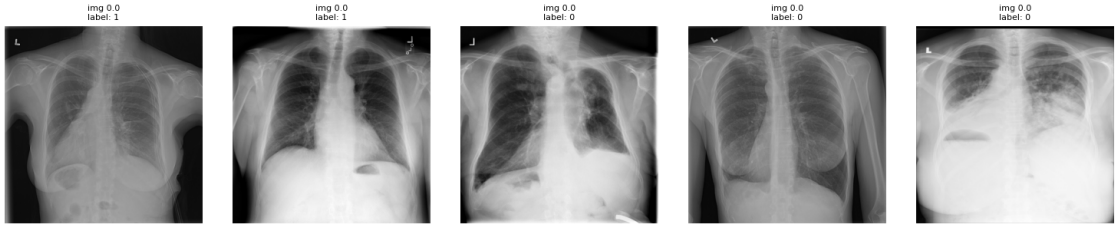

```
2025-04-13 03:59:28.761856: W tensorflow/core/framework/local_rendezvous.cc:404]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
```




```
2025-04-13 03:59:29.753271: W tensorflow/core/framework/local_rendezvous.cc:404]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
```




```
2025-04-13 03:59:40.075718: W tensorflow/core/framework/local_rendezvous.cc:404]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
```



0.5 Model Training

[367]:
```python
# Save the history to a JSON file
def save_history(history, filename):
    with open(filename, 'w') as f:
        json.dump(history.history, f)

# Load the history from a JSON file
def load_history(filename):
    with open(filename, 'r') as f:
        history = json.load(f)
    return history
```

