

Final Project Section IN1-Team 3

June 21, 2025

1 Final Team Project - Group 3

1.1 Machine learning: Fundamentals and Applications (AAI-510-IN1)

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2 The Sound of Feelings: Analyzing Emotional Speech Patterns

Overview

“The Sound of Feelings” is a machine learning project that explores the emotional signatures embedded in human speech. Using the RAVDESS Emotional Speech Audio dataset, the objective is to train models that can identify and understand emotions based on acoustic features like pitch, energy, zero-crossing rate, MFCCs, and more.

By teaching machines to listen the way humans do, this project attempts to bridge the gap between technology and human emotions through the art of vocal expression.

Problem Statement and Justification

Human communication relies heavily on tone and emotion. Identifying emotional content in speech is essential for human-computer interaction, therapy, customer service, and accessibility technology. The main goal of this project is to classify emotional states from raw speech signals and understand why certain acoustic features correlate with specific emotions.

We approached this problem using classical machine learning models, neural networks, and feature-rich spectrogram analysis to explore and predict emotional categories.

Dataset Description

Source: Kaggle RAVDESS Dataset

Size: 1440 audio-only files (.wav format)

Actors: 24 (12 male, 12 female)

Emotions: Calm, Happy, Sad, Angry, Fearful, Surprise, Disgust, Neutral

Sampling Rate: 48kHz

Each file name contains encoded metadata like emotion, intensity, repetition, and actor identity. We used these identifiers for label extraction and emotional categorization.

3 Mount Google Drive

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

Mounted at /content/drive

4 Unzip Audio Dataset

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[9]: !unzip '/content/drive/MyDrive/Audio.zip' -d '/content/audio_dataset'
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    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_11/03-01-06-
01-02-01-11.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_11/03-01-06-
```


02-02-02-12.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_12/03-01-08-01-01-01-12.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_12/03-01-08-01-01-02-12.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_12/03-01-08-01-02-01-12.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_12/03-01-08-02-01-01-12.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_12/03-01-08-02-01-02-12.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_12/03-01-08-02-02-01-12.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_12/03-01-08-02-02-02-12.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_13/03-01-01-01-01-01-13.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_13/03-01-01-01-01-02-13.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_13/03-01-01-01-02-01-13.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_13/03-01-01-01-02-02-13.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_13/03-01-02-01-01-13.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_13/03-01-02-01-02-13.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_13/03-01-02-01-02-01-13.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_13/03-01-02-01-02-02-13.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_13/03-01-02-02-01-13.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_13/03-01-02-02-02-13.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_13/03-01-03-01-01-01-13.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_13/03-01-03-01-01-02-13.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_13/03-01-03-01-02-01-13.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_13/03-01-03-01-02-02-13.wav


```
11-02-02-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-06-
02-01-01-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-06-
02-01-02-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-06-
02-02-01-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-06-
02-02-02-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-07-
01-01-01-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-07-
01-01-02-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-07-
01-02-01-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-07-
01-02-02-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-07-
02-01-01-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-07-
02-01-02-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-07-
02-02-01-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-07-
02-02-02-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-08-
01-01-01-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-08-
01-01-02-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-08-
01-02-01-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-08-
02-01-01-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-08-
02-01-02-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-08-
02-02-01-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_15/03-01-08-
02-02-02-15.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_16/03-01-01-
01-01-01-16.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_16/03-01-01-
01-01-02-16.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_16/03-01-01-
01-02-01-16.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_16/03-01-01-
```


02-02-02-18.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_18/03-01-08-01-01-01-18.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_18/03-01-08-01-01-02-18.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_18/03-01-08-01-02-01-18.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_18/03-01-08-02-01-01-18.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_18/03-01-08-02-01-02-18.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_18/03-01-08-02-02-01-18.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_18/03-01-08-02-02-02-18.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_19/03-01-01-01-01-01-19.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_19/03-01-01-01-01-02-19.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_19/03-01-01-01-02-01-19.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_19/03-01-01-01-02-02-19.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_19/03-01-02-01-01-19.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_19/03-01-02-01-02-19.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_19/03-01-02-01-02-01-19.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_19/03-01-02-01-02-02-19.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_19/03-01-02-02-01-19.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_19/03-01-02-02-02-19.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_19/03-01-03-01-01-01-19.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_19/03-01-03-01-01-02-19.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_19/03-01-03-01-02-01-19.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_19/03-01-03-01-02-02-19.wav

02-02-02-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-05-01-01-01-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-05-01-01-02-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-05-01-02-01-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-05-02-01-01-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-05-02-01-02-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-05-02-02-01-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-05-02-02-02-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-06-01-01-01-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-06-01-01-02-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-06-01-02-01-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-06-02-01-01-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-06-02-01-02-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-06-02-02-01-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-06-02-02-02-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-07-01-01-01-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-07-01-01-02-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-07-01-02-01-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-07-02-01-01-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-07-02-01-02-20.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_20/03-01-07-02-02-01-20.wav

11-02-02-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-06-02-01-01-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-06-02-01-02-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-06-02-02-01-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-06-02-02-02-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-07-01-01-01-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-07-01-01-02-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-07-01-02-01-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-07-02-01-01-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-07-02-01-02-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-07-02-02-01-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-07-02-02-02-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-08-01-01-01-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-08-01-01-02-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-08-01-02-01-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-08-02-01-01-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-08-02-01-02-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-08-02-02-01-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_21/03-01-08-02-02-02-21.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_22/03-01-01-01-01-01-22.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_22/03-01-01-01-01-02-22.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_22/03-01-01-01-02-01-22.wav
inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_22/03-01-01-01-02-02-22.wav