[368]:
```python
import math
EPOCHS=40
AUC_PATIENCE_FACTOR = 4
AUC_PATIENCE=math.ceil(EPOCHS/AUC_PATIENCE_FACTOR)
LR_PATIENCE=math.ceil(EPOCHS/10)
LR_PATIENCE=3
print(f"{EPOCHS=} {AUC_PATIENCE=} {LR_PATIENCE=}")

callbacks = [
    tf.keras.callbacks.EarlyStopping(
        # monitor='val_auc',
        monitor='val_loss',
        patience=AUC_PATIENCE,
        # mode='max',
        restore_best_weights=True,
        # min_delta=1e-4,       # ignore <0.0001 change
    ),
    tf.keras.callbacks.ReduceLROnPlateau(
        # monitor='val_auc',
        monitor='val_loss',
        factor=0.5,
        patience=LR_PATIENCE,
        min_lr=1e-6
    )
]



all_models = []
for i, (train_ds, val_ds, _) in enumerate(tasks_datasets):
    # Create and train the model
    # Get the number of tabular features using X_train_tab.shape[1]
    # print(X_train_tab.shape[1])
    # break
```

```
    num_tabular_features = 3
    model = create_hybrid_model_v1(num_tabular_features)

    LOAD_FROM_FILE_DONT_TRAIN = False
    model_path   = os.path.join(DRIVE_PATH, f'model_{i+1}.keras')
    history_path = os.path.join(DRIVE_PATH, f'model_{i+1}_history.json')

    if LOAD_FROM_FILE_DONT_TRAIN:
        model = tf.keras.models.load_model(model_path)
        history = load_history(history_path)
        print(f"Model {i+1} LOADED from file {model_path} and {history_path}")
    else:
        history = model.fit(
            train_ds,
            epochs=EPOCHS,
            validation_data=val_ds,
            callbacks=callbacks
        )
        print(f"Model {i+1} trained successfully")

        model.save(model_path)
        save_history(history, history_path)
        print(f"Saved to keras file {model_path} and {history_path}")

    all_models.append( (model, history) )
```

```
EPOCHS=40 AUC_PATIENCE=10 LR_PATIENCE=3
Epoch 1/40

2025-04-13 03:59:57.186632: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7340 of 8000
2025-04-13 03:59:57.908665: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            65s 69ms/step -
accuracy: 0.5153 - auc: 0.5197 - bin_accuracy: 0.5153 - loss: 3.5455 -
precision: 0.5221 - recall: 0.5209 - val_accuracy: 0.4930 - val_auc: 0.5313 -
val_bin_accuracy: 0.4930 - val_loss: 2.6505 - val_precision: 0.5263 -
val_recall: 0.1934 - learning_rate: 1.0000e-04
Epoch 2/40
  2/500            30s 61ms/step - accuracy:
0.5781 - auc: 0.5936 - bin_accuracy: 0.5781 - loss: 2.6240 - precision: 0.5000 -
recall: 0.5934

2025-04-13 04:00:55.684448: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7814 of 8000
2025-04-13 04:00:55.717907: I
```

```
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.5259 - auc: 0.5353 - bin_accuracy: 0.5259 - loss: 2.4493 -
precision: 0.5252 - recall: 0.5379 - val_accuracy: 0.5270 - val_auc: 0.5734 -
val_bin_accuracy: 0.5270 - val_loss: 1.9270 - val_precision: 0.6279 -
val_recall: 0.2089 - learning_rate: 1.0000e-04
Epoch 3/40
  1/500            1:25:32 10s/step -
accuracy: 0.6250 - auc: 0.6429 - bin_accuracy: 0.6250 - loss: 1.9023 -
precision: 0.6364 - recall: 0.7778

2025-04-13 04:01:37.199411: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7749 of 8000
2025-04-13 04:01:37.326302: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            41s 62ms/step -
accuracy: 0.5245 - auc: 0.5288 - bin_accuracy: 0.5245 - loss: 1.8032 -
precision: 0.5226 - recall: 0.5348 - val_accuracy: 0.5540 - val_auc: 0.5723 -
val_bin_accuracy: 0.5540 - val_loss: 1.4640 - val_precision: 0.5709 -
val_recall: 0.5532 - learning_rate: 1.0000e-04
Epoch 4/40
500/500            41s 63ms/step -
accuracy: 0.5323 - auc: 0.5490 - bin_accuracy: 0.5323 - loss: 1.3863 -
precision: 0.5315 - recall: 0.5465 - val_accuracy: 0.5440 - val_auc: 0.5732 -
val_bin_accuracy: 0.5440 - val_loss: 1.1741 - val_precision: 0.6034 -
val_recall: 0.3443 - learning_rate: 1.0000e-04
Epoch 5/40
500/500            42s 63ms/step -
accuracy: 0.5543 - auc: 0.5722 - bin_accuracy: 0.5543 - loss: 1.1191 -
precision: 0.5536 - recall: 0.5952 - val_accuracy: 0.5450 - val_auc: 0.5635 -
val_bin_accuracy: 0.5450 - val_loss: 0.9891 - val_precision: 0.5560 -
val_recall: 0.5957 - learning_rate: 1.0000e-04
Epoch 6/40

2025-04-13 04:03:41.406486: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7433 of 8000

  3/500            30s 62ms/step - accuracy:
0.4097 - auc: 0.4057 - bin_accuracy: 0.4097 - loss: 1.0034 - precision: 0.6635 -
recall: 0.4454

2025-04-13 04:03:41.917129: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 62ms/step -
accuracy: 0.5445 - auc: 0.5592 - bin_accuracy: 0.5445 - loss: 0.9562 -
precision: 0.5464 - recall: 0.5874 - val_accuracy: 0.5530 - val_auc: 0.5700 -
```

```
val_bin_accuracy: 0.5530 - val_loss: 0.8730 - val_precision: 0.5792 -
val_recall: 0.4952 - learning_rate: 1.0000e-04
Epoch 7/40
500/500            41s 63ms/step -
accuracy: 0.5430 - auc: 0.5535 - bin_accuracy: 0.5430 - loss: 0.8553 -
precision: 0.5382 - recall: 0.5591 - val_accuracy: 0.5440 - val_auc: 0.5701 -
val_bin_accuracy: 0.5440 - val_loss: 0.8042 - val_precision: 0.5836 -
val_recall: 0.4120 - learning_rate: 1.0000e-04
Epoch 8/40
  2/500            32s 64ms/step - accuracy:
0.4688 - auc: 0.6508 - bin_accuracy: 0.4688 - loss: 0.7786 - precision: 0.5714 -
recall: 0.4222

2025-04-13 04:05:04.489831: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7909 of 8000
2025-04-13 04:05:04.522255: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            41s 62ms/step -
accuracy: 0.5439 - auc: 0.5659 - bin_accuracy: 0.5439 - loss: 0.7898 -
precision: 0.5414 - recall: 0.5921 - val_accuracy: 0.5530 - val_auc: 0.5745 -
val_bin_accuracy: 0.5530 - val_loss: 0.7593 - val_precision: 0.5518 -
val_recall: 0.7215 - learning_rate: 1.0000e-04
Epoch 9/40
500/500            41s 63ms/step -
accuracy: 0.5385 - auc: 0.5581 - bin_accuracy: 0.5385 - loss: 0.7548 -
precision: 0.5321 - recall: 0.5759 - val_accuracy: 0.5420 - val_auc: 0.5752 -
val_bin_accuracy: 0.5420 - val_loss: 0.7350 - val_precision: 0.5448 -
val_recall: 0.6944 - learning_rate: 1.0000e-04
Epoch 10/40
500/500            42s 63ms/step -
accuracy: 0.5516 - auc: 0.5689 - bin_accuracy: 0.5516 - loss: 0.7307 -
precision: 0.5410 - recall: 0.6471 - val_accuracy: 0.5520 - val_auc: 0.5728 -
val_bin_accuracy: 0.5520 - val_loss: 0.7212 - val_precision: 0.5714 -
val_recall: 0.5338 - learning_rate: 1.0000e-04
Epoch 11/40

2025-04-13 04:07:08.887585: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7630 of 8000

  2/500            30s 61ms/step - accuracy:
0.6094 - auc: 0.6886 - bin_accuracy: 0.6094 - loss: 0.7089 - precision: 0.4605 -
recall: 0.8167

2025-04-13 04:07:09.125459: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.5547 - auc: 0.5696 - bin_accuracy: 0.5547 - loss: 0.7177 -
```

```
precision: 0.5456 - recall: 0.5951 - val_accuracy: 0.5450 - val_auc: 0.5711 -
val_bin_accuracy: 0.5450 - val_loss: 0.7110 - val_precision: 0.5468 -
val_recall: 0.7002 - learning_rate: 1.0000e-04
Epoch 12/40

2025-04-13 04:07:50.792295: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7641 of 8000

  3/500             29s 60ms/step - accuracy:
0.3576 - auc: 0.3960 - bin_accuracy: 0.3576 - loss: 0.7347 - precision: 0.3615 -
recall: 0.4670

2025-04-13 04:07:51.109599: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 62ms/step -
accuracy: 0.5520 - auc: 0.5674 - bin_accuracy: 0.5520 - loss: 0.7090 -
precision: 0.5458 - recall: 0.6735 - val_accuracy: 0.5350 - val_auc: 0.5687 -
val_bin_accuracy: 0.5350 - val_loss: 0.7084 - val_precision: 0.5747 -
val_recall: 0.3868 - learning_rate: 1.0000e-04
Epoch 13/40

2025-04-13 04:08:32.386082: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7589 of 8000

  2/500             30s 60ms/step - accuracy:
0.4375 - auc: 0.3764 - bin_accuracy: 0.4375 - loss: 0.7300 - precision: 0.3214 -
recall: 0.3512

2025-04-13 04:08:32.629574: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.5468 - auc: 0.5665 - bin_accuracy: 0.5468 - loss: 0.7043 -
precision: 0.5398 - recall: 0.5714 - val_accuracy: 0.5200 - val_auc: 0.5651 -
val_bin_accuracy: 0.5200 - val_loss: 0.7134 - val_precision: 0.5939 -
val_recall: 0.2263 - learning_rate: 1.0000e-04
Epoch 14/40

2025-04-13 04:09:14.192594: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7557 of 8000

  3/500             29s 60ms/step - accuracy:
0.5278 - auc: 0.6647 - bin_accuracy: 0.5278 - loss: 0.6758 - precision: 0.5796 -
recall: 0.6008

2025-04-13 04:09:14.623948: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.5489 - auc: 0.5696 - bin_accuracy: 0.5489 - loss: 0.6995 -
```

```
precision: 0.5411 - recall: 0.6500 - val_accuracy: 0.5500 - val_auc: 0.5761 -
val_bin_accuracy: 0.5500 - val_loss: 0.6969 - val_precision: 0.5466 -
val_recall: 0.7602 - learning_rate: 1.0000e-04
Epoch 15/40
  2/500             30s 61ms/step - accuracy:
0.4062 - auc: 0.4245 - bin_accuracy: 0.4062 - loss: 0.7222 - precision: 0.3985 -
recall: 0.4359

2025-04-13 04:09:56.197606: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7888 of 8000
2025-04-13 04:09:56.223410: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             42s 63ms/step -
accuracy: 0.5593 - auc: 0.5733 - bin_accuracy: 0.5593 - loss: 0.6986 -
precision: 0.5510 - recall: 0.6152 - val_accuracy: 0.5310 - val_auc: 0.5743 -
val_bin_accuracy: 0.5310 - val_loss: 0.6993 - val_precision: 0.5863 -
val_recall: 0.3153 - learning_rate: 1.0000e-04
Epoch 16/40
  2/500             32s 65ms/step - accuracy:
0.5312 - auc: 0.4127 - bin_accuracy: 0.5312 - loss: 0.7279 - precision: 0.5714 -
recall: 0.6333

2025-04-13 04:10:37.886982: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7770 of 8000
2025-04-13 04:10:37.931794: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             41s 63ms/step -
accuracy: 0.5486 - auc: 0.5715 - bin_accuracy: 0.5486 - loss: 0.6942 -
precision: 0.5372 - recall: 0.6466 - val_accuracy: 0.5290 - val_auc: 0.5630 -
val_bin_accuracy: 0.5290 - val_loss: 0.7030 - val_precision: 0.5966 -
val_recall: 0.2747 - learning_rate: 1.0000e-04
Epoch 17/40

2025-04-13 04:11:19.304663: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7344 of 8000

  3/500             31s 63ms/step - accuracy:
0.5868 - auc: 0.5884 - bin_accuracy: 0.5868 - loss: 0.6989 - precision: 0.5988 -
recall: 0.6408

2025-04-13 04:11:20.010237: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             42s 63ms/step -
accuracy: 0.5482 - auc: 0.5745 - bin_accuracy: 0.5482 - loss: 0.6930 -
precision: 0.5426 - recall: 0.6348 - val_accuracy: 0.5400 - val_auc: 0.5722 -
val_bin_accuracy: 0.5400 - val_loss: 0.6933 - val_precision: 0.5391 -
```

```
val_recall: 0.7602 - learning_rate: 1.0000e-04
Epoch 18/40

2025-04-13 04:12:01.586474: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7474 of 8000

  3/500            30s 61ms/step - accuracy:
0.4653 - auc: 0.4990 - bin_accuracy: 0.4653 - loss: 0.6895 - precision: 0.4815 -
recall: 0.5739

2025-04-13 04:12:02.119699: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.5486 - auc: 0.5734 - bin_accuracy: 0.5486 - loss: 0.6911 -
precision: 0.5390 - recall: 0.6904 - val_accuracy: 0.5450 - val_auc: 0.5767 -
val_bin_accuracy: 0.5450 - val_loss: 0.6924 - val_precision: 0.5518 -
val_recall: 0.6383 - learning_rate: 1.0000e-04
Epoch 19/40
500/500            41s 62ms/step -
accuracy: 0.5508 - auc: 0.5729 - bin_accuracy: 0.5508 - loss: 0.6896 -
precision: 0.5452 - recall: 0.6794 - val_accuracy: 0.5550 - val_auc: 0.5709 -
val_bin_accuracy: 0.5550 - val_loss: 0.6944 - val_precision: 0.5700 -
val_recall: 0.5667 - learning_rate: 1.0000e-04
Epoch 20/40
500/500            41s 62ms/step -
accuracy: 0.5641 - auc: 0.5841 - bin_accuracy: 0.5641 - loss: 0.6880 -
precision: 0.5514 - recall: 0.6724 - val_accuracy: 0.5440 - val_auc: 0.5675 -
val_bin_accuracy: 0.5440 - val_loss: 0.6946 - val_precision: 0.5749 -
val_recall: 0.4526 - learning_rate: 1.0000e-04
Epoch 21/40

2025-04-13 04:14:05.784490: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7711 of 8000

  3/500            29s 59ms/step - accuracy:
0.5069 - auc: 0.4921 - bin_accuracy: 0.5069 - loss: 0.7089 - precision: 0.5662 -
recall: 0.7064

2025-04-13 04:14:06.028262: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 62ms/step -
accuracy: 0.5632 - auc: 0.5818 - bin_accuracy: 0.5632 - loss: 0.6886 -
precision: 0.5498 - recall: 0.7149 - val_accuracy: 0.5370 - val_auc: 0.5755 -
val_bin_accuracy: 0.5370 - val_loss: 0.6901 - val_precision: 0.5390 -
val_recall: 0.7215 - learning_rate: 1.0000e-04
Epoch 22/40
  1/500            1:26:17 10s/step -
```

```
accuracy: 0.3750 - auc: 0.3175 - bin_accuracy: 0.3750 - loss: 0.6999 -
precision: 0.3333 - recall: 0.4286

2025-04-13 04:14:47.388809: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7752 of 8000
2025-04-13 04:14:47.523829: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.5495 - auc: 0.5756 - bin_accuracy: 0.5495 - loss: 0.6873 -
precision: 0.5415 - recall: 0.6679 - val_accuracy: 0.5550 - val_auc: 0.5778 -
val_bin_accuracy: 0.5550 - val_loss: 0.6902 - val_precision: 0.5465 -
val_recall: 0.8182 - learning_rate: 1.0000e-04
Epoch 23/40

2025-04-13 04:15:28.985496: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7603 of 8000

  3/500            29s 60ms/step - accuracy:
0.5000 - auc: 0.4986 - bin_accuracy: 0.5000 - loss: 0.7163 - precision: 0.5873 -
recall: 0.4272

2025-04-13 04:15:29.303164: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.5417 - auc: 0.5611 - bin_accuracy: 0.5417 - loss: 0.6905 -
precision: 0.5322 - recall: 0.6353 - val_accuracy: 0.5330 - val_auc: 0.5690 -
val_bin_accuracy: 0.5330 - val_loss: 0.6919 - val_precision: 0.5317 -
val_recall: 0.8104 - learning_rate: 1.0000e-04
Epoch 24/40
500/500            42s 63ms/step -
accuracy: 0.5492 - auc: 0.5683 - bin_accuracy: 0.5492 - loss: 0.6893 -
precision: 0.5361 - recall: 0.6265 - val_accuracy: 0.5590 - val_auc: 0.5749 -
val_bin_accuracy: 0.5590 - val_loss: 0.6896 - val_precision: 0.5766 -
val_recall: 0.5532 - learning_rate: 1.0000e-04
Epoch 25/40

2025-04-13 04:16:52.287635: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7398 of 8000

  3/500            29s 60ms/step - accuracy:
0.6736 - auc: 0.6660 - bin_accuracy: 0.6736 - loss: 0.6691 - precision: 0.6597 -
recall: 0.8692

2025-04-13 04:16:52.810081: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.5586 - auc: 0.5772 - bin_accuracy: 0.5586 - loss: 0.6868 -
```

```
precision: 0.5510 - recall: 0.6843 - val_accuracy: 0.5650 - val_auc: 0.5810 -
val_bin_accuracy: 0.5650 - val_loss: 0.6887 - val_precision: 0.5697 -
val_recall: 0.6480 - learning_rate: 1.0000e-04
Epoch 26/40

2025-04-13 04:17:34.489855: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7336 of 8000

  3/500            29s 59ms/step - accuracy:
0.6111 - auc: 0.6698 - bin_accuracy: 0.6111 - loss: 0.6921 - precision: 0.5910 -
recall: 0.6598

2025-04-13 04:17:35.204351: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 62ms/step -
accuracy: 0.5653 - auc: 0.5805 - bin_accuracy: 0.5653 - loss: 0.6878 -
precision: 0.5603 - recall: 0.6917 - val_accuracy: 0.5410 - val_auc: 0.5711 -
val_bin_accuracy: 0.5410 - val_loss: 0.6902 - val_precision: 0.5428 -
val_recall: 0.7118 - learning_rate: 1.0000e-04
Epoch 27/40

2025-04-13 04:18:16.586043: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7646 of 8000

  3/500            30s 62ms/step - accuracy:
0.5521 - auc: 0.6184 - bin_accuracy: 0.5521 - loss: 0.6804 - precision: 0.6902 -
recall: 0.5349

2025-04-13 04:18:16.824492: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.5610 - auc: 0.5853 - bin_accuracy: 0.5610 - loss: 0.6849 -
precision: 0.5616 - recall: 0.6468 - val_accuracy: 0.5460 - val_auc: 0.5740 -
val_bin_accuracy: 0.5460 - val_loss: 0.6897 - val_precision: 0.5417 -
val_recall: 0.7911 - learning_rate: 1.0000e-04
Epoch 28/40
500/500            41s 62ms/step -
accuracy: 0.5463 - auc: 0.5786 - bin_accuracy: 0.5463 - loss: 0.6855 -
precision: 0.5296 - recall: 0.6192 - val_accuracy: 0.5550 - val_auc: 0.5820 -
val_bin_accuracy: 0.5550 - val_loss: 0.6874 - val_precision: 0.5503 -
val_recall: 0.7621 - learning_rate: 1.0000e-04
Epoch 29/40
500/500            41s 63ms/step -
accuracy: 0.5711 - auc: 0.5948 - bin_accuracy: 0.5711 - loss: 0.6816 -
precision: 0.5554 - recall: 0.7061 - val_accuracy: 0.5580 - val_auc: 0.5795 -
val_bin_accuracy: 0.5580 - val_loss: 0.6874 - val_precision: 0.5626 -
val_recall: 0.6518 - learning_rate: 1.0000e-04
Epoch 30/40
```

```
2025-04-13 04:20:19.598071: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7692 of 8000

  3/500            30s 61ms/step - accuracy:
0.5660 - auc: 0.5294 - bin_accuracy: 0.5660 - loss: 0.6956 - precision: 0.5192 -
recall: 0.5079

2025-04-13 04:20:19.810173: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 62ms/step -
accuracy: 0.5713 - auc: 0.5856 - bin_accuracy: 0.5713 - loss: 0.6855 -
precision: 0.5686 - recall: 0.6744 - val_accuracy: 0.5510 - val_auc: 0.5788 -
val_bin_accuracy: 0.5510 - val_loss: 0.6894 - val_precision: 0.5705 -
val_recall: 0.5319 - learning_rate: 1.0000e-04
Epoch 31/40
500/500            41s 62ms/step -
accuracy: 0.5563 - auc: 0.5836 - bin_accuracy: 0.5563 - loss: 0.6858 -
precision: 0.5509 - recall: 0.6370 - val_accuracy: 0.5610 - val_auc: 0.5885 -
val_bin_accuracy: 0.5610 - val_loss: 0.6862 - val_precision: 0.5552 -
val_recall: 0.7582 - learning_rate: 1.0000e-04
Epoch 32/40

2025-04-13 04:21:42.484448: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7067 of 8000

  3/500            30s 61ms/step - accuracy:
0.7292 - auc: 0.7394 - bin_accuracy: 0.7292 - loss: 0.6786 - precision: 0.8889 -
recall: 0.6527

2025-04-13 04:21:43.518936: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            43s 63ms/step -
accuracy: 0.5587 - auc: 0.5836 - bin_accuracy: 0.5587 - loss: 0.6863 -
precision: 0.5534 - recall: 0.6499 - val_accuracy: 0.5140 - val_auc: 0.5658 -
val_bin_accuracy: 0.5140 - val_loss: 0.7154 - val_precision: 0.5756 -
val_recall: 0.2282 - learning_rate: 1.0000e-04
Epoch 33/40
  1/500            1:25:28 10s/step -
accuracy: 0.6250 - auc: 0.5635 - bin_accuracy: 0.6250 - loss: 0.7021 -
precision: 0.6667 - recall: 0.6667

2025-04-13 04:22:24.988601: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7778 of 8000
2025-04-13 04:22:25.107655: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            41s 62ms/step -
```

```
accuracy: 0.5615 - auc: 0.5769 - bin_accuracy: 0.5615 - loss: 0.6870 -
precision: 0.5529 - recall: 0.6561 - val_accuracy: 0.5670 - val_auc: 0.5852 -
val_bin_accuracy: 0.5670 - val_loss: 0.6873 - val_precision: 0.5580 -
val_recall: 0.7814 - learning_rate: 1.0000e-04
Epoch 34/40
500/500             41s 62ms/step -
accuracy: 0.5507 - auc: 0.5745 - bin_accuracy: 0.5507 - loss: 0.6856 -
precision: 0.5369 - recall: 0.6473 - val_accuracy: 0.5510 - val_auc: 0.5850 -
val_bin_accuracy: 0.5510 - val_loss: 0.6850 - val_precision: 0.5702 -
val_recall: 0.5338 - learning_rate: 1.0000e-04
Epoch 35/40
500/500             41s 63ms/step -
accuracy: 0.5565 - auc: 0.5838 - bin_accuracy: 0.5565 - loss: 0.6840 -
precision: 0.5450 - recall: 0.6660 - val_accuracy: 0.5550 - val_auc: 0.5828 -
val_bin_accuracy: 0.5550 - val_loss: 0.6862 - val_precision: 0.5744 -
val_recall: 0.5377 - learning_rate: 1.0000e-04
Epoch 36/40
  1/500             1:25:13 10s/step -
accuracy: 0.5000 - auc: 0.7381 - bin_accuracy: 0.5000 - loss: 0.6588 -
precision: 0.4000 - recall: 0.2857

2025-04-13 04:24:29.005057: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7845 of 8000
2025-04-13 04:24:29.091734: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             41s 63ms/step -
accuracy: 0.5653 - auc: 0.5972 - bin_accuracy: 0.5653 - loss: 0.6798 -
precision: 0.5482 - recall: 0.6355 - val_accuracy: 0.5530 - val_auc: 0.5841 -
val_bin_accuracy: 0.5530 - val_loss: 0.6854 - val_precision: 0.5543 -
val_recall: 0.6905 - learning_rate: 1.0000e-04
Epoch 37/40

2025-04-13 04:25:10.496472: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7623 of 8000

  3/500             29s 59ms/step - accuracy:
0.5417 - auc: 0.5288 - bin_accuracy: 0.5417 - loss: 0.6981 - precision: 0.5210 -
recall: 0.6730

2025-04-13 04:25:10.913244: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             42s 63ms/step -
accuracy: 0.5661 - auc: 0.5868 - bin_accuracy: 0.5661 - loss: 0.6847 -
precision: 0.5540 - recall: 0.7116 - val_accuracy: 0.5330 - val_auc: 0.5701 -
val_bin_accuracy: 0.5330 - val_loss: 0.6974 - val_precision: 0.5714 -
val_recall: 0.3868 - learning_rate: 1.0000e-04
Epoch 38/40
```

```
  1/500             1:25:19 10s/step -
accuracy: 0.6250 - auc: 0.5859 - bin_accuracy: 0.6250 - loss: 0.6925 -
precision: 0.6250 - recall: 0.6250

2025-04-13 04:25:52.307347: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7894 of 8000
2025-04-13 04:25:52.413268: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             41s 63ms/step -
accuracy: 0.5706 - auc: 0.5981 - bin_accuracy: 0.5706 - loss: 0.6815 -
precision: 0.5537 - recall: 0.6898 - val_accuracy: 0.5730 - val_auc: 0.5956 -
val_bin_accuracy: 0.5730 - val_loss: 0.6839 - val_precision: 0.5620 -
val_recall: 0.7892 - learning_rate: 5.0000e-05
Epoch 39/40
500/500             41s 63ms/step -
accuracy: 0.5715 - auc: 0.5972 - bin_accuracy: 0.5715 - loss: 0.6799 -
precision: 0.5574 - recall: 0.7099 - val_accuracy: 0.5550 - val_auc: 0.5847 -
val_bin_accuracy: 0.5550 - val_loss: 0.6850 - val_precision: 0.5541 -
val_recall: 0.7137 - learning_rate: 5.0000e-05
Epoch 40/40
  2/500             31s 64ms/step - accuracy:
0.5781 - auc: 0.6621 - bin_accuracy: 0.5781 - loss: 0.6457 - precision: 0.5632 -
recall: 0.6875

2025-04-13 04:27:15.084711: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53358:
Filling up shuffle buffer (this may take a while): 7802 of 8000
2025-04-13 04:27:15.134693: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             42s 63ms/step -
accuracy: 0.5712 - auc: 0.6020 - bin_accuracy: 0.5712 - loss: 0.6787 -
precision: 0.5619 - recall: 0.6746 - val_accuracy: 0.5520 - val_auc: 0.5818 -
val_bin_accuracy: 0.5520 - val_loss: 0.6869 - val_precision: 0.5647 -
val_recall: 0.5822 - learning_rate: 5.0000e-05
Model 1 trained successfully
Saved to keras file /workspace/chest/drive/MyDrive/AAI-590_Collabs/model_1.keras
and /workspace/chest/drive/MyDrive/AAI-590_Collabs/model_1_history.json
Epoch 1/40

2025-04-13 04:28:03.085792: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7424 of 8000
2025-04-13 04:28:03.621797: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             64s 69ms/step -
accuracy: 0.5261 - auc: 0.5306 - bin_accuracy: 0.5261 - loss: 3.5267 -
precision: 0.5261 - recall: 0.4414 - val_accuracy: 0.6110 - val_auc: 0.6539 -
```

```
val_bin_accuracy: 0.6110 - val_loss: 2.5708 - val_precision: 0.5930 -
val_recall: 0.7892 - learning_rate: 1.0000e-04
Epoch 2/40
500/500            42s 63ms/step -
accuracy: 0.5870 - auc: 0.6299 - bin_accuracy: 0.5870 - loss: 2.3599 -
precision: 0.5938 - recall: 0.5662 - val_accuracy: 0.6080 - val_auc: 0.6654 -
val_bin_accuracy: 0.6080 - val_loss: 1.8209 - val_precision: 0.6181 -
val_recall: 0.6325 - learning_rate: 1.0000e-04
Epoch 3/40

2025-04-13 04:29:42.787078: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7511 of 8000

  3/500            30s 62ms/step - accuracy:
0.4410 - auc: 0.4606 - bin_accuracy: 0.4410 - loss: 1.9114 - precision: 0.4640 -
recall: 0.4303

2025-04-13 04:29:43.332852: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.6146 - auc: 0.6444 - bin_accuracy: 0.6146 - loss: 1.7005 -
precision: 0.6152 - recall: 0.5868 - val_accuracy: 0.6130 - val_auc: 0.6757 -
val_bin_accuracy: 0.6130 - val_loss: 1.3762 - val_precision: 0.5923 -
val_recall: 0.8066 - learning_rate: 1.0000e-04
Epoch 4/40

2025-04-13 04:30:24.793782: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7535 of 8000

  3/500            30s 61ms/step - accuracy:
0.6215 - auc: 0.6581 - bin_accuracy: 0.6215 - loss: 1.3809 - precision: 0.6379 -
recall: 0.6799

2025-04-13 04:30:25.212178: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.6251 - auc: 0.6662 - bin_accuracy: 0.6251 - loss: 1.2952 -
precision: 0.6356 - recall: 0.6159 - val_accuracy: 0.6160 - val_auc: 0.6883 -
val_bin_accuracy: 0.6160 - val_loss: 1.1142 - val_precision: 0.7125 -
val_recall: 0.4313 - learning_rate: 1.0000e-04
Epoch 5/40

2025-04-13 04:31:06.685108: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7678 of 8000

  3/500            30s 62ms/step - accuracy:
0.5556 - auc: 0.7304 - bin_accuracy: 0.5556 - loss: 1.0721 - precision: 0.6710 -
recall: 0.4542
```

```
2025-04-13 04:31:06.927639: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.6319 - auc: 0.6818 - bin_accuracy: 0.6319 - loss: 1.0485 -
precision: 0.6346 - recall: 0.6033 - val_accuracy: 0.6390 - val_auc: 0.6874 -
val_bin_accuracy: 0.6390 - val_loss: 0.9329 - val_precision: 0.6718 -
val_recall: 0.5899 - learning_rate: 1.0000e-04
Epoch 6/40

2025-04-13 04:31:48.489370: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7471 of 8000

  3/500            30s 61ms/step - accuracy:
0.6701 - auc: 0.7123 - bin_accuracy: 0.6701 - loss: 0.9164 - precision: 0.7468 -
recall: 0.6290

2025-04-13 04:31:48.939325: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.6475 - auc: 0.6998 - bin_accuracy: 0.6475 - loss: 0.8922 -
precision: 0.6495 - recall: 0.6396 - val_accuracy: 0.6590 - val_auc: 0.7063 -
val_bin_accuracy: 0.6590 - val_loss: 0.8165 - val_precision: 0.6492 -
val_recall: 0.7408 - learning_rate: 1.0000e-04
Epoch 7/40

2025-04-13 04:32:30.487078: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7698 of 8000

  3/500            29s 59ms/step - accuracy:
0.8021 - auc: 0.8216 - bin_accuracy: 0.8021 - loss: 0.7756 - precision: 0.6991 -
recall: 0.8694

2025-04-13 04:32:30.721189: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.6637 - auc: 0.7121 - bin_accuracy: 0.6637 - loss: 0.7949 -
precision: 0.6669 - recall: 0.6835 - val_accuracy: 0.4990 - val_auc: 0.6916 -
val_bin_accuracy: 0.4990 - val_loss: 0.9768 - val_precision: 0.8333 -
val_recall: 0.0387 - learning_rate: 1.0000e-04
Epoch 8/40
500/500            41s 63ms/step -
accuracy: 0.6531 - auc: 0.6974 - bin_accuracy: 0.6531 - loss: 0.7484 -
precision: 0.6596 - recall: 0.6624 - val_accuracy: 0.6580 - val_auc: 0.7162 -
val_bin_accuracy: 0.6580 - val_loss: 0.7078 - val_precision: 0.6636 -
val_recall: 0.6867 - learning_rate: 1.0000e-04
Epoch 9/40
500/500            41s 63ms/step -
```

```
accuracy: 0.6617 - auc: 0.7143 - bin_accuracy: 0.6617 - loss: 0.7041 -
precision: 0.6665 - recall: 0.6751 - val_accuracy: 0.6510 - val_auc: 0.7135 -
val_bin_accuracy: 0.6510 - val_loss: 0.6959 - val_precision: 0.6935 -
val_recall: 0.5822 - learning_rate: 1.0000e-04
Epoch 10/40

2025-04-13 04:34:34.985924: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7477 of 8000

  3/500             29s 60ms/step - accuracy:
0.7535 - auc: 0.8269 - bin_accuracy: 0.7535 - loss: 0.6249 - precision: 0.7016 -
recall: 0.8111

2025-04-13 04:34:35.521030: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             42s 63ms/step -
accuracy: 0.6666 - auc: 0.7225 - bin_accuracy: 0.6666 - loss: 0.6766 -
precision: 0.6611 - recall: 0.6779 - val_accuracy: 0.6650 - val_auc: 0.7131 -
val_bin_accuracy: 0.6650 - val_loss: 0.6750 - val_precision: 0.6417 -
val_recall: 0.7969 - learning_rate: 1.0000e-04
Epoch 11/40

2025-04-13 04:35:17.084738: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7285 of 8000

  3/500             29s 60ms/step - accuracy:
0.7083 - auc: 0.8824 - bin_accuracy: 0.7083 - loss: 0.5905 - precision: 0.5787 -
recall: 0.8333

2025-04-13 04:35:17.807511: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             42s 63ms/step -
accuracy: 0.6737 - auc: 0.7330 - bin_accuracy: 0.6737 - loss: 0.6562 -
precision: 0.6596 - recall: 0.6902 - val_accuracy: 0.6450 - val_auc: 0.7132 -
val_bin_accuracy: 0.6450 - val_loss: 0.6793 - val_precision: 0.7056 -
val_recall: 0.5377 - learning_rate: 1.0000e-04
Epoch 12/40
500/500             41s 63ms/step -
accuracy: 0.6869 - auc: 0.7434 - bin_accuracy: 0.6869 - loss: 0.6381 -
precision: 0.6815 - recall: 0.7059 - val_accuracy: 0.4830 - val_auc: 0.5880 -
val_bin_accuracy: 0.4830 - val_loss: 1.7560 - val_precision: 0.5000 -
val_recall: 0.0116 - learning_rate: 1.0000e-04
Epoch 13/40
500/500             41s 63ms/step -
accuracy: 0.6962 - auc: 0.7528 - bin_accuracy: 0.6962 - loss: 0.6250 -
precision: 0.6892 - recall: 0.6815 - val_accuracy: 0.4970 - val_auc: 0.7300 -
val_bin_accuracy: 0.4970 - val_loss: 1.0843 - val_precision: 0.9375 -
```

```
val_recall: 0.0290 - learning_rate: 1.0000e-04
Epoch 14/40

2025-04-13 04:37:22.184767: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7727 of 8000
2025-04-13 04:37:22.327864: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.7037 - auc: 0.7629 - bin_accuracy: 0.7037 - loss: 0.6109 -
precision: 0.7020 - recall: 0.7228 - val_accuracy: 0.6960 - val_auc: 0.7563 -
val_bin_accuracy: 0.6960 - val_loss: 0.6222 - val_precision: 0.6885 -
val_recall: 0.7524 - learning_rate: 5.0000e-05
Epoch 15/40
500/500            41s 63ms/step -
accuracy: 0.7073 - auc: 0.7713 - bin_accuracy: 0.7073 - loss: 0.6011 -
precision: 0.7094 - recall: 0.6917 - val_accuracy: 0.6910 - val_auc: 0.7598 -
val_bin_accuracy: 0.6910 - val_loss: 0.6348 - val_precision: 0.7353 -
val_recall: 0.6286 - learning_rate: 5.0000e-05
Epoch 16/40

2025-04-13 04:38:44.984699: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7650 of 8000

  3/500            30s 61ms/step - accuracy:
0.7431 - auc: 0.7720 - bin_accuracy: 0.7431 - loss: 0.5937 - precision: 0.7302 -
recall: 0.7345

2025-04-13 04:38:45.207489: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.7111 - auc: 0.7738 - bin_accuracy: 0.7111 - loss: 0.5974 -
precision: 0.7128 - recall: 0.7017 - val_accuracy: 0.6090 - val_auc: 0.7133 -
val_bin_accuracy: 0.6090 - val_loss: 0.7650 - val_precision: 0.7480 -
val_recall: 0.3675 - learning_rate: 5.0000e-05
Epoch 17/40

2025-04-13 04:39:26.698629: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7336 of 8000

  3/500            31s 64ms/step - accuracy:
0.7083 - auc: 0.8132 - bin_accuracy: 0.7083 - loss: 0.5851 - precision: 0.6069 -
recall: 0.7980

2025-04-13 04:39:27.515106: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.7203 - auc: 0.7851 - bin_accuracy: 0.7203 - loss: 0.5877 -
```

```
precision: 0.7152 - recall: 0.7231 - val_accuracy: 0.6340 - val_auc: 0.7425 -
val_bin_accuracy: 0.6340 - val_loss: 0.7701 - val_precision: 0.6005 -
val_recall: 0.8723 - learning_rate: 5.0000e-05
Epoch 18/40
  2/500             30s 61ms/step - accuracy:
0.7812 - auc: 0.7310 - bin_accuracy: 0.7812 - loss: 0.5927 - precision: 0.7411 -
recall: 0.7917

2025-04-13 04:40:08.884827: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7810 of 8000
2025-04-13 04:40:08.925697: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             42s 63ms/step -
accuracy: 0.7339 - auc: 0.7956 - bin_accuracy: 0.7339 - loss: 0.5735 -
precision: 0.7299 - recall: 0.7317 - val_accuracy: 0.6680 - val_auc: 0.7685 -
val_bin_accuracy: 0.6680 - val_loss: 0.6679 - val_precision: 0.6316 -
val_recall: 0.8588 - learning_rate: 2.5000e-05
Epoch 19/40
  1/500             1:25:21 10s/step -
accuracy: 0.7500 - auc: 0.7656 - bin_accuracy: 0.7500 - loss: 0.6027 -
precision: 0.7500 - recall: 0.7500

2025-04-13 04:40:50.508352: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7897 of 8000
2025-04-13 04:40:50.600357: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             42s 63ms/step -
accuracy: 0.7282 - auc: 0.7973 - bin_accuracy: 0.7282 - loss: 0.5724 -
precision: 0.7276 - recall: 0.7246 - val_accuracy: 0.7000 - val_auc: 0.7751 -
val_bin_accuracy: 0.7000 - val_loss: 0.6377 - val_precision: 0.6667 -
val_recall: 0.8395 - learning_rate: 2.5000e-05
Epoch 20/40

2025-04-13 04:41:32.284680: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7705 of 8000
2025-04-13 04:41:32.422846: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             42s 63ms/step -
accuracy: 0.7320 - auc: 0.7971 - bin_accuracy: 0.7320 - loss: 0.5714 -
precision: 0.7210 - recall: 0.7253 - val_accuracy: 0.6380 - val_auc: 0.7563 -
val_bin_accuracy: 0.6380 - val_loss: 0.7325 - val_precision: 0.5982 -
val_recall: 0.9130 - learning_rate: 2.5000e-05
Epoch 21/40

2025-04-13 04:42:13.887818: I
```

```
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7706 of 8000

  3/500            30s 61ms/step - accuracy:
0.8403 - auc: 0.8713 - bin_accuracy: 0.8403 - loss: 0.4953 - precision: 0.8271 -
recall: 0.8794

2025-04-13 04:42:14.111610: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.7358 - auc: 0.8031 - bin_accuracy: 0.7358 - loss: 0.5646 -
precision: 0.7407 - recall: 0.7335 - val_accuracy: 0.7070 - val_auc: 0.7771 -
val_bin_accuracy: 0.7070 - val_loss: 0.6498 - val_precision: 0.6860 -
val_recall: 0.7988 - learning_rate: 1.2500e-05
Epoch 22/40

2025-04-13 04:42:55.584505: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7764 of 8000
2025-04-13 04:42:55.725407: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.7393 - auc: 0.8018 - bin_accuracy: 0.7393 - loss: 0.5671 -
precision: 0.7404 - recall: 0.7327 - val_accuracy: 0.6970 - val_auc: 0.7792 -
val_bin_accuracy: 0.6970 - val_loss: 0.6681 - val_precision: 0.6693 -
val_recall: 0.8182 - learning_rate: 1.2500e-05
Epoch 23/40
  2/500            31s 63ms/step - accuracy:
0.4531 - auc: 0.6341 - bin_accuracy: 0.4531 - loss: 0.7293 - precision: 0.3229 -
recall: 0.4773

2025-04-13 04:43:37.294363: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7875 of 8000
2025-04-13 04:43:37.319830: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            41s 63ms/step -
accuracy: 0.7410 - auc: 0.8129 - bin_accuracy: 0.7410 - loss: 0.5532 -
precision: 0.7439 - recall: 0.7340 - val_accuracy: 0.6940 - val_auc: 0.7734 -
val_bin_accuracy: 0.6940 - val_loss: 0.6744 - val_precision: 0.6596 -
val_recall: 0.8433 - learning_rate: 1.2500e-05
Epoch 24/40

2025-04-13 04:44:18.785230: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53375:
Filling up shuffle buffer (this may take a while): 7402 of 8000

  3/500            29s 60ms/step - accuracy:
0.9062 - auc: 0.9523 - bin_accuracy: 0.9062 - loss: 0.4429 - precision: 0.8581 -
```

```
recall: 0.9087

2025-04-13 04:44:19.397155: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.7379 - auc: 0.8086 - bin_accuracy: 0.7379 - loss: 0.5607 -
precision: 0.7418 - recall: 0.7341 - val_accuracy: 0.6820 - val_auc: 0.7762 -
val_bin_accuracy: 0.6820 - val_loss: 0.7372 - val_precision: 0.6396 -
val_recall: 0.8820 - learning_rate: 6.2500e-06
Model 2 trained successfully
Saved to keras file /workspace/chest/drive/MyDrive/AAI-590_Collabs/model_2.keras
and /workspace/chest/drive/MyDrive/AAI-590_Collabs/model_2_history.json
Epoch 1/40

2025-04-13 04:45:10.199941: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53392:
Filling up shuffle buffer (this may take a while): 7873 of 8000
2025-04-13 04:45:10.235064: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            67s 70ms/step -
accuracy: 0.5251 - auc: 0.5351 - bin_accuracy: 0.5251 - loss: 3.5626 -
precision: 0.5334 - recall: 0.4974 - val_accuracy: 0.6030 - val_auc: 0.6521 -
val_bin_accuracy: 0.6030 - val_loss: 2.6594 - val_precision: 0.6456 -
val_recall: 0.5145 - learning_rate: 1.0000e-04
Epoch 2/40

2025-04-13 04:46:08.009792: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53392:
Filling up shuffle buffer (this may take a while): 7381 of 8000

  3/500            30s 61ms/step - accuracy:
0.6736 - auc: 0.6669 - bin_accuracy: 0.6736 - loss: 2.6395 - precision: 0.7064 -
recall: 0.6514

2025-04-13 04:46:08.636057: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.5884 - auc: 0.6145 - bin_accuracy: 0.5884 - loss: 2.4605 -
precision: 0.5884 - recall: 0.5531 - val_accuracy: 0.6020 - val_auc: 0.6516 -
val_bin_accuracy: 0.6020 - val_loss: 1.9195 - val_precision: 0.6280 -
val_recall: 0.5648 - learning_rate: 1.0000e-04
Epoch 3/40
500/500            41s 62ms/step -
accuracy: 0.6040 - auc: 0.6314 - bin_accuracy: 0.6040 - loss: 1.7993 -
precision: 0.6012 - recall: 0.5865 - val_accuracy: 0.6040 - val_auc: 0.6512 -
val_bin_accuracy: 0.6040 - val_loss: 1.4531 - val_precision: 0.6118 -
val_recall: 0.6402 - learning_rate: 1.0000e-04
Epoch 4/40
```

```
2025-04-13 04:47:31.398821: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53392:
Filling up shuffle buffer (this may take a while): 7768 of 8000
2025-04-13 04:47:31.530043: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.6121 - auc: 0.6442 - bin_accuracy: 0.6121 - loss: 1.3758 -
precision: 0.6153 - recall: 0.6250 - val_accuracy: 0.6030 - val_auc: 0.6531 -
val_bin_accuracy: 0.6030 - val_loss: 1.1589 - val_precision: 0.6149 -
val_recall: 0.6209 - learning_rate: 1.0000e-04
Epoch 5/40
  3/500            30s 62ms/step - accuracy:
0.5174 - auc: 0.5241 - bin_accuracy: 0.5174 - loss: 1.2273 - precision: 0.4356 -
recall: 0.5472

2025-04-13 04:48:12.989698: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53392:
Filling up shuffle buffer (this may take a while): 7944 of 8000
2025-04-13 04:48:12.990504: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            41s 62ms/step -
accuracy: 0.6093 - auc: 0.6485 - bin_accuracy: 0.6093 - loss: 1.1108 -
precision: 0.6103 - recall: 0.6094 - val_accuracy: 0.6060 - val_auc: 0.6559 -
val_bin_accuracy: 0.6060 - val_loss: 0.9697 - val_precision: 0.6171 -
val_recall: 0.6267 - learning_rate: 1.0000e-04
Epoch 6/40
500/500            41s 63ms/step -
accuracy: 0.6190 - auc: 0.6472 - bin_accuracy: 0.6190 - loss: 0.9407 -
precision: 0.6045 - recall: 0.6257 - val_accuracy: 0.6100 - val_auc: 0.6530 -
val_bin_accuracy: 0.6100 - val_loss: 0.8515 - val_precision: 0.6053 -
val_recall: 0.7060 - learning_rate: 1.0000e-04
Epoch 7/40

2025-04-13 04:49:35.694143: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53392:
Filling up shuffle buffer (this may take a while): 7721 of 8000

  3/500            30s 61ms/step - accuracy:
0.5694 - auc: 0.6197 - bin_accuracy: 0.5694 - loss: 0.8716 - precision: 0.5390 -
recall: 0.7609

2025-04-13 04:49:35.912525: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.6069 - auc: 0.6469 - bin_accuracy: 0.6069 - loss: 0.8351 -
precision: 0.6010 - recall: 0.6452 - val_accuracy: 0.6110 - val_auc: 0.6560 -
val_bin_accuracy: 0.6110 - val_loss: 0.7783 - val_precision: 0.6067 -
val_recall: 0.7041 - learning_rate: 1.0000e-04
```

```
Epoch 8/40
  1/500             1:25:25 10s/step -
accuracy: 0.6250 - auc: 0.7500 - bin_accuracy: 0.6250 - loss: 0.7425 -
precision: 0.7500 - recall: 0.6000

2025-04-13 04:50:17.400510: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53392:
Filling up shuffle buffer (this may take a while): 7868 of 8000
2025-04-13 04:50:17.489394: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            41s 62ms/step -
accuracy: 0.6031 - auc: 0.6388 - bin_accuracy: 0.6031 - loss: 0.7741 -
precision: 0.5996 - recall: 0.6355 - val_accuracy: 0.6120 - val_auc: 0.6550 -
val_bin_accuracy: 0.6120 - val_loss: 0.7359 - val_precision: 0.6073 -
val_recall: 0.7060 - learning_rate: 1.0000e-04
Epoch 9/40
500/500            42s 63ms/step -
accuracy: 0.6170 - auc: 0.6574 - bin_accuracy: 0.6170 - loss: 0.7283 -
precision: 0.6054 - recall: 0.6476 - val_accuracy: 0.6060 - val_auc: 0.6526 -
val_bin_accuracy: 0.6060 - val_loss: 0.7174 - val_precision: 0.5890 -
val_recall: 0.7872 - learning_rate: 1.0000e-04
Epoch 10/40
  1/500             1:25:56 10s/step -
accuracy: 0.3750 - auc: 0.4250 - bin_accuracy: 0.3750 - loss: 0.8036 -
precision: 0.3000 - recall: 0.5000

2025-04-13 04:51:40.488031: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53392:
Filling up shuffle buffer (this may take a while): 7697 of 8000
2025-04-13 04:51:40.622871: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            41s 62ms/step -
accuracy: 0.6215 - auc: 0.6570 - bin_accuracy: 0.6215 - loss: 0.7060 -
precision: 0.6109 - recall: 0.6729 - val_accuracy: 0.6270 - val_auc: 0.6755 -
val_bin_accuracy: 0.6270 - val_loss: 0.6845 - val_precision: 0.6319 -
val_recall: 0.6673 - learning_rate: 1.0000e-04
Model 3 trained successfully
Saved to keras file /workspace/chest/drive/MyDrive/AAI-590_Collabs/model_3.keras
and /workspace/chest/drive/MyDrive/AAI-590_Collabs/model_3_history.json
Epoch 1/40

2025-04-13 04:52:28.092104: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53409:
Filling up shuffle buffer (this may take a while): 7720 of 8000
2025-04-13 04:52:28.306830: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            62s 67ms/step -
accuracy: 0.4971 - auc: 0.4939 - bin_accuracy: 0.4971 - loss: 3.5780 -
```

```
precision: 0.5014 - recall: 0.4725 - val_accuracy: 0.5490 - val_auc: 0.5591 -
val_bin_accuracy: 0.5490 - val_loss: 2.6876 - val_precision: 0.5618 -
val_recall: 0.5803 - learning_rate: 1.0000e-04
Epoch 2/40
  2/500             30s 61ms/step - accuracy:
0.5625 - auc: 0.5571 - bin_accuracy: 0.5625 - loss: 2.6844 - precision: 0.6571 -
recall: 0.5147

2025-04-13 04:53:24.186104: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53409:
Filling up shuffle buffer (this may take a while): 7905 of 8000
2025-04-13 04:53:24.215613: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             42s 63ms/step -
accuracy: 0.5183 - auc: 0.5255 - bin_accuracy: 0.5183 - loss: 2.5002 -
precision: 0.5112 - recall: 0.4920 - val_accuracy: 0.5290 - val_auc: 0.5631 -
val_bin_accuracy: 0.5290 - val_loss: 1.9680 - val_precision: 0.5669 -
val_recall: 0.3772 - learning_rate: 1.0000e-04
Epoch 3/40
  1/500             1:25:35 10s/step -
accuracy: 0.3750 - auc: 0.4545 - bin_accuracy: 0.3750 - loss: 2.0365 -
precision: 0.2222 - recall: 0.4000

2025-04-13 04:54:05.890154: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53409:
Filling up shuffle buffer (this may take a while): 7767 of 8000
2025-04-13 04:54:06.017832: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             42s 63ms/step -
accuracy: 0.5174 - auc: 0.5364 - bin_accuracy: 0.5174 - loss: 1.8411 -
precision: 0.5234 - recall: 0.5605 - val_accuracy: 0.5470 - val_auc: 0.5578 -
val_bin_accuracy: 0.5470 - val_loss: 1.4949 - val_precision: 0.5409 -
val_recall: 0.8182 - learning_rate: 1.0000e-04
Epoch 4/40
  2/500             31s 63ms/step - accuracy:
0.5156 - auc: 0.5873 - bin_accuracy: 0.5156 - loss: 1.5017 - precision: 0.5146 -
recall: 0.5992

2025-04-13 04:54:47.604435: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53409:
Filling up shuffle buffer (this may take a while): 7857 of 8000
2025-04-13 04:54:47.622484: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             42s 63ms/step -
accuracy: 0.5234 - auc: 0.5344 - bin_accuracy: 0.5234 - loss: 1.4155 -
precision: 0.5281 - recall: 0.5377 - val_accuracy: 0.5400 - val_auc: 0.5584 -
val_bin_accuracy: 0.5400 - val_loss: 1.1908 - val_precision: 0.5583 -
val_recall: 0.5280 - learning_rate: 1.0000e-04
```

```
Epoch 5/40
500/500             41s 63ms/step -
accuracy: 0.5295 - auc: 0.5482 - bin_accuracy: 0.5295 - loss: 1.1386 -
precision: 0.5305 - recall: 0.5128 - val_accuracy: 0.5310 - val_auc: 0.5451 -
val_bin_accuracy: 0.5310 - val_loss: 1.0013 - val_precision: 0.5435 -
val_recall: 0.5803 - learning_rate: 1.0000e-04
Epoch 6/40

2025-04-13 04:56:10.186180: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53409:
Filling up shuffle buffer (this may take a while): 7606 of 8000

  3/500             30s 61ms/step - accuracy:
0.4896 - auc: 0.4348 - bin_accuracy: 0.4896 - loss: 1.0297 - precision: 0.5111 -
recall: 0.5079

2025-04-13 04:56:10.516626: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             42s 63ms/step -
accuracy: 0.5370 - auc: 0.5459 - bin_accuracy: 0.5370 - loss: 0.9683 -
precision: 0.5281 - recall: 0.4759 - val_accuracy: 0.5310 - val_auc: 0.5685 -
val_bin_accuracy: 0.5310 - val_loss: 0.8812 - val_precision: 0.5774 -
val_recall: 0.3462 - learning_rate: 1.0000e-04
Epoch 7/40
  3/500             29s 59ms/step - accuracy:
0.4410 - auc: 0.4519 - bin_accuracy: 0.4410 - loss: 0.8976 - precision: 0.4978 -
recall: 0.3689

2025-04-13 04:56:51.996767: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53409:
Filling up shuffle buffer (this may take a while): 7929 of 8000
2025-04-13 04:56:52.004552: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             41s 63ms/step -
accuracy: 0.5361 - auc: 0.5508 - bin_accuracy: 0.5361 - loss: 0.8619 -
precision: 0.5383 - recall: 0.5396 - val_accuracy: 0.5380 - val_auc: 0.5531 -
val_bin_accuracy: 0.5380 - val_loss: 0.8100 - val_precision: 0.5473 -
val_recall: 0.6151 - learning_rate: 1.0000e-04
Epoch 8/40

2025-04-13 04:57:33.388603: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53409:
Filling up shuffle buffer (this may take a while): 7517 of 8000

  3/500             30s 62ms/step - accuracy:
0.5382 - auc: 0.5893 - bin_accuracy: 0.5382 - loss: 0.8058 - precision: 0.4375 -
recall: 0.5462

2025-04-13 04:57:33.791977: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.
```

```
500/500            42s 62ms/step -
accuracy: 0.5557 - auc: 0.5730 - bin_accuracy: 0.5557 - loss: 0.7942 -
precision: 0.5545 - recall: 0.5214 - val_accuracy: 0.5160 - val_auc: 0.5683 -
val_bin_accuracy: 0.5160 - val_loss: 0.7684 - val_precision: 0.6025 -
val_recall: 0.1876 - learning_rate: 1.0000e-04
Epoch 9/40

2025-04-13 04:58:15.090301: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53409:
Filling up shuffle buffer (this may take a while): 7647 of 8000

  2/500            31s 63ms/step - accuracy:
0.6562 - auc: 0.7589 - bin_accuracy: 0.6562 - loss: 0.7315 - precision: 0.5778 -
recall: 0.7917

2025-04-13 04:58:15.325912: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 62ms/step -
accuracy: 0.5367 - auc: 0.5550 - bin_accuracy: 0.5367 - loss: 0.7581 -
precision: 0.5318 - recall: 0.5383 - val_accuracy: 0.5480 - val_auc: 0.5627 -
val_bin_accuracy: 0.5480 - val_loss: 0.7401 - val_precision: 0.5386 -
val_recall: 0.8762 - learning_rate: 1.0000e-04
Epoch 10/40
  1/500            1:26:04 10s/step -
accuracy: 0.6875 - auc: 0.8646 - bin_accuracy: 0.6875 - loss: 0.6982 -
precision: 1.0000 - recall: 0.5833

2025-04-13 04:58:56.787334: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53409:
Filling up shuffle buffer (this may take a while): 7716 of 8000
2025-04-13 04:58:56.907404: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 62ms/step -
accuracy: 0.5611 - auc: 0.5815 - bin_accuracy: 0.5611 - loss: 0.7324 -
precision: 0.5588 - recall: 0.5451 - val_accuracy: 0.5490 - val_auc: 0.5560 -
val_bin_accuracy: 0.5490 - val_loss: 0.7257 - val_precision: 0.5388 -
val_recall: 0.8859 - learning_rate: 1.0000e-04
Model 4 trained successfully
Saved to keras file /workspace/chest/drive/MyDrive/AAI-590_Collabs/model_4.keras
and /workspace/chest/drive/MyDrive/AAI-590_Collabs/model_4_history.json
Epoch 1/40
125/125            45s 179ms/step -
accuracy: 0.5346 - auc: 0.5252 - bin_accuracy: 0.5346 - loss: 3.8055 -
precision: 0.5514 - recall: 0.5444 - val_accuracy: 0.5141 - val_auc: 0.5717 -
val_bin_accuracy: 0.5141 - val_loss: 3.4436 - val_precision: 0.5141 -
val_recall: 1.0000 - learning_rate: 1.0000e-04
Epoch 2/40
125/125            11s 64ms/step -
accuracy: 0.5839 - auc: 0.6117 - bin_accuracy: 0.5839 - loss: 3.3244 -
```

```
precision: 0.5943 - recall: 0.6200 - val_accuracy: 0.5261 - val_auc: 0.6092 -
val_bin_accuracy: 0.5261 - val_loss: 3.0897 - val_precision: 0.5203 -
val_recall: 1.0000 - learning_rate: 1.0000e-04
Epoch 3/40
125/125            10s 63ms/step -
accuracy: 0.5841 - auc: 0.6098 - bin_accuracy: 0.5841 - loss: 3.0105 -
precision: 0.6008 - recall: 0.5704 - val_accuracy: 0.5904 - val_auc: 0.6227 -
val_bin_accuracy: 0.5904 - val_loss: 2.7872 - val_precision: 0.5915 -
val_recall: 0.6562 - learning_rate: 1.0000e-04
Epoch 4/40
125/125            11s 63ms/step -
accuracy: 0.5886 - auc: 0.6217 - bin_accuracy: 0.5886 - loss: 2.7293 -
precision: 0.5985 - recall: 0.5547 - val_accuracy: 0.6345 - val_auc: 0.6672 -
val_bin_accuracy: 0.6345 - val_loss: 2.5324 - val_precision: 0.6370 -
val_recall: 0.6719 - learning_rate: 1.0000e-04
Epoch 5/40
125/125            10s 63ms/step -
accuracy: 0.5699 - auc: 0.6154 - bin_accuracy: 0.5699 - loss: 2.4950 -
precision: 0.5662 - recall: 0.5202 - val_accuracy: 0.5904 - val_auc: 0.6645 -
val_bin_accuracy: 0.5904 - val_loss: 2.3166 - val_precision: 0.6204 -
val_recall: 0.5234 - learning_rate: 1.0000e-04
Epoch 6/40
125/125            11s 64ms/step -
accuracy: 0.6128 - auc: 0.6668 - bin_accuracy: 0.6128 - loss: 2.2649 -
precision: 0.6037 - recall: 0.6495 - val_accuracy: 0.6305 - val_auc: 0.6624 -
val_bin_accuracy: 0.6305 - val_loss: 2.1305 - val_precision: 0.6023 -
val_recall: 0.8281 - learning_rate: 1.0000e-04
Epoch 7/40
125/125            11s 63ms/step -
accuracy: 0.5963 - auc: 0.6352 - bin_accuracy: 0.5963 - loss: 2.0968 -
precision: 0.6005 - recall: 0.6733 - val_accuracy: 0.5863 - val_auc: 0.6548 -
val_bin_accuracy: 0.5863 - val_loss: 1.9625 - val_precision: 0.6068 -
val_recall: 0.5547 - learning_rate: 1.0000e-04
Epoch 8/40
125/125            10s 63ms/step -
accuracy: 0.6413 - auc: 0.6892 - bin_accuracy: 0.6413 - loss: 1.9126 -
precision: 0.6537 - recall: 0.5915 - val_accuracy: 0.5863 - val_auc: 0.6514 -
val_bin_accuracy: 0.5863 - val_loss: 1.8157 - val_precision: 0.6000 -
val_recall: 0.5859 - learning_rate: 1.0000e-04
Epoch 9/40
125/125            10s 64ms/step -
accuracy: 0.6534 - auc: 0.6925 - bin_accuracy: 0.6534 - loss: 1.7719 -
precision: 0.6554 - recall: 0.6593 - val_accuracy: 0.6225 - val_auc: 0.6619 -
val_bin_accuracy: 0.6225 - val_loss: 1.6864 - val_precision: 0.6269 -
val_recall: 0.6562 - learning_rate: 1.0000e-04
Epoch 10/40
125/125            10s 64ms/step -
accuracy: 0.6327 - auc: 0.6859 - bin_accuracy: 0.6327 - loss: 1.6517 -
```

```
precision: 0.6182 - recall: 0.6513 - val_accuracy: 0.5301 - val_auc: 0.6840 -
val_bin_accuracy: 0.5301 - val_loss: 1.7169 - val_precision: 0.7037 -
val_recall: 0.1484 - learning_rate: 1.0000e-04
Model 5 trained successfully
Saved to keras file /workspace/chest/drive/MyDrive/AAI-590_Collabs/model_5.keras
and /workspace/chest/drive/MyDrive/AAI-590_Collabs/model_5_history.json
Epoch 1/40
16/16             35s 1s/step -
accuracy: 0.4882 - auc: 0.4839 - bin_accuracy: 0.4882 - loss: 4.0206 -
precision: 0.4750 - recall: 0.6606 - val_accuracy: 0.4839 - val_auc: 0.4333 -
val_bin_accuracy: 0.4839 - val_loss: 3.8275 - val_precision: 0.4839 -
val_recall: 1.0000 - learning_rate: 1.0000e-04
Epoch 2/40
16/16             2s 69ms/step -
accuracy: 0.5330 - auc: 0.5339 - bin_accuracy: 0.5330 - loss: 3.8308 -
precision: 0.5331 - recall: 0.5709 - val_accuracy: 0.6129 - val_auc: 0.5750 -
val_bin_accuracy: 0.6129 - val_loss: 3.7247 - val_precision: 0.5652 -
val_recall: 0.8667 - learning_rate: 1.0000e-04
Epoch 3/40
16/16             2s 71ms/step -
accuracy: 0.5052 - auc: 0.5260 - bin_accuracy: 0.5052 - loss: 3.7578 -
precision: 0.5665 - recall: 0.5869 - val_accuracy: 0.5806 - val_auc: 0.6146 -
val_bin_accuracy: 0.5806 - val_loss: 3.6686 - val_precision: 0.5417 -
val_recall: 0.8667 - learning_rate: 1.0000e-04
Epoch 4/40
16/16             1s 70ms/step -
accuracy: 0.5937 - auc: 0.6051 - bin_accuracy: 0.5937 - loss: 3.6629 -
precision: 0.5797 - recall: 0.6145 - val_accuracy: 0.5806 - val_auc: 0.6562 -
val_bin_accuracy: 0.5806 - val_loss: 3.6166 - val_precision: 0.5417 -
val_recall: 0.8667 - learning_rate: 1.0000e-04
Epoch 5/40
16/16             2s 71ms/step -
accuracy: 0.6461 - auc: 0.6999 - bin_accuracy: 0.6461 - loss: 3.5491 -
precision: 0.6874 - recall: 0.6550 - val_accuracy: 0.5484 - val_auc: 0.7021 -
val_bin_accuracy: 0.5484 - val_loss: 3.5642 - val_precision: 0.5172 -
val_recall: 1.0000 - learning_rate: 1.0000e-04
Epoch 6/40
16/16             2s 71ms/step -
accuracy: 0.6013 - auc: 0.6525 - bin_accuracy: 0.6013 - loss: 3.5425 -
precision: 0.5871 - recall: 0.7223 - val_accuracy: 0.5484 - val_auc: 0.7708 -
val_bin_accuracy: 0.5484 - val_loss: 3.5096 - val_precision: 0.5185 -
val_recall: 0.9333 - learning_rate: 1.0000e-04
Epoch 7/40
16/16             2s 69ms/step -
accuracy: 0.5483 - auc: 0.5970 - bin_accuracy: 0.5483 - loss: 3.5117 -
precision: 0.5231 - recall: 0.5973 - val_accuracy: 0.4839 - val_auc: 0.8354 -
val_bin_accuracy: 0.4839 - val_loss: 3.4583 - val_precision: 0.4839 -
val_recall: 1.0000 - learning_rate: 1.0000e-04
```

```
Epoch 8/40
16/16             2s 71ms/step -
accuracy: 0.6626 - auc: 0.7358 - bin_accuracy: 0.6626 - loss: 3.4029 -
precision: 0.6428 - recall: 0.8002 - val_accuracy: 0.4839 - val_auc: 0.8167 -
val_bin_accuracy: 0.4839 - val_loss: 3.4146 - val_precision: 0.4839 -
val_recall: 1.0000 - learning_rate: 1.0000e-04
Epoch 9/40
16/16             2s 71ms/step -
accuracy: 0.6051 - auc: 0.6412 - bin_accuracy: 0.6051 - loss: 3.4026 -
precision: 0.6311 - recall: 0.5557 - val_accuracy: 0.4839 - val_auc: 0.8417 -
val_bin_accuracy: 0.4839 - val_loss: 3.3703 - val_precision: 0.4839 -
val_recall: 1.0000 - learning_rate: 1.0000e-04
Epoch 10/40
16/16             2s 70ms/step -
accuracy: 0.6399 - auc: 0.7023 - bin_accuracy: 0.6399 - loss: 3.3238 -
precision: 0.6175 - recall: 0.7120 - val_accuracy: 0.5484 - val_auc: 0.8375 -
val_bin_accuracy: 0.5484 - val_loss: 3.3188 - val_precision: 0.5172 -
val_recall: 1.0000 - learning_rate: 1.0000e-04
Model 6 trained successfully
Saved to keras file /workspace/chest/drive/MyDrive/AAI-590_Collabs/model_6.keras
and /workspace/chest/drive/MyDrive/AAI-590_Collabs/model_6_history.json
Epoch 1/40
500/500             62s 69ms/step -
accuracy: 0.5090 - auc: 0.5119 - bin_accuracy: 0.5090 - loss: 3.5037 -
precision: 0.5126 - recall: 0.5445 - val_accuracy: 0.5670 - val_auc: 0.6079 -
val_bin_accuracy: 0.5670 - val_loss: 2.6046 - val_precision: 0.5929 -
val_recall: 0.5184 - learning_rate: 1.0000e-04
Epoch 2/40

2025-04-13 05:03:50.889966: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53460:
Filling up shuffle buffer (this may take a while): 7275 of 8000

  3/500             29s 60ms/step - accuracy:
0.7326 - auc: 0.7405 - bin_accuracy: 0.7326 - loss: 2.5637 - precision: 0.6911 -
recall: 0.6638

2025-04-13 05:03:51.628735: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500             42s 63ms/step -
accuracy: 0.6007 - auc: 0.6228 - bin_accuracy: 0.6007 - loss: 2.4015 -
precision: 0.6004 - recall: 0.5821 - val_accuracy: 0.5750 - val_auc: 0.6189 -
val_bin_accuracy: 0.5750 - val_loss: 1.8830 - val_precision: 0.6139 -
val_recall: 0.4797 - learning_rate: 1.0000e-04
Epoch 3/40

2025-04-13 05:04:33.194562: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53460:
Filling up shuffle buffer (this may take a while): 7687 of 8000
```

```
  3/500             30s 62ms/step - accuracy:
0.6875 - auc: 0.7391 - bin_accuracy: 0.6875 - loss: 1.8403 - precision: 0.7299 -
recall: 0.7558

2025-04-13 05:04:33.413138: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            41s 62ms/step -
accuracy: 0.5983 - auc: 0.6324 - bin_accuracy: 0.5983 - loss: 1.7483 -
precision: 0.5924 - recall: 0.6529 - val_accuracy: 0.5750 - val_auc: 0.6269 -
val_bin_accuracy: 0.5750 - val_loss: 1.4287 - val_precision: 0.6186 -
val_recall: 0.4642 - learning_rate: 1.0000e-04
Epoch 4/40

2025-04-13 05:05:14.585016: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53460:
Filling up shuffle buffer (this may take a while): 7488 of 8000

  2/500             34s 68ms/step - accuracy:
0.5156 - auc: 0.6005 - bin_accuracy: 0.5156 - loss: 1.4718 - precision: 0.5778 -
recall: 0.5941

2025-04-13 05:05:15.021625: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.6176 - auc: 0.6561 - bin_accuracy: 0.6176 - loss: 1.3336 -
precision: 0.6127 - recall: 0.6629 - val_accuracy: 0.6060 - val_auc: 0.6418 -
val_bin_accuracy: 0.6060 - val_loss: 1.1332 - val_precision: 0.6085 -
val_recall: 0.6673 - learning_rate: 1.0000e-04
Epoch 5/40
500/500            41s 63ms/step -
accuracy: 0.6274 - auc: 0.6623 - bin_accuracy: 0.6274 - loss: 1.0757 -
precision: 0.6250 - recall: 0.6355 - val_accuracy: 0.6010 - val_auc: 0.6491 -
val_bin_accuracy: 0.6010 - val_loss: 0.9569 - val_precision: 0.6234 -
val_recall: 0.5764 - learning_rate: 1.0000e-04
Epoch 6/40
500/500            41s 63ms/step -
accuracy: 0.6317 - auc: 0.6784 - bin_accuracy: 0.6317 - loss: 0.9125 -
precision: 0.6295 - recall: 0.6491 - val_accuracy: 0.5980 - val_auc: 0.6651 -
val_bin_accuracy: 0.5980 - val_loss: 0.8500 - val_precision: 0.6456 -
val_recall: 0.4932 - learning_rate: 1.0000e-04
Epoch 7/40
  1/500             1:26:02 10s/step -
accuracy: 0.4375 - auc: 0.4727 - bin_accuracy: 0.4375 - loss: 0.9818 -
precision: 0.3000 - recall: 0.6000

2025-04-13 05:07:19.499298: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53460:
Filling up shuffle buffer (this may take a while): 7806 of 8000
2025-04-13 05:07:19.599972: I
```

```
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.6328 - auc: 0.6766 - bin_accuracy: 0.6328 - loss: 0.8221 -
precision: 0.6236 - recall: 0.6436 - val_accuracy: 0.5180 - val_auc: 0.6717 -
val_bin_accuracy: 0.5180 - val_loss: 0.9318 - val_precision: 0.7869 -
val_recall: 0.0928 - learning_rate: 1.0000e-04
Epoch 8/40
500/500            41s 63ms/step -
accuracy: 0.6380 - auc: 0.6889 - bin_accuracy: 0.6380 - loss: 0.7567 -
precision: 0.6397 - recall: 0.6799 - val_accuracy: 0.5110 - val_auc: 0.6549 -
val_bin_accuracy: 0.5110 - val_loss: 1.0648 - val_precision: 0.8889 -
val_recall: 0.0619 - learning_rate: 1.0000e-04
Epoch 9/40

2025-04-13 05:08:42.500547: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53460:
Filling up shuffle buffer (this may take a while): 7679 of 8000

  3/500            30s 61ms/step - accuracy:
0.6354 - auc: 0.6583 - bin_accuracy: 0.6354 - loss: 0.7341 - precision: 0.5627 -
recall: 0.6939

2025-04-13 05:08:42.808647: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.6454 - auc: 0.6950 - bin_accuracy: 0.6454 - loss: 0.7192 -
precision: 0.6428 - recall: 0.6695 - val_accuracy: 0.6040 - val_auc: 0.7006 -
val_bin_accuracy: 0.6040 - val_loss: 0.7404 - val_precision: 0.7232 -
val_recall: 0.3791 - learning_rate: 1.0000e-04
Epoch 10/40

2025-04-13 05:09:24.391894: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:450] ShuffleDatasetV3:53460:
Filling up shuffle buffer (this may take a while): 7659 of 8000

  3/500            30s 61ms/step - accuracy:
0.7049 - auc: 0.7223 - bin_accuracy: 0.7049 - loss: 0.6785 - precision: 0.6458 -
recall: 0.8246

2025-04-13 05:09:24.620920: I
tensorflow/core/kernels/data/shuffle_dataset_op.cc:480] Shuffle buffer filled.

500/500            42s 63ms/step -
accuracy: 0.6512 - auc: 0.7016 - bin_accuracy: 0.6512 - loss: 0.6916 -
precision: 0.6433 - recall: 0.6652 - val_accuracy: 0.4830 - val_auc: 0.4999 -
val_bin_accuracy: 0.4830 - val_loss: 4.7858 - val_precision: 0.0000e+00 -
val_recall: 0.0000e+00 - learning_rate: 1.0000e-04
Model 7 trained successfully
Saved to keras file /workspace/chest/drive/MyDrive/AAI-590_Collabs/model_7.keras
and /workspace/chest/drive/MyDrive/AAI-590_Collabs/model_7_history.json
```