```
02-02-02-24.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_24/03-01-08-
01-01-01-24.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_24/03-01-08-
01-01-02-24.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_24/03-01-08-
01-02-01-24.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_24/03-01-08-
01-02-02-24.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_24/03-01-08-
02-01-01-24.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_24/03-01-08-
02-01-02-24.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_24/03-01-08-
02-02-01-24.wav
    inflating: /content/audio_dataset/audio_speech_actors_01-24/Actor_24/03-01-08-
02-02-02-24.wav
```

5 Import libraries

[1]: `!pip install pyloudnorm`

```
Requirement already satisfied: pyloudnorm in /usr/local/lib/python3.11/dist-
packages (0.1.1)
Requirement already satisfied: scipy>=1.0.1 in /usr/local/lib/python3.11/dist-
packages (from pyloudnorm) (1.15.3)
Requirement already satisfied: numpy>=1.14.2 in /usr/local/lib/python3.11/dist-
packages (from pyloudnorm) (2.0.2)
Requirement already satisfied: future>=0.16.0 in /usr/local/lib/python3.11/dist-
packages (from pyloudnorm) (1.0.0)
```

[2]: `!pip install xgboost`

```
Requirement already satisfied: xgboost in /usr/local/lib/python3.11/dist-
packages (2.1.4)
Requirement already satisfied: numpy in /usr/local/lib/python3.11/dist-packages
(from xgboost) (2.0.2)
Requirement already satisfied: nvidia-nccl-cu12 in
/usr/local/lib/python3.11/dist-packages (from xgboost) (2.21.5)
Requirement already satisfied: scipy in /usr/local/lib/python3.11/dist-packages
(from xgboost) (1.15.3)
```

[35]: `!pip install catboost`

```
Collecting catboost
  Downloading catboost-1.2.8-cp311-cp311-manylinux2014_x86_64.whl.metadata (1.2
kB)
```