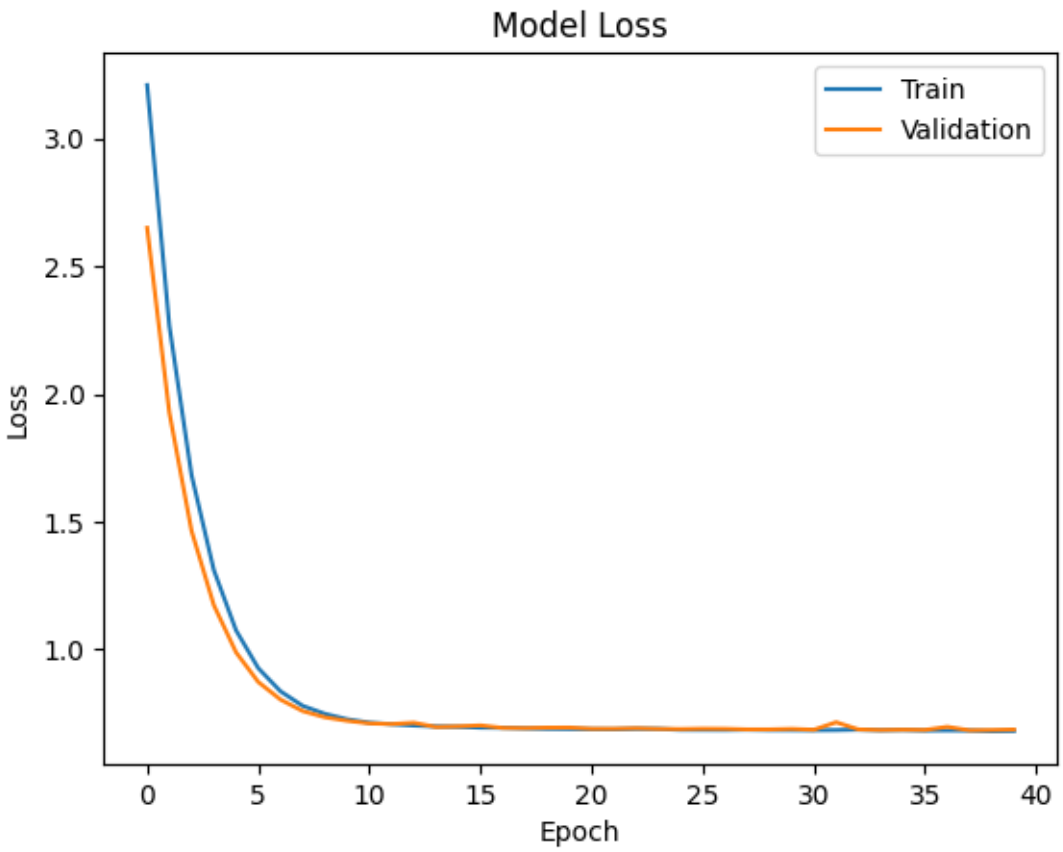
0.6 Model Evaluation

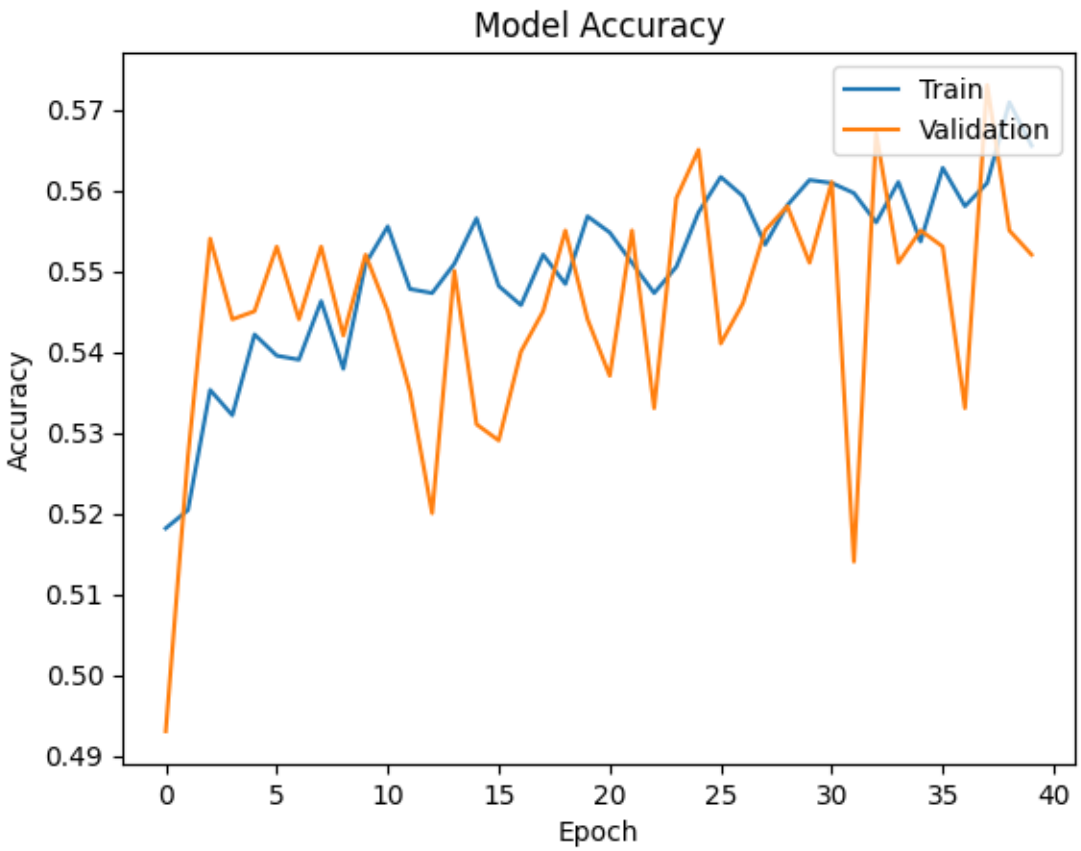
[369]:
```
# tf.keras.backend.clear_session() # Destroys the current TF graph and creates␣
↪a new one
```

[371]:
```
# import classification_report
from sklearn.metrics import classification_report
from sklearn.metrics import accuracy_score, precision_score, recall_score

for i, m_h in enumerate(all_models):
    model, history = m_h
    # Get validation data for the current model
    ds_train, ds_val, ds_test = tasks_datasets[i]

    # Make predictions on the validation set
    results = model.evaluate(ds_val, verbose=1, return_dict=True)

    # plot loss and accuracy
    # history = model.history
    plt.plot(history.history['loss']) # Access the loss from the history object
    plt.plot(history.history['val_loss'])

    plt.title('Model Loss')
    plt.ylabel('Loss')
    plt.xlabel('Epoch')
    plt.legend(['Train', 'Validation'], loc='upper right')
    plt.show()

    # Check if 'accuracy' is in the history keys before plotting
    if 'accuracy' in history.history:
        plt.plot(history.history['accuracy'])
        plt.plot(history.history['val_accuracy'])

        plt.title('Model Accuracy')
        plt.ylabel('Accuracy')
        plt.xlabel('Epoch')
        plt.legend(['Train', 'Validation'], loc='upper right')
        plt.show()
    else:
        print("Accuracy not found in history. Skipping accuracy plot.")

    # Evaluate the model
    print(f"  AUC (ROC): {results.get('auc', 'N/A'):.4f}")
    print(f"  Accuracy:  {results.get('accuracy', 'N/A'):.4f}")
    print(f"  Precision: {results.get('precision', 'N/A'):.4f}")
    print(f"  Recall:    {results.get('recall', 'N/A'):.4f}")
    print(f"  Loss:      {results.get('loss', 'N/A'):.4f}")
    # y_pred = (predictions > 0.5).astype(int)
```

```
    # accuracy = accuracy_score(y_val, y_pred)
    # precision = precision_score(y_val, y_pred)
    # recall = recall_score(y_val, y_pred)
    # print(f"Accuracy: {accuracy}, Precision: {precision}, Recall: {recall}")
    # print(classification_report(y_val, y_pred))

    # Prepare for classification_report
    y_true = []
    y_pred = []

    # Iterate through the validation dataset to get true labels and predictions
    for x_batch, y_batch in ds_val:
        # Get true labels
        y_true.extend(y_batch.numpy())

        # Make predictions
        predictions = model.predict(x_batch)

        # Determine predicted labels based on the model's output
        if predictions.shape[-1] > 1:  # Multi-class classification
            predicted_labels = np.argmax(predictions, axis=-1)
        else:  # Binary classification (assuming sigmoid activation)
            predicted_labels = (predictions > 0.5).astype(int).flatten()
        y_pred.extend(predicted_labels)

    # Generate and print the classification report
    print("\nClassification Report:")
    print(classification_report(y_true, y_pred))
```

```
63/63             2s 29ms/step -
accuracy: 0.5591 - auc: 0.5807 - bin_accuracy: 0.5591 - loss: 0.6864 -
precision: 0.5515 - recall: 0.7697
```


Model Loss
Train
Validation
Loss
Epoch
3.0
2.5
2.0
1.5
1.0
0
5
10
15
20
25
30
35
40




```
  AUC (ROC): 0.5956
  Accuracy:  0.5730
  Precision: 0.5620
  Recall:    0.7892
  Loss:      0.6839
1/1              0s 303ms/step
1/1              0s 61ms/step
1/1              0s 64ms/step
1/1              0s 47ms/step
1/1              0s 52ms/step
1/1              0s 49ms/step
1/1              0s 55ms/step
1/1              0s 48ms/step
1/1              0s 48ms/step
1/1              0s 50ms/step
1/1              0s 58ms/step
1/1              0s 50ms/step
1/1              0s 46ms/step
1/1              0s 49ms/step
1/1              0s 47ms/step
```

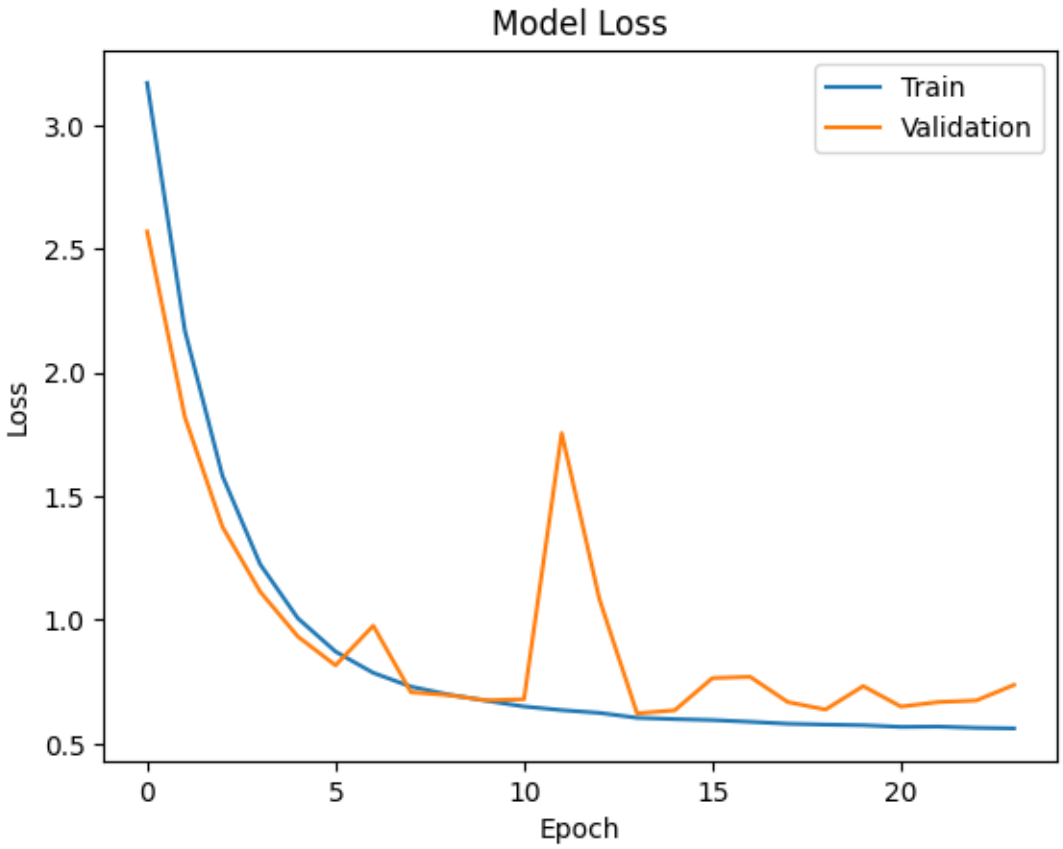
```
1/1             0s 57ms/step
1/1             0s 50ms/step
1/1             0s 48ms/step
1/1             0s 47ms/step
1/1             0s 64ms/step
1/1             0s 67ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 55ms/step
1/1             0s 47ms/step
1/1             0s 71ms/step
1/1             0s 53ms/step
1/1             0s 48ms/step
1/1             0s 47ms/step
1/1             0s 53ms/step
1/1             0s 46ms/step
1/1             0s 64ms/step
1/1             0s 52ms/step
1/1             0s 55ms/step
1/1             0s 46ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
1/1             0s 58ms/step
1/1             0s 48ms/step
1/1             0s 55ms/step
1/1             0s 57ms/step
1/1             0s 51ms/step
1/1             0s 55ms/step
1/1             0s 46ms/step
1/1             0s 61ms/step
1/1             0s 52ms/step
1/1             0s 52ms/step
1/1             0s 52ms/step
1/1             0s 53ms/step
1/1             0s 54ms/step
1/1             0s 52ms/step
1/1             0s 53ms/step
1/1             0s 52ms/step
1/1             0s 70ms/step
1/1             0s 61ms/step
1/1             0s 52ms/step
1/1             0s 64ms/step
```

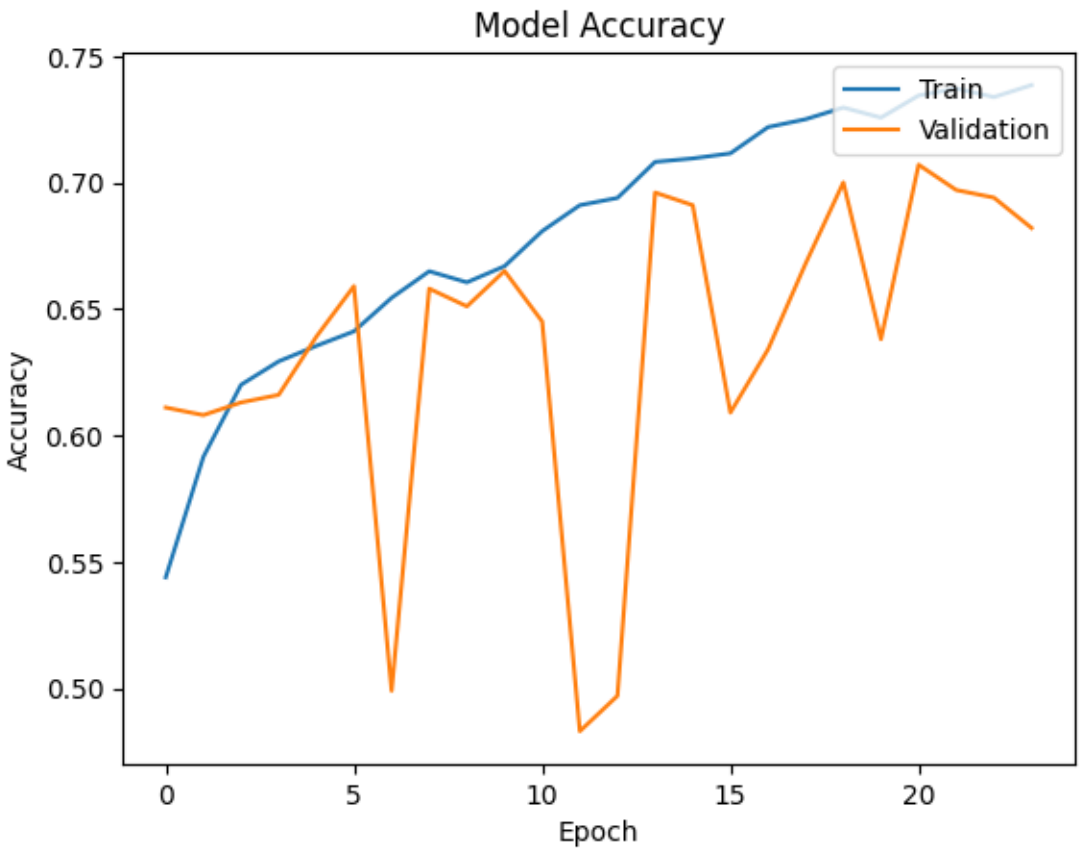
```
Classification Report:
              precision    recall  f1-score   support

           0       0.60      0.34      0.44       483
           1       0.56      0.79      0.66       517

    accuracy                           0.57      1000
   macro avg       0.58      0.57      0.55      1000
weighted avg       0.58      0.57      0.55      1000
```

```
 1/63              9s 152ms/step - accuracy:
0.6250 - auc: 0.5364 - bin_accuracy: 0.6250 - loss: 0.7775 - precision: 0.7273 -
recall: 0.7273
```

```
2025-04-13 05:28:02.288675: W tensorflow/core/framework/local_rendezvous.cc:404]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
```

```
63/63              2s 28ms/step -
accuracy: 0.6926 - auc: 0.7553 - bin_accuracy: 0.6926 - loss: 0.6250 -
precision: 0.6781 - recall: 0.7670
```





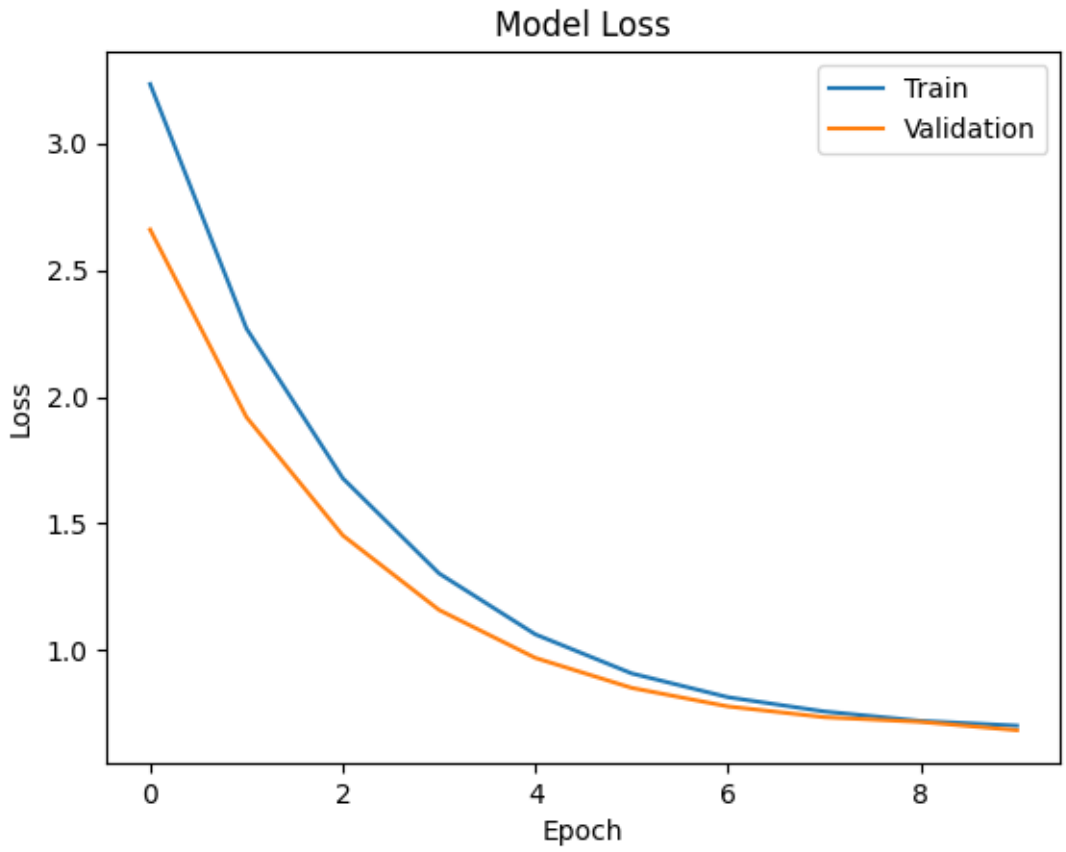

```
  AUC (ROC): 0.7563
  Accuracy:  0.6960
  Precision: 0.6885
  Recall:    0.7524
  Loss:      0.6222
1/1              0s 229ms/step
1/1              0s 56ms/step
1/1              0s 46ms/step
1/1              0s 50ms/step
1/1              0s 48ms/step
1/1              0s 48ms/step
1/1              0s 49ms/step
1/1              0s 47ms/step
1/1              0s 47ms/step
1/1              0s 48ms/step
1/1              0s 48ms/step
1/1              0s 50ms/step
1/1              0s 51ms/step
1/1              0s 67ms/step
1/1              0s 64ms/step
```

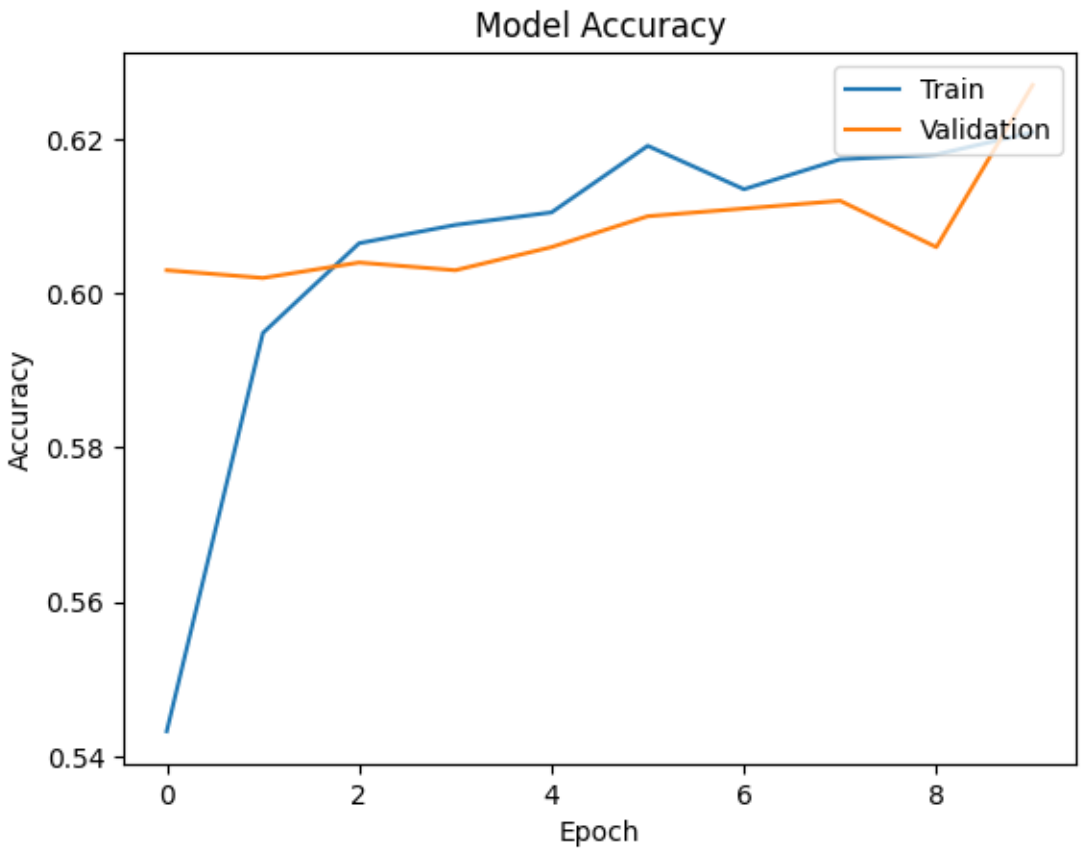
```
1/1             0s 48ms/step
1/1             0s 69ms/step
1/1             0s 54ms/step
1/1             0s 46ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 71ms/step
1/1             0s 62ms/step
1/1             0s 51ms/step
1/1             0s 56ms/step
1/1             0s 53ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 53ms/step
1/1             0s 54ms/step
1/1             0s 52ms/step
1/1             0s 52ms/step
1/1             0s 52ms/step
1/1             0s 51ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 69ms/step
1/1             0s 54ms/step
1/1             0s 53ms/step
1/1             0s 52ms/step
1/1             0s 69ms/step
1/1             0s 52ms/step
1/1             0s 47ms/step
1/1             0s 53ms/step
1/1             0s 52ms/step
1/1             0s 54ms/step
1/1             0s 47ms/step
1/1             0s 71ms/step
1/1             0s 58ms/step
1/1             0s 51ms/step
1/1             0s 53ms/step
1/1             0s 54ms/step
1/1             0s 52ms/step
1/1             0s 55ms/step
1/1             0s 53ms/step
1/1             0s 53ms/step
1/1             0s 52ms/step
1/1             0s 57ms/step
1/1             0s 53ms/step
1/1             0s 65ms/step
1/1             0s 48ms/step
1/1             0s 60ms/step
```

```
Classification Report:
              precision    recall  f1-score   support

           0       0.71      0.64      0.67       483
           1       0.69      0.75      0.72       517

    accuracy                           0.70      1000
   macro avg       0.70      0.69      0.69      1000
weighted avg       0.70      0.70      0.69      1000
```

```
2025-04-13 05:28:14.067156: W tensorflow/core/framework/local_rendezvous.cc:404]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
```

```
63/63              2s 29ms/step -
accuracy: 0.5984 - auc: 0.6440 - bin_accuracy: 0.5984 - loss: 2.6617 -
precision: 0.6384 - recall: 0.5067
```






```
  AUC (ROC): 0.6521
  Accuracy:  0.6030
  Precision: 0.6456
  Recall:    0.5145
  Loss:      2.6594
1/1              0s 493ms/step
1/1              0s 52ms/step
1/1              0s 47ms/step
1/1              0s 47ms/step
1/1              0s 53ms/step
1/1              0s 46ms/step
1/1              0s 46ms/step
1/1              0s 48ms/step
1/1              0s 52ms/step
1/1              0s 47ms/step
1/1              0s 52ms/step
1/1              0s 46ms/step
1/1              0s 46ms/step
1/1              0s 48ms/step
1/1              0s 47ms/step
```