```

Requirement already satisfied: graphviz in /usr/local/lib/python3.11/dist-
packages (from catboost) (0.21)
Requirement already satisfied: matplotlib in /usr/local/lib/python3.11/dist-
packages (from catboost) (3.10.0)
Requirement already satisfied: numpy<3.0,>=1.16.0 in
/usr/local/lib/python3.11/dist-packages (from catboost) (2.0.2)
Requirement already satisfied: pandas>=0.24 in /usr/local/lib/python3.11/dist-
packages (from catboost) (2.2.2)
Requirement already satisfied: scipy in /usr/local/lib/python3.11/dist-packages
(from catboost) (1.15.3)
Requirement already satisfied: plotly in /usr/local/lib/python3.11/dist-packages
(from catboost) (5.24.1)
Requirement already satisfied: six in /usr/local/lib/python3.11/dist-packages
(from catboost) (1.17.0)
Requirement already satisfied: python-dateutil>=2.8.2 in
/usr/local/lib/python3.11/dist-packages (from pandas>=0.24->catboost)
(2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.11/dist-
packages (from pandas>=0.24->catboost) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in /usr/local/lib/python3.11/dist-
packages (from pandas>=0.24->catboost) (2025.2)
Requirement already satisfied: contourpy>=1.0.1 in
/usr/local/lib/python3.11/dist-packages (from matplotlib->catboost) (1.3.2)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.11/dist-
packages (from matplotlib->catboost) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in
/usr/local/lib/python3.11/dist-packages (from matplotlib->catboost) (4.58.4)
Requirement already satisfied: kiwisolver>=1.3.1 in
/usr/local/lib/python3.11/dist-packages (from matplotlib->catboost) (1.4.8)
Requirement already satisfied: packaging>=20.0 in
/usr/local/lib/python3.11/dist-packages (from matplotlib->catboost) (24.2)
Requirement already satisfied: pillow>=8 in /usr/local/lib/python3.11/dist-
packages (from matplotlib->catboost) (11.2.1)
Requirement already satisfied: pyparsing>=2.3.1 in
/usr/local/lib/python3.11/dist-packages (from matplotlib->catboost) (3.2.3)
Requirement already satisfied: tenacity>=6.2.0 in
/usr/local/lib/python3.11/dist-packages (from plotly->catboost) (9.1.2)
Downloading catboost-1.2.8-cp311-cp311-manylinux2014_x86_64.whl (99.2 MB)
  99.2/99.2 MB
 7.2 MB/s eta 0:00:00
Installing collected packages: catboost
Successfully installed catboost-1.2.8

```

```
[46]: import os
import gc
import math
import itertools
```

```

import json
import time
import librosa
import numpy as np
import pandas as pd
import seaborn as sns
from tqdm import tqdm
import pyloudnorm as pyln
import IPython.display as ipd
import matplotlib.pyplot as plt
import matplotlib.cm as cm
from joblib import delayed, Parallel

import warnings
warnings.filterwarnings("ignore")

%matplotlib inline

import torch
import torch.nn as nn
import torch.nn.functional as F
from torch.utils.data import Dataset, DataLoader

import torchaudio
import torchaudio.transforms as T

from sklearn.linear_model import RidgeClassifier
from sklearn.ensemble import HistGradientBoostingClassifier
from sklearn.discriminant_analysis import QuadraticDiscriminantAnalysis
from sklearn.tree import DecisionTreeClassifier
from xgboost import XGBClassifier
from lightgbm import LGBMClassifier
from catboost import CatBoostClassifier
from sklearn.preprocessing import LabelEncoder, StandardScaler, label_binarize
from sklearn.ensemble import RandomForestClassifier, ExtraTreesClassifier, ↴
    GradientBoostingClassifier, AdaBoostClassifier, BaggingClassifier
from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score, precision_score, recall_score, ↴
    f1_score, confusion_matrix, roc_curve, auc, roc_auc_score
from sklearn.neighbors import KNeighborsClassifier
from sklearn.neural_network import MLPClassifier
from sklearn.naive_bayes import GaussianNB

from sklearn.preprocessing import StandardScaler

```

```

from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout, BatchNormalization, Activation
from tensorflow.keras.utils import to_categorical

```

6 EDA and Preprocessing

Graphical and statistical methods were used:

Count plots: Emotion distribution

Strip/Swarm/Point/Bar plots: Duration, pitch, energy, and zero-crossing rate by emotion

Spectrograms: Visualizing frequency distribution over time

Correlation heatmaps: Relationship between acoustic features

```
[47]: # Base directory where files are extracted
base_dir = "/content/audio_dataset"
```

```
[48]: # Lists to hold parsed data
emotion_labels = []
audio_file_paths = []

# Helper function to extract .wav file paths and associated emotion codes
def extract_audio_data_from_dir(directory_path):
    for root_dir, _, files in os.walk(directory_path):
        for filename in files:
            if filename.endswith('.wav'):
                parts = filename.split('.')[0].split('-')
                if len(parts) >= 3:
                    try:
                        emotion_code = int(parts[2])
                        emotion_labels.append(emotion_code)
                        audio_file_paths.append(os.path.join(root_dir, filename))
                    except ValueError:
                        continue # Skip files with unexpected naming format
```

```
[49]: # Traverse dataset directories
extract_audio_data_from_dir(os.path.join(base_dir, "audio_speech_actors_01-24"))
extract_audio_data_from_dir(base_dir)