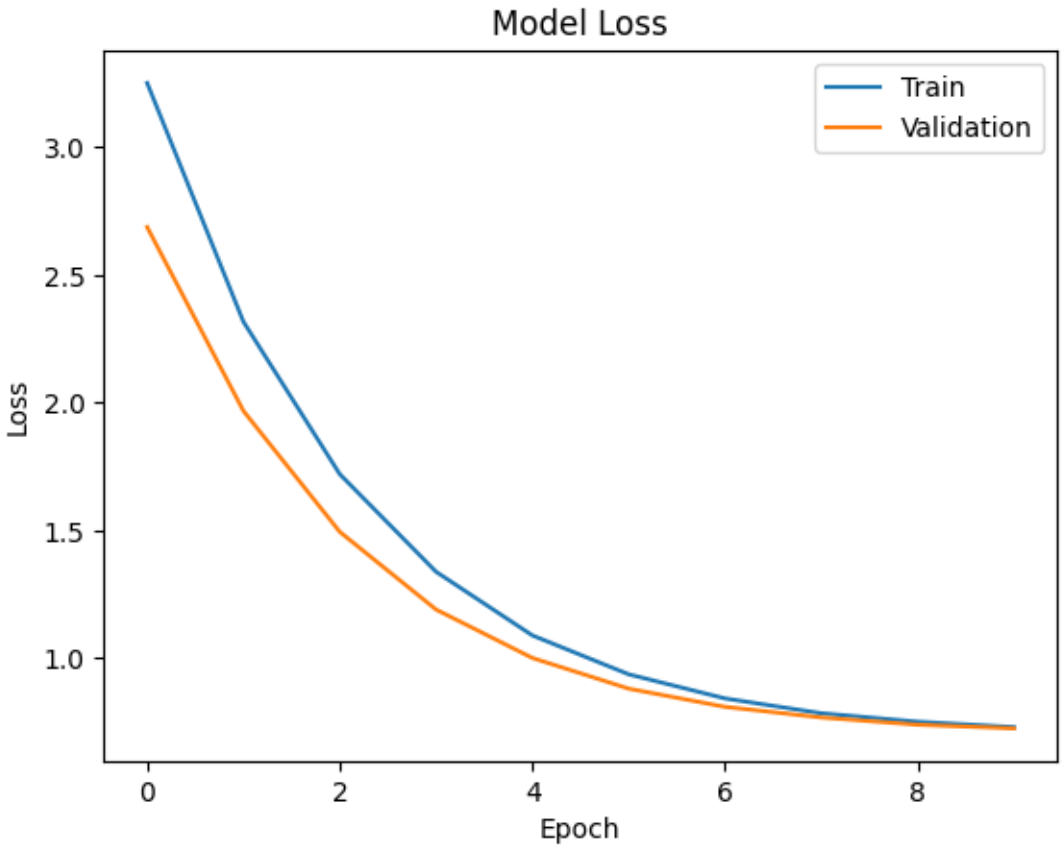
```
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 47ms/step
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 50ms/step
1/1             0s 46ms/step
1/1             0s 46ms/step
1/1             0s 52ms/step
1/1             0s 46ms/step
1/1             0s 53ms/step
1/1             0s 53ms/step
1/1             0s 55ms/step
1/1             0s 54ms/step
1/1             0s 52ms/step
1/1             0s 52ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 53ms/step
1/1             0s 64ms/step
1/1             0s 52ms/step
1/1             0s 47ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 53ms/step
1/1             0s 55ms/step
1/1             0s 68ms/step
1/1             0s 55ms/step
1/1             0s 51ms/step
1/1             0s 61ms/step
1/1             0s 61ms/step
1/1             0s 55ms/step
1/1             0s 53ms/step
1/1             0s 55ms/step
1/1             0s 52ms/step
1/1             0s 51ms/step
1/1             0s 70ms/step
1/1             0s 51ms/step
1/1             0s 57ms/step
1/1             0s 63ms/step
1/1             0s 52ms/step
1/1             0s 55ms/step
1/1             0s 53ms/step
1/1             0s 53ms/step
1/1             0s 48ms/step
1/1             0s 64ms/step
1/1             0s 48ms/step
1/1             0s 57ms/step
```

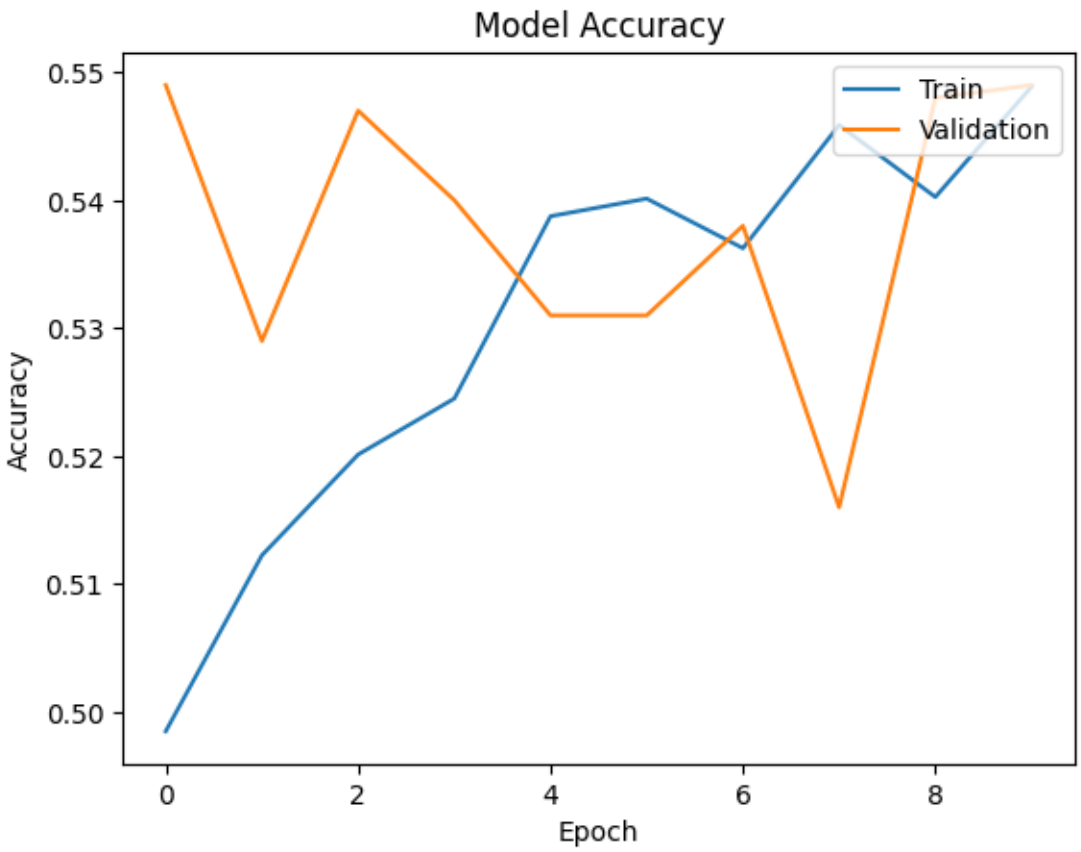
```
Classification Report:
              precision    recall  f1-score   support

           0       0.57      0.70      0.63       483
           1       0.65      0.51      0.57       517

    accuracy                           0.60      1000
   macro avg       0.61      0.61      0.60      1000
weighted avg       0.61      0.60      0.60      1000
```

```
 1/63              6s 110ms/step - accuracy:
0.5625 - auc: 0.6091 - bin_accuracy: 0.5625 - loss: 2.6697 - precision: 0.7000 -
recall: 0.6364
```

```
2025-04-13 05:28:25.864939: W tensorflow/core/framework/local_rendezvous.cc:404]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
```

```
63/63              2s 29ms/step -
accuracy: 0.5500 - auc: 0.5554 - bin_accuracy: 0.5500 - loss: 2.6887 -
precision: 0.5603 - recall: 0.5828
```

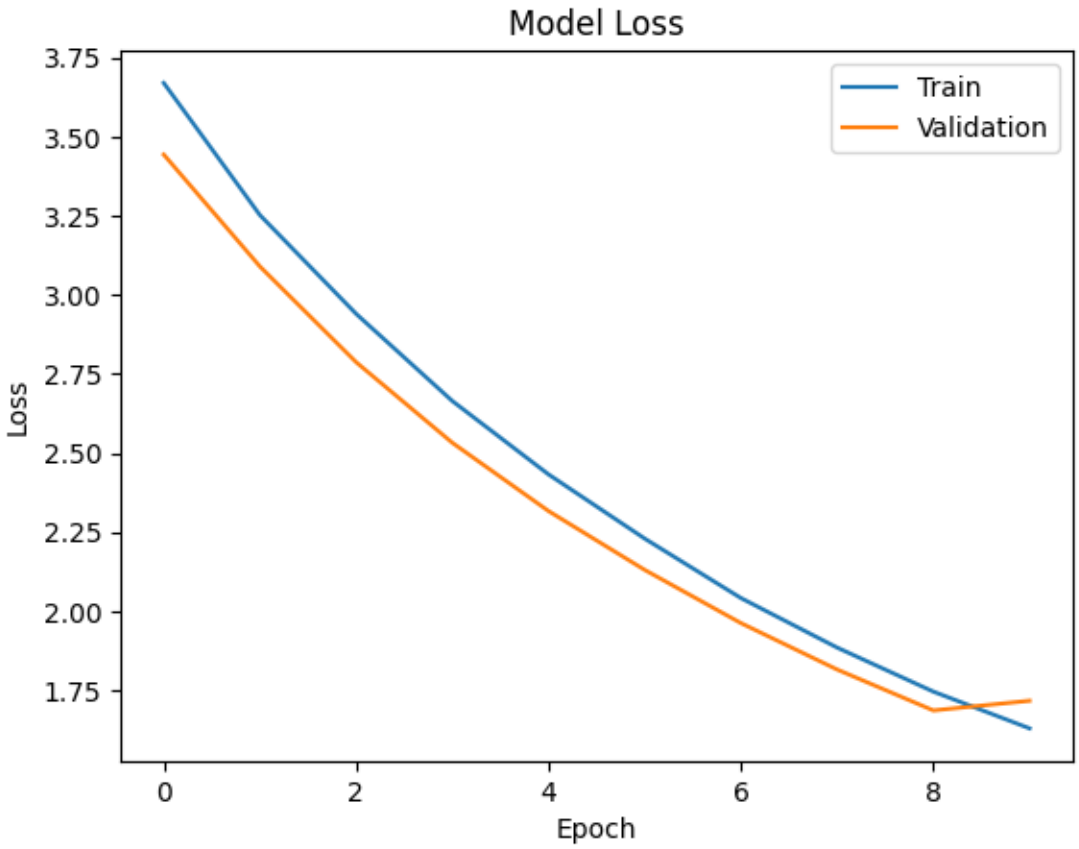


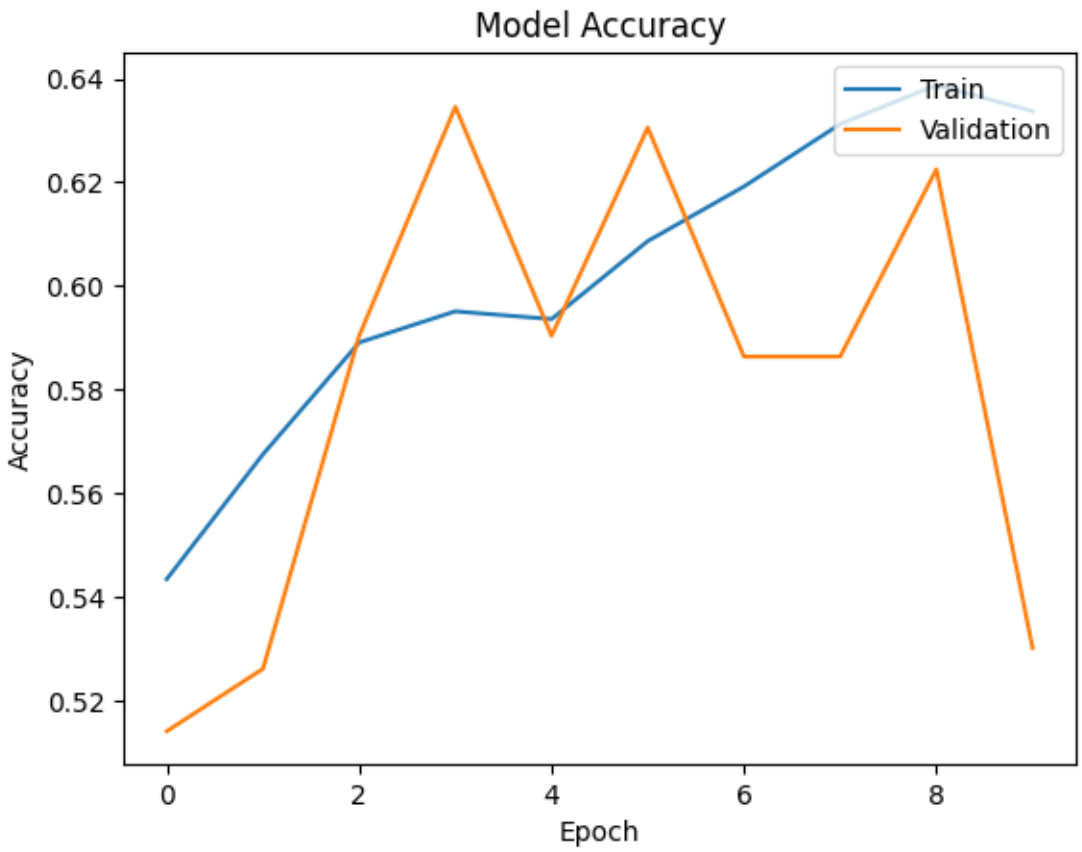



```
  AUC (ROC): 0.5591
  Accuracy:  0.5490
  Precision: 0.5618
  Recall:    0.5803
  Loss:      2.6876
1/1              0s 255ms/step
1/1              0s 48ms/step
1/1              0s 47ms/step
1/1              0s 54ms/step
1/1              0s 47ms/step
1/1              0s 49ms/step
1/1              0s 49ms/step
1/1              0s 47ms/step
1/1              0s 48ms/step
1/1              0s 47ms/step
1/1              0s 48ms/step
1/1              0s 61ms/step
1/1              0s 64ms/step
1/1              0s 47ms/step
1/1              0s 46ms/step
```

```
1/1             0s 46ms/step
1/1             0s 46ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 52ms/step
1/1             0s 70ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 57ms/step
1/1             0s 53ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 64ms/step
1/1             0s 55ms/step
1/1             0s 47ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 51ms/step
1/1             0s 53ms/step
1/1             0s 48ms/step
1/1             0s 47ms/step
1/1             0s 63ms/step
1/1             0s 70ms/step
1/1             0s 57ms/step
1/1             0s 51ms/step
1/1             0s 47ms/step
1/1             0s 89ms/step
1/1             0s 55ms/step
1/1             0s 47ms/step
1/1             0s 58ms/step
1/1             0s 54ms/step
1/1             0s 60ms/step
1/1             0s 58ms/step
1/1             0s 47ms/step
1/1             0s 46ms/step
1/1             0s 49ms/step
1/1             0s 61ms/step
1/1             0s 49ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 48ms/step
1/1             0s 46ms/step
1/1             0s 55ms/step
```

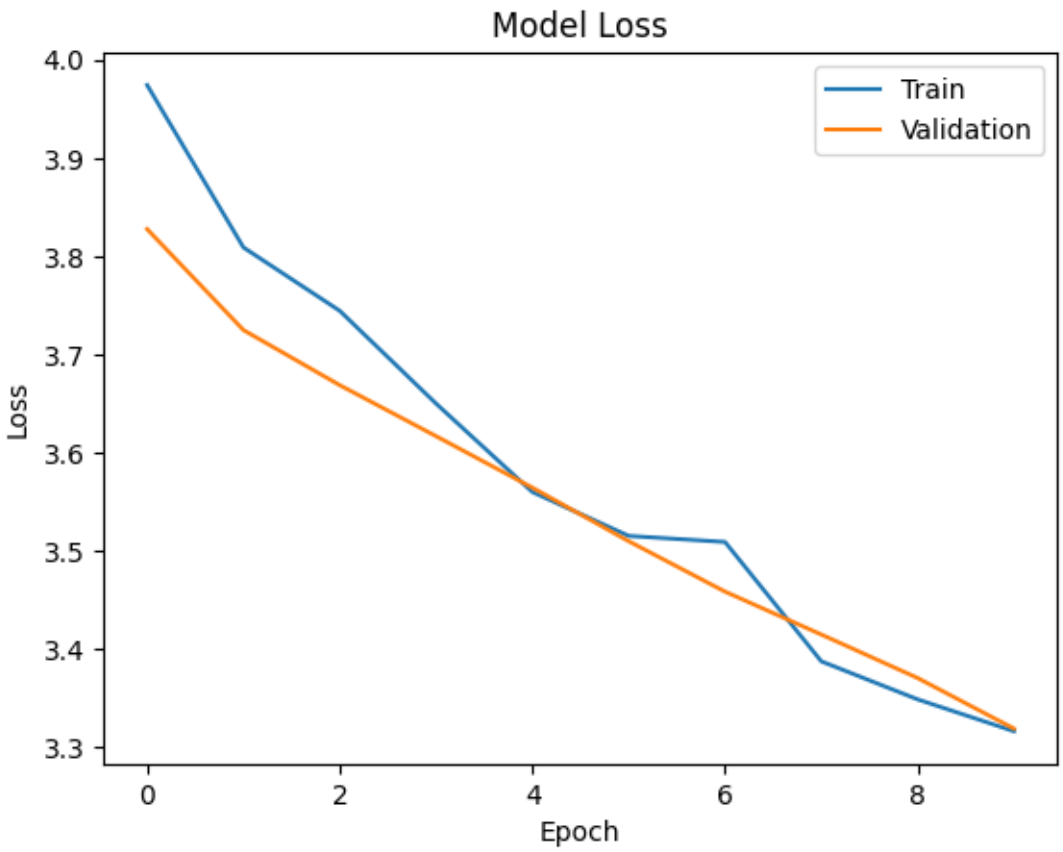
```
Classification Report:
              precision    recall  f1-score   support

           0       0.53      0.52      0.52       483
           1       0.56      0.58      0.57       517

    accuracy                           0.55      1000
   macro avg       0.55      0.55      0.55      1000
weighted avg       0.55      0.55      0.55      1000

 1/16              1s 129ms/step -
accuracy: 0.6875 - auc: 0.6455 - bin_accuracy: 0.6875 - loss: 3.3499 -
precision: 0.6875 - recall: 1.0000

2025-04-13 05:28:37.308044: W tensorflow/core/framework/local_rendezvous.cc:404]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence

16/16              1s 30ms/step -
accuracy: 0.5097 - auc: 0.5857 - bin_accuracy: 0.5097 - loss: 3.4491 -
precision: 0.5097 - recall: 1.0000
```

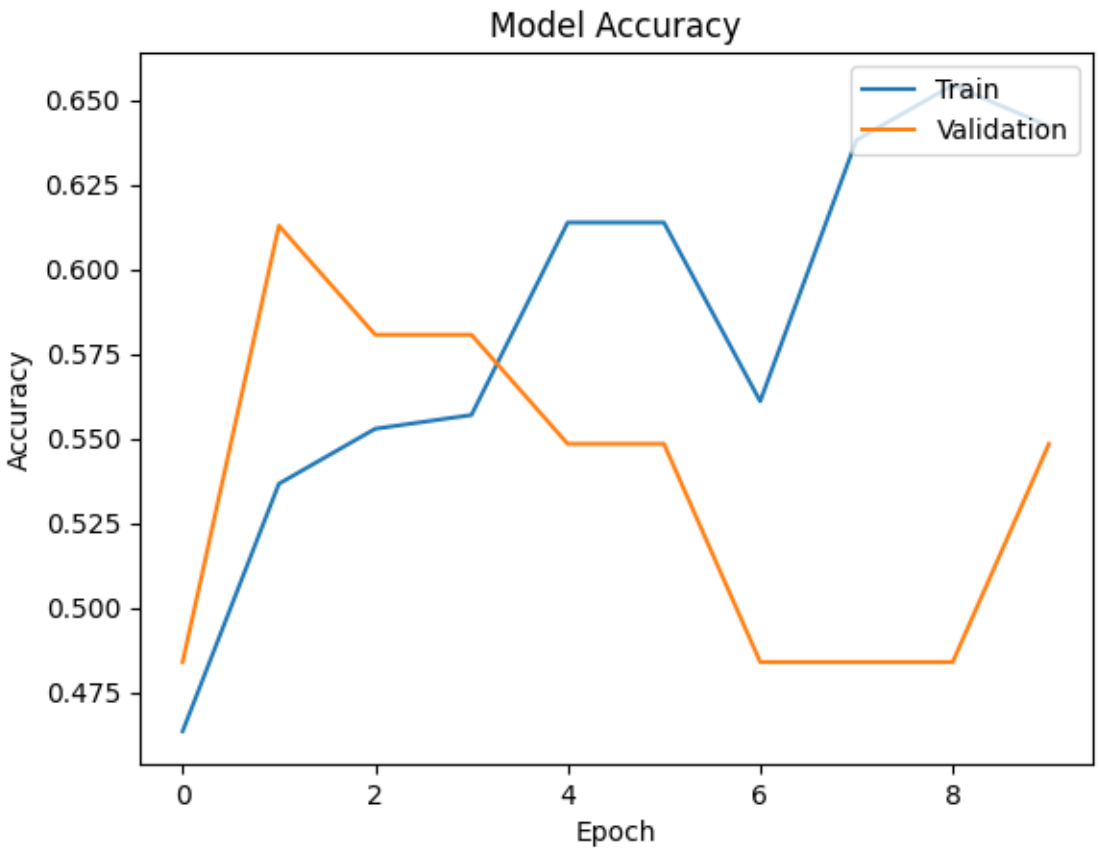





```
  AUC (ROC): 0.5717
  Accuracy:  0.5141
  Precision: 0.5141
  Recall:    1.0000
  Loss:      3.4436
1/1              0s 148ms/step
1/1              0s 49ms/step
1/1              0s 47ms/step
1/1              0s 48ms/step
1/1              0s 48ms/step
1/1              0s 49ms/step
1/1              0s 50ms/step
1/1              0s 51ms/step
1/1              0s 52ms/step
1/1              0s 46ms/step
1/1              0s 57ms/step
1/1              0s 46ms/step
1/1              0s 46ms/step
1/1              0s 49ms/step
1/1              0s 61ms/step
```

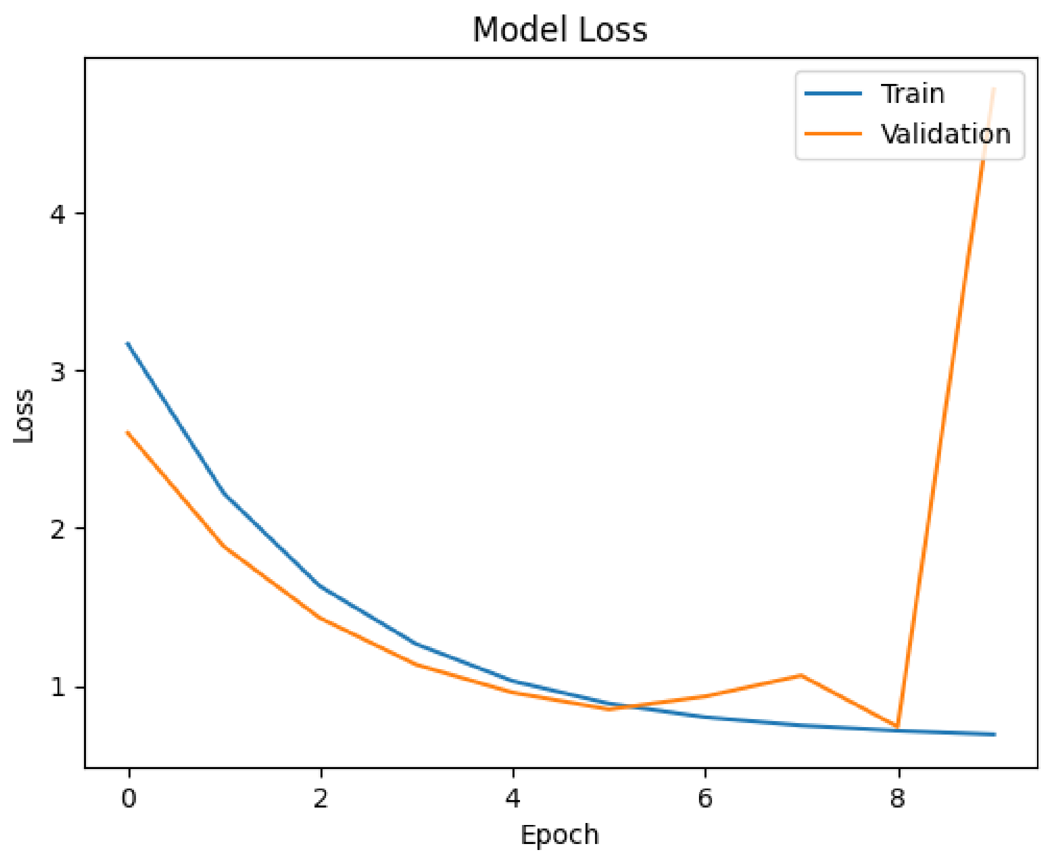
```
1/1            0s 57ms/step

Classification Report:
              precision    recall  f1-score   support

           0       0.00      0.00      0.00       121
           1       0.51      1.00      0.68       128

    accuracy                           0.51       249
   macro avg       0.26      0.50      0.34       249
weighted avg       0.26      0.51      0.35       249

1/2            0s 124ms/step -
accuracy: 0.6250 - auc: 0.5333 - bin_accuracy: 0.6250 - loss: 3.7562 -
precision: 0.6250 - recall: 1.0000

2025-04-13 05:28:40.729825: W tensorflow/core/framework/local_rendezvous.cc:404]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
/usr/local/lib/python3.11/dist-packages/sklearn/metrics/_classification.py:1565:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels
with no predicted samples. Use `zero_division` parameter to control this
behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.11/dist-packages/sklearn/metrics/_classification.py:1565:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels
with no predicted samples. Use `zero_division` parameter to control this
behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.11/dist-packages/sklearn/metrics/_classification.py:1565:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels
with no predicted samples. Use `zero_division` parameter to control this
behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))

2/2            0s 60ms/step -
accuracy: 0.5309 - auc: 0.4667 - bin_accuracy: 0.5309 - loss: 3.8037 -
precision: 0.5309 - recall: 1.0000
```

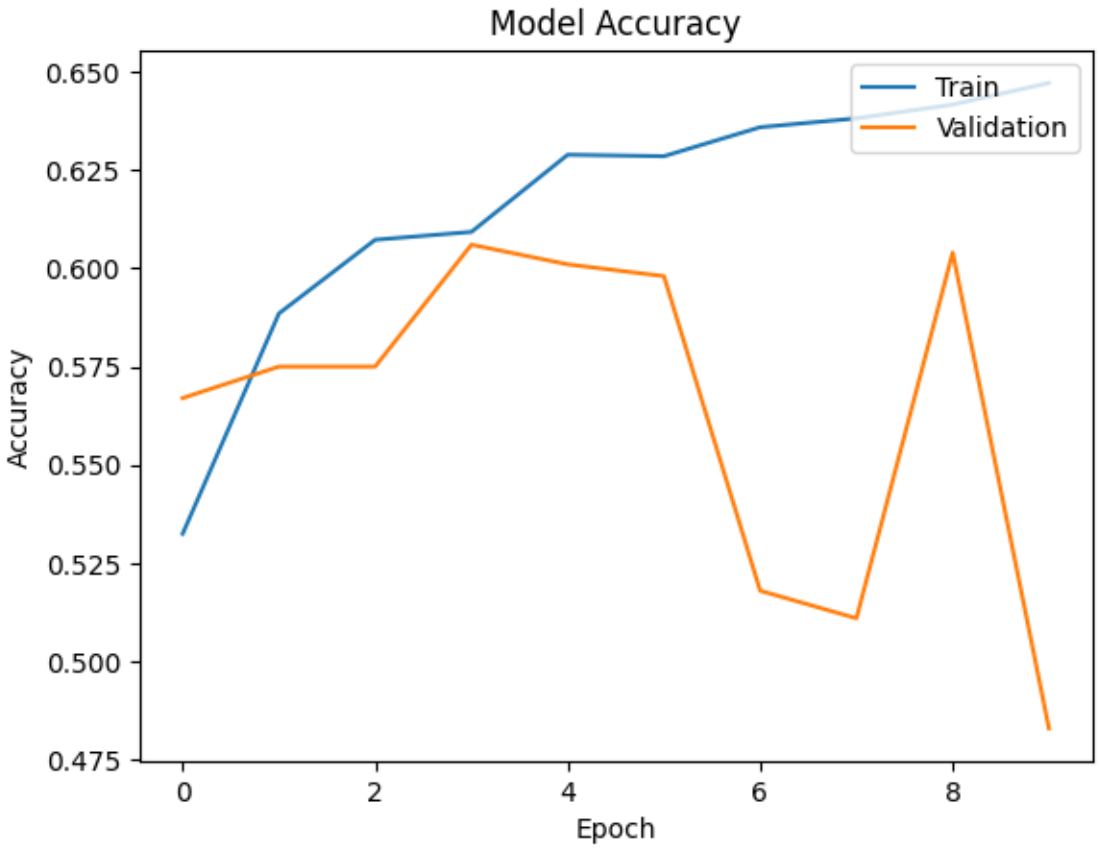

Model Loss
Train
Validation
Loss
Epoch
4.0
3.9
3.8
3.7
3.6
3.5
3.4
3.3
0
2
4
6
8




```
  AUC (ROC): 0.4333
  Accuracy:  0.4839
  Precision: 0.4839
  Recall:    1.0000
  Loss:      3.8275
1/1             0s 48ms/step
1/1             0s 47ms/step

Classification Report:
              precision    recall  f1-score   support

           0       0.00      0.00      0.00        16
           1       0.48      1.00      0.65        15

    accuracy                           0.48        31
   macro avg       0.24      0.50      0.33        31
weighted avg       0.23      0.48      0.32        31

 1/63             7s 114ms/step - accuracy:
0.5000 - auc: 0.6455 - bin_accuracy: 0.5000 - loss: 2.5979 - precision: 0.8000 -
```

```
recall: 0.3636

2025-04-13 05:28:41.545532: W tensorflow/core/framework/local_rendezvous.cc:404]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
/usr/local/lib/python3.11/dist-packages/sklearn/metrics/_classification.py:1565:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels
with no predicted samples. Use `zero_division` parameter to control this
behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.11/dist-packages/sklearn/metrics/_classification.py:1565:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels
with no predicted samples. Use `zero_division` parameter to control this
behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.11/dist-packages/sklearn/metrics/_classification.py:1565:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 in labels
with no predicted samples. Use `zero_division` parameter to control this
behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))

63/63            2s 29ms/step -
accuracy: 0.5509 - auc: 0.5963 - bin_accuracy: 0.5509 - loss: 2.6068 -
precision: 0.5748 - recall: 0.4927
```






```
  AUC (ROC): 0.6079
  Accuracy:  0.5670
  Precision: 0.5929
  Recall:    0.5184
  Loss:      2.6046
1/1              0s 331ms/step
1/1              0s 49ms/step
1/1              0s 49ms/step
1/1              0s 50ms/step
1/1              0s 48ms/step
1/1              0s 49ms/step
1/1              0s 55ms/step
1/1              0s 57ms/step
1/1              0s 50ms/step
1/1              0s 50ms/step
1/1              0s 49ms/step
1/1              0s 49ms/step
1/1              0s 57ms/step
```

```
1/1             0s 48ms/step
1/1             0s 49ms/step
1/1             0s 56ms/step
1/1             0s 50ms/step
1/1             0s 64ms/step
1/1             0s 66ms/step
1/1             0s 50ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 57ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 47ms/step
1/1             0s 49ms/step
1/1             0s 51ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 57ms/step
1/1             0s 51ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 58ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
1/1             0s 59ms/step
1/1             0s 50ms/step
1/1             0s 51ms/step
1/1             0s 56ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 62ms/step
1/1             0s 61ms/step
1/1             0s 63ms/step
1/1             0s 52ms/step
1/1             0s 47ms/step
1/1             0s 49ms/step
1/1             0s 53ms/step
1/1             0s 69ms/step
1/1             0s 57ms/step
1/1             0s 55ms/step
1/1             0s 50ms/step
1/1             0s 48ms/step
```

```
1/1             0s 49ms/step
1/1             0s 48ms/step

Classification Report:
              precision    recall  f1-score   support

           0       0.55      0.62      0.58       483
           1       0.59      0.52      0.55       517

    accuracy                           0.57      1000
   macro avg       0.57      0.57      0.57      1000
weighted avg       0.57      0.57      0.57      1000


2025-04-13 05:28:55.715183: W tensorflow/core/framework/local_rendezvous.cc:404]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
```

0.7 Data Post Processing for Single Tasks Combination

[375]:
```
tasks_with_models = {}
tasks_enumerated = prepared_datasets.keys()
display(tasks_enumerated)

for i, task in enumerate(tasks_enumerated):
    model = all_models[i]
    tasks_with_models[task] = model

# Define the categories and their corresponding labels
category_map = {
    'Infection/Infiltration': ['has_Pneumonia', 'has_Consolidation',␣
 ↪'has_Infiltration'],
    'Fluid Related Issues': ['has_Edema', 'has_Effusion',␣
 ↪'has_Pleural_Thickening'],
    'Lung Structure Issues': ['has_Atelectasis', 'has_Pneumothorax',␣
 ↪'has_Fibrosis', 'has_Emphysema'],
    'Nodule/Mass': ['has_Nodule', 'has_Mass'],
    'Cardiac Issues': ['has_Cardiomegaly'],
    'Hernia': ['has_Hernia'],
    'No Finding': ['has_No Finding']
}

categories = category_map.keys()
display(categories)
```

```
dict_keys(['has_Infection/Infiltration', 'has_Fluid Related Issues', 'has_Lung␣
 ↪Structure Issues', 'has_Nodule/Mass', 'has_Cardiac Issues', 'has_Hernia',␣
 ↪'has_No Finding'])
```

```
dict_keys(['Infection/Infiltration', 'Fluid Related Issues', 'Lung Structure␣
↪Issues', 'Nodule/Mass', 'Cardiac Issues', 'Hernia', 'No Finding'])
```

[399]:
```python
def predict_all_tasks(image_path, tabular_data, resized_images_path,␣
↪tasks_with_models):
    """
    Predicts the results for all tasks using the provided models, then applies␣
↪the heuristic.

    Args:
        image_path: Path to the image file.
        tabular_data: A numpy array of tabular data for the image.
        resized_images_path: Path to the directory containing the resized␣
↪images.
        tasks_with_models: The dictionary containing task names and their␣
↪corresponding models.

    Returns:
        A NumPy array of predictions for the broader categories.
    """
    # Define threshold for individual task predictions
    THRESHOLD = 0.5

    # Preprocess the image and tabular data
    image_data = np.expand_dims(preprocess_image(os.path.
↪join(resized_images_path, os.path.basename(image_path))), axis=0)
    tabular_data = np.expand_dims(tabular_data, axis=0)
    inputs = (image_data, tabular_data)
    if isinstance(inputs, tuple):
        inputs = {"image_input": inputs[0], "tabular_input": inputs[1]}

    batch_size = inputs["image_input"].shape[0]

    # Initialize a dictionary to store individual task predictions
    predictions = {}

    # Get predictions for all individual tasks and store them in the dictionary
    for task, m_h in tasks_with_models.items():
        model, history = m_h
        pred = model.predict(inputs).reshape(batch_size)
        predictions[task] = float(pred)

    return np.array(list(predictions.values()))
```

[400]:
```python
def generate_group_labels(df):
    group_labels = []
```

```
    for _, row in df.iterrows():
        task_predictions = df[tasks_enumerated]
        task_predictions_dict = row[tasks_enumerated].to_dict()
        group_labels.append(np.array(list(task_predictions_dict.values())))

    return group_labels
```

0.7.1 Test with Test data

[409]:
```
tasks = prepared_datasets.keys()
# Select a few rows from the test dataset
num_rows_to_pick = 1000 # Adjust the number of rows as needed
rows_to_predict = test_df.sample(n=num_rows_to_pick, random_state=42)
display(rows_to_predict.head())
```

	Image Index	Follow-up #	Patient Age	Patient Gender	has_Infection/Infiltration	has_Fluid Related Issues	has_Lung Structure Issues	has_Nodule/Mass	has_Cardiac Issues	has_Hernia	has_No Finding
4457	00013549_002.png	-0.362342	0.587909	0	0	0	0	1	0	0	0
5605	00019087_017.png	1.065656	-0.964004	1	0	1	0	0	0	0	0
4686	00014647_010.png	0.399257	-0.343239	1	0	0	1	0	0	0	0
1055	00010047_000.png	-0.552742	-0.653622	0	0	0	0	0	0	0	1
4813	00015163_001.png	-0.457542	1.705287	1	0	0	0	1	0	0	0

[ ]:
```
# Prepare the image paths and tabular data for prediction
image_paths = rows_to_predict['Image Index'].values
tabular_data = rows_to_predict[['Follow-up #', 'Patient Age', 'Patient␣
 ↪Gender']].values
# Assuming 'RESIZED_IMAGES_PATH' is defined correctly
```

```
resized_images_path = RESIZED_IMAGES_PATH

# Predict labels for each picked image
predictions_results = []
for image_path, tabular_row in zip(image_paths, tabular_data):
    predictions = predict_all_tasks(image_path, tabular_row,␣
 ↪resized_images_path, tasks_with_models)
    predictions_results.append(predictions)

rows_to_predict['group_labels'] = generate_group_labels(rows_to_predict)
rows_to_predict['predicted_group_labels'] = predictions_results
```

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```

```
/tmp/ipykernel_617090/1120432779.py:33: DeprecationWarning: Conversion of an
array with ndim > 0 to a scalar is deprecated, and will error in future. Ensure
you extract a single element from your array before performing this operation.
(Deprecated NumPy 1.25.)
  predictions[task] = float(pred)
```

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1/1             0s 47ms/step
1/1             0s 43ms/step
1/1             0s 46ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 47ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 47ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 52ms/step
1/1             0s 52ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 52ms/step
1/1             0s 51ms/step
1/1             0s 49ms/step
1/1             0s 51ms/step
1/1             0s 49ms/step
```

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1/1             0s 45ms/step
1/1             0s 45ms/step
1/1             0s 51ms/step
1/1             0s 52ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
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1/1             0s 49ms/step
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1/1             0s 44ms/step
1/1             0s 51ms/step
1/1             0s 50ms/step
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1/1             0s 43ms/step
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1/1             0s 43ms/step
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1/1             0s 45ms/step
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1/1             0s 60ms/step
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1/1             0s 44ms/step
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1/1             0s 42ms/step
1/1             0s 52ms/step
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1/1             0s 50ms/step
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1/1             0s 48ms/step
```

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1/1             0s 43ms/step
1/1             0s 50ms/step
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1/1             0s 50ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 51ms/step
1/1             0s 48ms/step
1/1             0s 50ms/step
1/1             0s 45ms/step
1/1             0s 49ms/step
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1/1             0s 50ms/step
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1/1             0s 50ms/step
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1/1             0s 51ms/step
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1/1             0s 56ms/step
1/1             0s 45ms/step
1/1             0s 42ms/step
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1/1             0s 44ms/step
1/1             0s 41ms/step
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```

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1/1             0s 44ms/step
1/1             0s 44ms/step
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1/1             0s 46ms/step
1/1             0s 55ms/step
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1/1             0s 46ms/step
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1/1             0s 45ms/step
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1/1             0s 46ms/step
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1/1             0s 43ms/step
1/1             0s 43ms/step
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1/1             0s 44ms/step
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1/1             0s 43ms/step
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```

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1/1             0s 52ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 43ms/step
1/1             0s 60ms/step
1/1             0s 52ms/step
1/1             0s 44ms/step
1/1             0s 42ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 69ms/step
1/1             0s 51ms/step
1/1             0s 45ms/step
1/1             0s 52ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
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1/1             0s 49ms/step
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1/1             0s 45ms/step
1/1             0s 52ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 46ms/step
1/1             0s 49ms/step
1/1             0s 61ms/step
1/1             0s 49ms/step
1/1             0s 43ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
1/1             0s 47ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 51ms/step
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1/1             0s 46ms/step
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1/1             0s 62ms/step
1/1             0s 48ms/step
1/1             0s 44ms/step
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1/1             0s 44ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 48ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 49ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 46ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 43ms/step
```