# Combine into DataFrame
emotion_df = pd.DataFrame(emotion_labels, columns=['EmotionCode'])
path_df = pd.DataFrame(audio_file_paths, columns=['AudioPath'])
audio_emotion_df = pd.concat([emotion_df, path_df], axis=1)
```

```
# Map numeric emotion codes to labels
emotion_code_map = {
    1: 'neutral',
    2: 'calm',
    3: 'happy',
    4: 'sad',
    5: 'angry',
    6: 'fear',
    7: 'disgust',
    8: 'surprise'
}
audio_emotion_df['EmotionLabel'] = audio_emotion_df['EmotionCode'].
    ↪map(emotion_code_map)
```

[50]: # Save as CSV

```
output_dir = "/content/EmotionData"
os.makedirs(output_dir, exist_ok=True)
audio_emotion_df.to_csv(os.path.join(output_dir, "emotion_audio_dataset.csv"), ↪
    index=False)
```

[51]: # View the CSV

```
audio_emotion_df.head(10)
```

	EmotionCode	AudioPath	EmotionLabel
0	8	/content/audio_dataset/audio_speech_actors_01...	surprise
1	2	/content/audio_dataset/audio_speech_actors_01...	calm
2	8	/content/audio_dataset/audio_speech_actors_01...	surprise
3	2	/content/audio_dataset/audio_speech_actors_01...	calm
4	1	/content/audio_dataset/audio_speech_actors_01...	neutral
5	6	/content/audio_dataset/audio_speech_actors_01...	fear
6	4	/content/audio_dataset/audio_speech_actors_01...	sad
7	4	/content/audio_dataset/audio_speech_actors_01...	sad
8	1	/content/audio_dataset/audio_speech_actors_01...	neutral
9	7	/content/audio_dataset/audio_speech_actors_01...	disgust

[9]: # Dark aesthetic theme

```
sns.set_theme(
    context='notebook',
    style='dark',
    palette='rocket',
    font='monospace',
    font_scale=1.1,
    color_codes=True
)

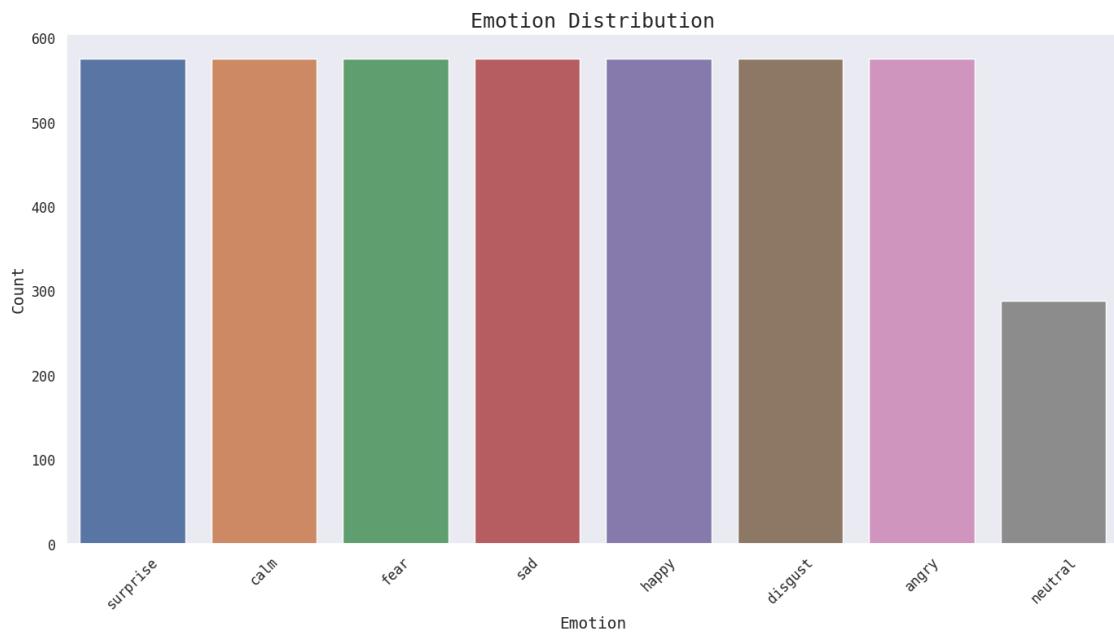
plt.figure(figsize=(14, 8))
sns.countplot(
```

```

        x='EmotionLabel',
        data=audio_emotion_df,
        order=audio_emotion_df['EmotionLabel'].value_counts().index,
        palette='deep' # clean, modern colors
    )
plt.title('Emotion Distribution', fontsize=18)
plt.xlabel('Emotion', fontsize=14)
plt.ylabel('Count', fontsize=14)
plt.xticks(rotation=45)
plt.tight_layout()

# Save and display plot
plt.savefig(os.path.join(output_dir, "emotions_plot.png"))
plt.show()

```



6.1 Spectrogram

```
[22]: def generate_and_save_spectrogram(audio_path, emotion_name, output_root):
    """
    Generates a spectrogram from the given audio file and saves it as a PNG
    ↪image
    in a subdirectory named after the emotion label.
    """
    try:
        # Load the audio file

```

```

    signal, sample_rate = librosa.load(audio_path)

    # Compute the Short-Time Fourier Transform (STFT)
    stft_result = librosa.stft(signal)
    stft_db = librosa.amplitude_to_db(abs(stft_result))

    # Define emotion-specific output directory
    emotion_folder = os.path.join(output_root, emotion_name)
    os.makedirs(emotion_folder, exist_ok=True)

    # Create filename by replacing .wav with .png
    file_name = os.path.basename(audio_path).replace('.wav', '.png')
    output_path = os.path.join(emotion_folder, file_name)

    # Plot the spectrogram
    plt.figure(figsize=(10, 3))
    librosa.display.specshow(stft_db, sr=sample_rate, x_axis='time', ▾
    ↵y_axis='hz')
    plt.colorbar(format="%+2.0f dB")
    plt.title(f"{emotion_name}", fontsize=12)
    plt.tight_layout()
    plt.savefig(output_path)
    plt.close()

except Exception as error:
    print(f"Error generating spectrogram for {audio_path}: {error}")

```

```

[ ]: # Directory where spectrograms will be saved
spectrogram_output_dir = os.path.join(output_dir, "spectrograms")

# Generate and save spectrograms for all audio files
for _, row in tqdm(audio_emotion_df.iterrows(), total=len(audio_emotion_df), ▾
    ↵desc="Generating Spectrograms"):
    generate_and_save_spectrogram(row['AudioPath'], row['EmotionLabel'], ▾
    ↵spectrogram_output_dir)

```

Generating Spectrograms: 24% | 1031/4320 [08:06<27:38, 1.98it/s]

7 Feature Engineering and Data Preparation

Parsing: Extracted file paths and emotion labels from filenames

Audio Processing:

Computed pitch, energy, zero-crossing rate, and duration

Extracted 15 MFCCs per audio sample

Normalization: Used RobustScaler instead of StandardScaler to reduce the impact of outliers

Label Encoding: Transformed categorical emotion labels to numeric

```
[52]: # Take a random sample of 1500 audio files from the full dataset
sampled_audio_df = audio_emotion_df.sample(n=2000, random_state=42).copy()

# Initialize lists to store extracted audio features
durations = []
pitches = []
energies = []
zcr_values = []

# Extract audio features from each sampled file
for audio_file in sampled_audio_df['AudioPath']:
    y, sr = librosa.load(audio_file, sr=None)

    # Pitch
    pitch_matrix, magnitude_matrix = librosa.piptrack(y=y, sr=sr)
    mean_pitch = pitch_matrix[magnitude_matrix > np.median(magnitude_matrix)].mean()

    # Energy
    mean_energy = np.mean(y**2)

    # Duration
    duration_sec = librosa.get_duration(y=y, sr=sr)

    # Zero Crossing Rate
    mean_zcr = np.mean(librosa.feature.zero_crossing_rate(y=y))

    pitches.append(mean_pitch)
    energies.append(mean_energy)
    durations.append(duration_sec)
    zcr_values.append(mean_zcr)

# Add extracted features to the sampled DataFrame
sampled_audio_df['Duration'] = durations
sampled_audio_df['Pitch'] = pitches
sampled_audio_df['Energy'] = energies
sampled_audio_df['ZCR'] = zcr_values
```

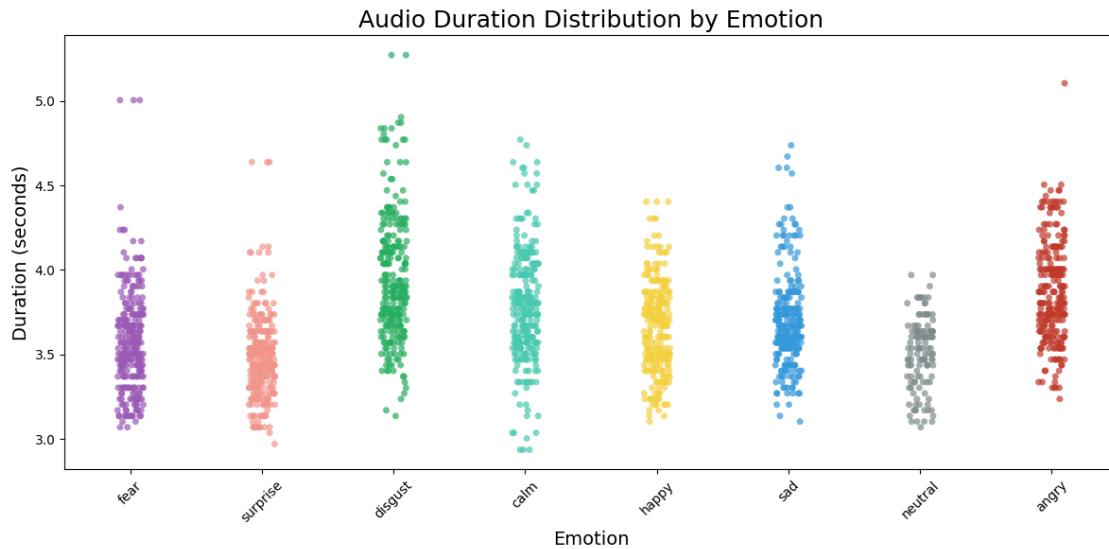
```
[53]: # custom colors for each emotion
emotion_color_palette = {
    "happy": "#F4D03F",      # golden yellow
    "sad": "#3498DB",       # rich blue
    "angry": "#C0392B",      # dark red
    "neutral": "#7F8C8D",    # stone gray
    "calm": "#48C9B0",       # mint green
```

```

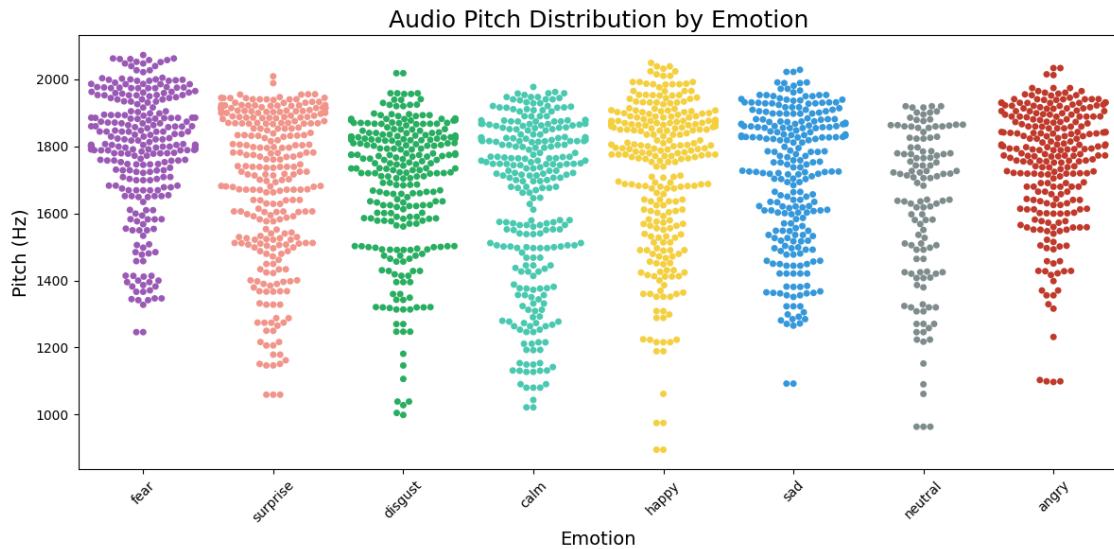
        "fear": "#9B59B6",           # soft violet
        "disgust": "#27AE60",         # emerald green
        "surprise": "#F1948A"
    }

```

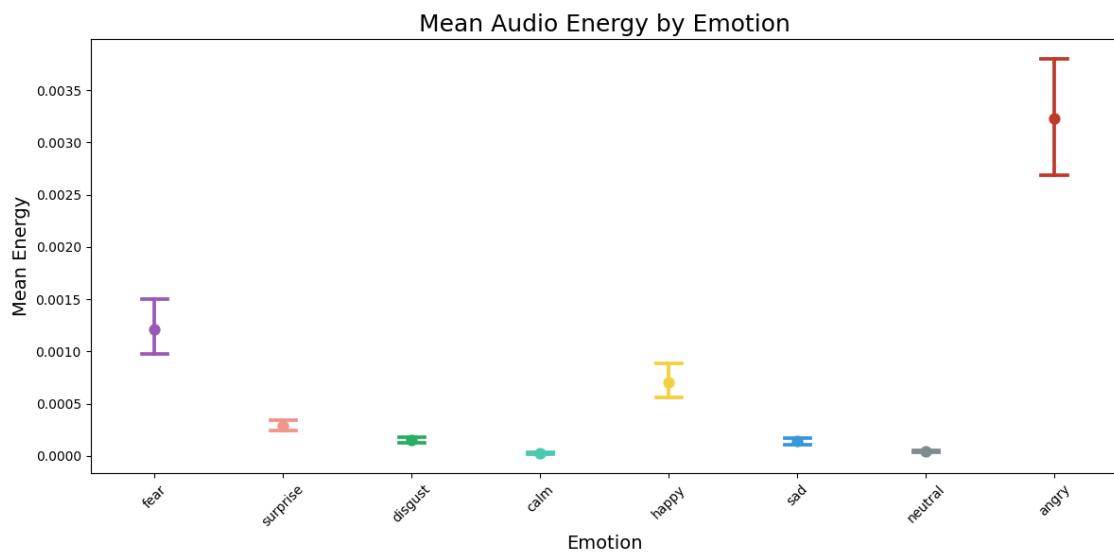
```
[54]: plt.figure(figsize=(12, 6))
sns.stripplot(x='EmotionLabel', y='Duration', data=sampled_audio_df,
               palette=emotion_color_palette, jitter=True, size=5, alpha=0.7)
plt.title("Audio Duration Distribution by Emotion", fontsize=18)
plt.xlabel("Emotion", fontsize=14)
plt.ylabel("Duration (seconds)", fontsize=14)
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```



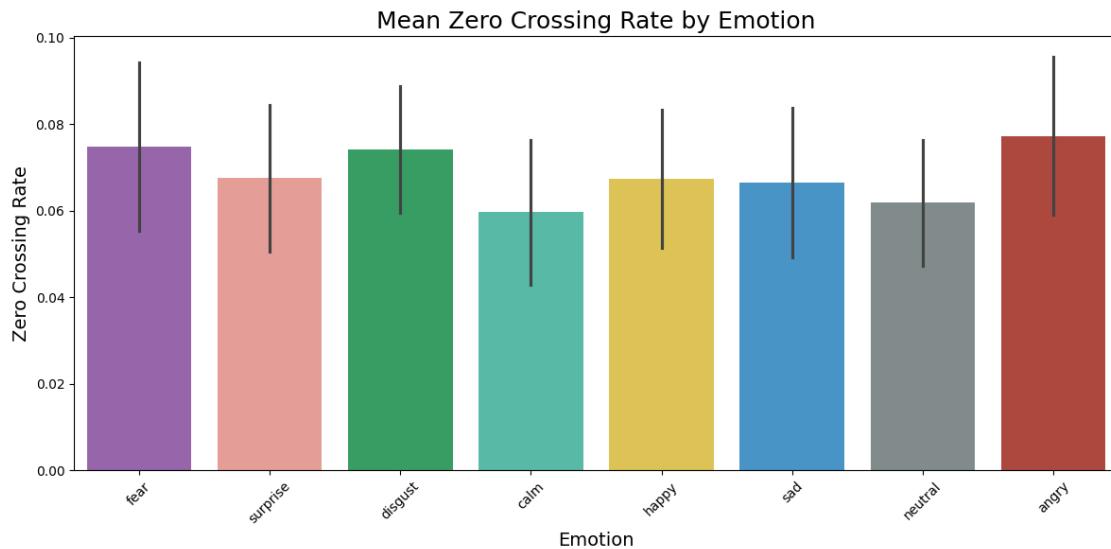
```
[55]: plt.figure(figsize=(12, 6))
sns.swarmplot(x='EmotionLabel', y='Pitch', data=sampled_audio_df,
               palette=emotion_color_palette, size=5)
plt.title("Audio Pitch Distribution by Emotion", fontsize=18)
plt.xlabel("Emotion", fontsize=14)
plt.ylabel("Pitch (Hz)", fontsize=14)
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```



```
[56]: plt.figure(figsize=(12, 6))
sns.pointplot(x='EmotionLabel', y='Energy', data=sampled_audio_df,
               palette=emotion_color_palette, join=False, capsize=0.2)
plt.title("Mean Audio Energy by Emotion", fontsize=18)
plt.xlabel("Emotion", fontsize=14)
plt.ylabel("Mean Energy", fontsize=14)
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```



```
[57]: plt.figure(figsize=(12, 6))
sns.barplot(x='EmotionLabel', y='ZCR', data=sampled_audio_df,
            palette=emotion_color_palette, ci="sd")
plt.title("Mean Zero Crossing Rate by Emotion", fontsize=18)
plt.xlabel("Emotion", fontsize=14)
plt.ylabel("Zero Crossing Rate", fontsize=14)
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```



```
[7]: # Function to normalize and clean emotion labels
def normalize_emotion_label(label):
    if isinstance(label, (np.ndarray, list)):
        return str(label[0])
    return str(label)
```

```
[8]: # Clean up any inconsistent emotion labels
sampled_audio_df['EmotionLabel'] = sampled_audio_df['EmotionLabel'].
    ↪apply(normalize_emotion_label)
```

7.1 Feature Selection

Features were selected based on:

Variability across emotion classes (e.g., pitch varies most for happy/fearful)

Correlation with the target emotion class

Experiments with different k-values in KMeans and performance of decision trees

Selected features included: Pitch, Energy, ZCR, Duration, and MFCC_1 to MFCC_15.

```
[9]: # Function to extract MFCCs
def extract_mfcc_features(audio_file, n_mfcc=15):
    try:
        y, sr = librosa.load(audio_file, sr=None)
        mfccs = librosa.feature.mfcc(y=y, sr=sr, n_mfcc=n_mfcc)
        return np.mean(mfccs, axis=1)
    except Exception as e:
        print(f"Failed MFCC extraction from {audio_file}: {e}")
        return np.zeros(n_mfcc)

[10]: # Extract MFCC features for each audio file
mfcc_feature_list = []
for audio_file in sampled_audio_df['AudioPath']:
    mfcc_feature_list.append(extract_mfcc_features(audio_file, n_mfcc=15))

# Convert MFCC features into DataFrame
mfcc_feature_df = pd.DataFrame(mfcc_feature_list, columns=[f'MFCC_{i+1}' for i in range(15)])
mfcc_feature_df.reset_index(drop=True, inplace=True)
sampled_audio_df.reset_index(drop=True, inplace=True)

[11]: # Combine MFCCs with other features
feature_df = pd.concat([
    mfcc_feature_df,
    sampled_audio_df[['Pitch', 'Energy', 'ZCR', 'Duration', 'EmotionLabel']]
], axis=1)

[29]: feature_df.head()

[29]:
```

	MFCC_1	MFCC_2	MFCC_3	MFCC_4	MFCC_5	MFCC_6	MFCC_7	MFCC_8	MFCC_9	MFCC_10	MFCC_11	MFCC_12	MFCC_13	MFCC_14	MFCC_15	Pitch	Energy	ZCR	Duration	EmotionLabel
0	-497.267181	29.747702	-16.749750	-2.781938	-13.290050	-4.604352	-16.823717	-5.616928	-8.648810	-9.526477	-6.052828	-4.417263	-5.346954	-2.165839	3.389515	1975.916504	0.001157	0.094916	4.070729	fear
1	-561.738159	63.771156	-8.193513	10.717543	1.528304	11.123491	-9.027408	-1.619140	-2.938692	-9.928777	-9.759050	1.479