```
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 45ms/step
1/1             0s 45ms/step
1/1             0s 52ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 44ms/step
1/1             0s 42ms/step
1/1             0s 49ms/step
1/1             0s 44ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 46ms/step
1/1             0s 57ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 57ms/step
1/1             0s 44ms/step
1/1             0s 52ms/step
1/1             0s 53ms/step
1/1             0s 55ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 50ms/step
1/1             0s 52ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 55ms/step
1/1             0s 44ms/step
1/1             0s 42ms/step
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 48ms/step
1/1             0s 52ms/step
1/1             0s 44ms/step
1/1             0s 51ms/step
1/1             0s 42ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 48ms/step
1/1             0s 42ms/step
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 42ms/step
1/1             0s 43ms/step
```

```
1/1             0s 50ms/step
1/1             0s 51ms/step
1/1             0s 49ms/step
1/1             0s 51ms/step
1/1             0s 63ms/step
1/1             0s 68ms/step
1/1             0s 45ms/step
1/1             0s 57ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
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1/1             0s 43ms/step
1/1             0s 47ms/step
1/1             0s 43ms/step
1/1             0s 74ms/step
1/1             0s 46ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 52ms/step
1/1             0s 42ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 96ms/step
1/1             0s 47ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 46ms/step
```

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1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
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1/1             0s 41ms/step
1/1             0s 43ms/step
1/1             0s 41ms/step
1/1             0s 42ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 106ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 83ms/step
1/1             0s 47ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 48ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 45ms/step
1/1             0s 49ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
```

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1/1             0s 45ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
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1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 47ms/step
1/1             0s 49ms/step
1/1             0s 45ms/step
1/1             0s 50ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 51ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
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1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 41ms/step
```

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1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 47ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 44ms/step
1/1             0s 51ms/step
1/1             0s 51ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 52ms/step
1/1             0s 44ms/step
1/1             0s 41ms/step
1/1             0s 45ms/step
1/1             0s 42ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 46ms/step
1/1             0s 57ms/step
1/1             0s 43ms/step
1/1             0s 60ms/step
1/1             0s 54ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 50ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 55ms/step
1/1             0s 51ms/step
1/1             0s 51ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 50ms/step
1/1             0s 42ms/step
1/1             0s 48ms/step
```

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1/1             0s 45ms/step
1/1             0s 53ms/step
1/1             0s 52ms/step
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1/1             0s 46ms/step
1/1             0s 43ms/step
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1/1             0s 45ms/step
1/1             0s 52ms/step
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1/1             0s 48ms/step
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1/1             0s 42ms/step
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1/1             0s 42ms/step
1/1             0s 51ms/step
1/1             0s 43ms/step
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1/1             0s 42ms/step
1/1             0s 46ms/step
1/1             0s 46ms/step
1/1             0s 48ms/step
1/1             0s 44ms/step
1/1             0s 47ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 50ms/step
1/1             0s 50ms/step
1/1             0s 50ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
```

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1/1             0s 45ms/step
1/1             0s 50ms/step
1/1             0s 44ms/step
1/1             0s 51ms/step
1/1             0s 51ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
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1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 46ms/step
1/1             0s 44ms/step
1/1             0s 48ms/step
1/1             0s 42ms/step
1/1             0s 50ms/step
1/1             0s 50ms/step
1/1             0s 47ms/step
1/1             0s 48ms/step
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1/1             0s 49ms/step
1/1             0s 51ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 42ms/step
1/1             0s 49ms/step
1/1             0s 47ms/step
1/1             0s 50ms/step
1/1             0s 51ms/step
1/1             0s 56ms/step
1/1             0s 50ms/step
1/1             0s 47ms/step
1/1             0s 48ms/step
1/1             0s 50ms/step
1/1             0s 50ms/step
1/1             0s 50ms/step
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1/1             0s 49ms/step
1/1             0s 49ms/step
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1/1             0s 45ms/step
1/1             0s 42ms/step
1/1             0s 48ms/step
1/1             0s 46ms/step
```

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1/1             0s 45ms/step
1/1             0s 53ms/step
1/1             0s 48ms/step
1/1             0s 52ms/step
1/1             0s 51ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 50ms/step
1/1             0s 47ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
1/1             0s 51ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 54ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 50ms/step
1/1             0s 44ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 43ms/step
1/1             0s 51ms/step
1/1             0s 50ms/step
1/1             0s 48ms/step
1/1             0s 42ms/step
1/1             0s 51ms/step
1/1             0s 43ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 47ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
```

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1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 47ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
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1/1             0s 47ms/step
1/1             0s 45ms/step
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1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 46ms/step
1/1             0s 50ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 48ms/step
1/1             0s 51ms/step
1/1             0s 43ms/step
1/1             0s 47ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 43ms/step
1/1             0s 41ms/step
1/1             0s 43ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 51ms/step
1/1             0s 50ms/step
1/1             0s 51ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 45ms/step
1/1             0s 42ms/step
```

```
1/1             0s 51ms/step
1/1             0s 45ms/step
1/1             0s 52ms/step
1/1             0s 44ms/step
1/1             0s 50ms/step
1/1             0s 53ms/step
1/1             0s 51ms/step
1/1             0s 48ms/step
1/1             0s 50ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 46ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 47ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 51ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 52ms/step
1/1             0s 42ms/step
1/1             0s 50ms/step
1/1             0s 47ms/step
1/1             0s 50ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 41ms/step
1/1             0s 41ms/step
1/1             0s 41ms/step
1/1             0s 62ms/step
1/1             0s 53ms/step
1/1             0s 44ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 46ms/step
1/1             0s 50ms/step
```

```
1/1             0s 47ms/step
1/1             0s 56ms/step
1/1             0s 45ms/step
1/1             0s 50ms/step
1/1             0s 50ms/step
1/1             0s 47ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 41ms/step
1/1             0s 48ms/step
1/1             0s 42ms/step
1/1             0s 48ms/step
1/1             0s 51ms/step
1/1             0s 48ms/step
1/1             0s 52ms/step
1/1             0s 47ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 46ms/step
1/1             0s 50ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 50ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 51ms/step
1/1             0s 43ms/step
1/1             0s 52ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 42ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 43ms/step
```

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1/1             0s 48ms/step
1/1             0s 46ms/step
1/1             0s 53ms/step
1/1             0s 45ms/step
1/1             0s 51ms/step
1/1             0s 45ms/step
1/1             0s 47ms/step
1/1             0s 49ms/step
1/1             0s 44ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 46ms/step
1/1             0s 52ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 50ms/step
1/1             0s 51ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 51ms/step
1/1             0s 43ms/step
1/1             0s 50ms/step
1/1             0s 45ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 43ms/step
1/1             0s 50ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 45ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
```

```
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
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1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 51ms/step
1/1             0s 42ms/step
1/1             0s 48ms/step
1/1             0s 50ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 46ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 47ms/step
1/1             0s 48ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 47ms/step
```

```
1/1             0s 46ms/step
1/1             0s 56ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 47ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 69ms/step
1/1             0s 44ms/step
1/1             0s 42ms/step
1/1             0s 46ms/step
1/1             0s 45ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 75ms/step
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1/1             0s 43ms/step
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1/1             0s 42ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 52ms/step
1/1             0s 48ms/step
1/1             0s 44ms/step
1/1             0s 51ms/step
1/1             0s 42ms/step
1/1             0s 47ms/step
1/1             0s 48ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 55ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
1/1             0s 50ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
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1/1             0s 50ms/step
1/1             0s 52ms/step
1/1             0s 69ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 48ms/step
1/1             0s 47ms/step
1/1             0s 52ms/step
1/1             0s 42ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
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1/1             0s 46ms/step
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1/1             0s 50ms/step
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```

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1/1             0s 51ms/step
1/1             0s 50ms/step
1/1             0s 56ms/step
1/1             0s 50ms/step
1/1             0s 50ms/step
1/1             0s 43ms/step
1/1             0s 51ms/step
1/1             0s 49ms/step
1/1             0s 47ms/step
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1/1             0s 46ms/step
1/1             0s 45ms/step
1/1             0s 45ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 49ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 51ms/step
1/1             0s 50ms/step
1/1             0s 50ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 42ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
```

```
1/1             0s 45ms/step
1/1             0s 53ms/step
1/1             0s 52ms/step
1/1             0s 52ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 41ms/step
1/1             0s 44ms/step
1/1             0s 42ms/step
1/1             0s 49ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 43ms/step
1/1             0s 50ms/step
1/1             0s 44ms/step
1/1             0s 51ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 53ms/step
1/1             0s 43ms/step
1/1             0s 47ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
1/1             0s 49ms/step
1/1             0s 51ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 49ms/step
1/1             0s 43ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 46ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
```

```
1/1             0s 50ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 48ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 46ms/step
1/1             0s 42ms/step
1/1             0s 49ms/step
1/1             0s 51ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
1/1             0s 52ms/step
1/1             0s 50ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 50ms/step
1/1             0s 50ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 44ms/step
1/1             0s 48ms/step
1/1             0s 47ms/step
1/1             0s 48ms/step
1/1             0s 50ms/step
1/1             0s 46ms/step
1/1             0s 47ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 43ms/step
1/1             0s 51ms/step
1/1             0s 48ms/step
1/1             0s 50ms/step
1/1             0s 48ms/step
1/1             0s 50ms/step
1/1             0s 50ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
```

```
1/1             0s 58ms/step
1/1             0s 44ms/step
1/1             0s 51ms/step
1/1             0s 45ms/step
1/1             0s 50ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 50ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 49ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 42ms/step
1/1             0s 48ms/step
1/1             0s 42ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 47ms/step
1/1             0s 44ms/step
1/1             0s 48ms/step
1/1             0s 53ms/step
1/1             0s 53ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 47ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
```

```
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 43ms/step
1/1             0s 46ms/step
1/1             0s 44ms/step
1/1             0s 42ms/step
1/1             0s 43ms/step
1/1             0s 48ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 44ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 50ms/step
1/1             0s 46ms/step
1/1             0s 48ms/step
1/1             0s 42ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 48ms/step
1/1             0s 47ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 47ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 47ms/step
1/1             0s 46ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 47ms/step
1/1             0s 48ms/step
1/1             0s 47ms/step
```

```
1/1             0s 46ms/step
1/1             0s 44ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 51ms/step
1/1             0s 42ms/step
1/1             0s 47ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 46ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 50ms/step
1/1             0s 48ms/step
1/1             0s 42ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 52ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 45ms/step
1/1             0s 49ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
1/1             0s 50ms/step
1/1             0s 50ms/step
1/1             0s 46ms/step
1/1             0s 47ms/step
1/1             0s 48ms/step
1/1             0s 47ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 48ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 46ms/step
1/1             0s 55ms/step
```

```
1/1             0s 49ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 50ms/step
1/1             0s 44ms/step
1/1             0s 46ms/step
1/1             0s 42ms/step
1/1             0s 43ms/step
1/1             0s 47ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 45ms/step
1/1             0s 51ms/step
1/1             0s 42ms/step
1/1             0s 50ms/step
1/1             0s 42ms/step
1/1             0s 46ms/step
1/1             0s 46ms/step
1/1             0s 47ms/step
1/1             0s 48ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 42ms/step
1/1             0s 74ms/step
1/1             0s 50ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 51ms/step
1/1             0s 47ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
1/1             0s 47ms/step
1/1             0s 43ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
```

```
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 48ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 47ms/step
1/1             0s 42ms/step
1/1             0s 46ms/step
1/1             0s 44ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 51ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 42ms/step
1/1             0s 41ms/step
1/1             0s 48ms/step
1/1             0s 47ms/step
1/1             0s 63ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 46ms/step
1/1             0s 49ms/step
1/1             0s 51ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
1/1             0s 44ms/step
1/1             0s 53ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
```

```
1/1             0s 50ms/step
1/1             0s 51ms/step
1/1             0s 56ms/step
1/1             0s 50ms/step
1/1             0s 48ms/step
1/1             0s 51ms/step
1/1             0s 46ms/step
1/1             0s 48ms/step
1/1             0s 42ms/step
1/1             0s 48ms/step
1/1             0s 44ms/step
1/1             0s 47ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 43ms/step
1/1             0s 48ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 42ms/step
1/1             0s 51ms/step
1/1             0s 47ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 48ms/step
1/1             0s 47ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 49ms/step
1/1             0s 44ms/step
1/1             0s 47ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 44ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 49ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 47ms/step
```

```
1/1             0s 53ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 52ms/step
1/1             0s 50ms/step
1/1             0s 46ms/step
1/1             0s 46ms/step
1/1             0s 50ms/step
1/1             0s 52ms/step
1/1             0s 49ms/step
1/1             0s 51ms/step
1/1             0s 52ms/step
1/1             0s 47ms/step
1/1             0s 46ms/step
1/1             0s 47ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
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1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 48ms/step
1/1             0s 46ms/step
1/1             0s 45ms/step
1/1             0s 48ms/step
1/1             0s 45ms/step
1/1             0s 47ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 46ms/step
1/1             0s 46ms/step
1/1             0s 47ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 55ms/step
1/1             0s 45ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
```

```
1/1             0s 47ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 46ms/step
1/1             0s 44ms/step
1/1             0s 42ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 41ms/step
1/1             0s 47ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 42ms/step
1/1             0s 43ms/step
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1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
```

```
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 48ms/step
1/1             0s 48ms/step
1/1             0s 46ms/step
1/1             0s 45ms/step
1/1             0s 52ms/step
1/1             0s 51ms/step
1/1             0s 46ms/step
1/1             0s 45ms/step
1/1             0s 45ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 43ms/step
1/1             0s 47ms/step
1/1             0s 42ms/step
1/1             0s 46ms/step
1/1             0s 47ms/step
1/1             0s 46ms/step
1/1             0s 50ms/step
1/1             0s 51ms/step
1/1             0s 44ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 43ms/step
1/1             0s 47ms/step
1/1             0s 44ms/step
1/1             0s 46ms/step
1/1             0s 43ms/step
1/1             0s 43ms/step
1/1             0s 50ms/step
1/1             0s 43ms/step
1/1             0s 45ms/step
1/1             0s 53ms/step
1/1             0s 46ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
1/1             0s 50ms/step
```

```
1/1             0s 44ms/step
1/1             0s 50ms/step
1/1             0s 51ms/step
1/1             0s 50ms/step
1/1             0s 42ms/step
1/1             0s 51ms/step
1/1             0s 47ms/step
1/1             0s 45ms/step
1/1             0s 47ms/step
1/1             0s 45ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 53ms/step
1/1             0s 51ms/step
1/1             0s 48ms/step
1/1             0s 47ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 43ms/step
1/1             0s 48ms/step
1/1             0s 44ms/step
1/1             0s 47ms/step
1/1             0s 43ms/step
1/1             0s 51ms/step
1/1             0s 43ms/step
1/1             0s 64ms/step
1/1             0s 49ms/step
1/1             0s 45ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 47ms/step
1/1             0s 50ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 46ms/step
1/1             0s 42ms/step
1/1             0s 49ms/step
1/1             0s 46ms/step
1/1             0s 44ms/step
1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 47ms/step
1/1             0s 42ms/step
```

```
1/1             0s 43ms/step
1/1             0s 47ms/step
1/1             0s 50ms/step
1/1             0s 51ms/step
1/1             0s 44ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
1/1             0s 47ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
1/1             0s 42ms/step
1/1             0s 41ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
1/1             0s 42ms/step
1/1             0s 51ms/step
1/1             0s 47ms/step
1/1             0s 46ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 47ms/step
1/1             0s 44ms/step
1/1             0s 42ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 48ms/step
1/1             0s 44ms/step
1/1             0s 50ms/step
1/1             0s 42ms/step
1/1             0s 48ms/step
1/1             0s 50ms/step
1/1             0s 46ms/step
1/1             0s 48ms/step
1/1             0s 45ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 47ms/step
1/1             0s 49ms/step
1/1             0s 57ms/step
1/1             0s 49ms/step
1/1             0s 45ms/step
1/1             0s 51ms/step
1/1             0s 48ms/step
1/1             0s 49ms/step
1/1             0s 49ms/step
```

```
1/1             0s 44ms/step
1/1             0s 51ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 50ms/step
1/1             0s 49ms/step
1/1             0s 42ms/step
1/1             0s 51ms/step
1/1             0s 48ms/step
1/1             0s 69ms/step
1/1             0s 52ms/step
1/1             0s 53ms/step
1/1             0s 54ms/step
1/1             0s 56ms/step
1/1             0s 51ms/step
1/1             0s 47ms/step
1/1             0s 53ms/step
1/1             0s 53ms/step
1/1             0s 45ms/step
1/1             0s 46ms/step
1/1             0s 48ms/step
1/1             0s 51ms/step
1/1             0s 46ms/step
1/1             0s 48ms/step
1/1             0s 43ms/step
1/1             0s 44ms/step
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1/1             0s 43ms/step
1/1             0s 49ms/step
1/1             0s 48ms/step
1/1             0s 46ms/step
1/1             0s 67ms/step
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1/1             0s 52ms/step
1/1             0s 60ms/step
1/1             0s 58ms/step
1/1             0s 42ms/step
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1/1             0s 41ms/step
1/1             0s 42ms/step
1/1             0s 41ms/step
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1/1             0s 45ms/step
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[411]:
```
display(rows_to_predict.head())
```

```
          Image Index  Follow-up #  Patient Age  Patient Gender  \
4457  00013549_002.png    -0.362342     0.587909               0
5605  00019087_017.png     1.065656    -0.964004               1
4686  00014647_010.png     0.399257    -0.343239               1
1055  00010047_000.png    -0.552742    -0.653622               0
4813  00015163_001.png    -0.457542     1.705287               1

      has_Infection/Infiltration  has_Fluid Related Issues  \
4457                           0                         0
5605                           0                         1
4686                           0                         0
1055                           0                         0
4813                           0                         0

      has_Lung Structure Issues  has_Nodule/Mass  has_Cardiac Issues  \
4457                          0                1                   0
5605                          0                0                   0
4686                          1                0                   0
```

```
1055                          0                0                    0
4813                          0                1                    0

      has_Hernia  has_No Finding           group_labels  \
4457           0               0  [0, 0, 0, 1, 0, 0, 0]
5605           0               0  [0, 1, 0, 0, 0, 0, 0]
4686           0               0  [0, 0, 1, 0, 0, 0, 0]
1055           0               1  [0, 0, 0, 0, 0, 0, 1]
4813           0               0  [0, 0, 0, 1, 0, 0, 0]

                                 predicted_group_labels
4457  [0.5562078952789307, 0.24440336227416992, 0.49…
5605  [0.5497235655784607, 0.8173720240592957, 0.585…
4686  [0.49886050820350647, 0.5623040199279785, 0.57…
1055  [0.5381428599357605, 0.20930270850658417, 0.42…
4813  [0.5382555723190308, 0.5873086452484131, 0.472…
```

[412]:
```
from sklearn.metrics import classification_report, accuracy_score

# Assumes categories = ['Cardiac Issues', 'Fluid Related Issues', ..., 'Nodule/
 ↪Mass']
print("\nClassification Report:\n")
print(f"{'Category':30} {'Precision':>9} {'Recall':>9} {'F1-score':>9}␣
 ↪{'Support':>9} {'Accuracy':>9}")

# Extract actual and predicted group labels
true_group_labels = list(rows_to_predict['group_labels'])
pred_group_labels = list(rows_to_predict['predicted_group_labels'])

# Loop over each category
for i, category in enumerate(categories):
    y_true = [row[i] for row in true_group_labels]
    y_pred = [1 if row[i] >= 0.5 else 0 for row in pred_group_labels]  # Apply␣
 ↪threshold

    report = classification_report(y_true, y_pred, output_dict=True,␣
 ↪zero_division=0)
    acc = accuracy_score(y_true, y_pred)

    precision = report['1']['precision']
    recall = report['1']['recall']
    f1 = report['1']['f1-score']
    support = int(report['1']['support'])

    print(f"{category:30} {precision:9.2f} {recall:9.2f} {f1:9.2f} {support:9d}␣
 ↪{acc:9.2f}")
```

Classification Report:

Category	Precision	Recall	F1-score	Support	Accuracy
Infection/Infiltration	0.29	0.81	0.43	267	0.42
Fluid Related Issues	0.38	0.82	0.52	209	0.69
Lung Structure Issues	0.34	0.48	0.40	259	0.63
Nodule/Mass	0.24	0.63	0.35	201	0.53
Cardiac Issues	0.04	1.00	0.08	41	0.04
Hernia	0.00	1.00	0.01	3	0.00
No Finding	0.37	0.53	0.44	288	0.60

[ ]: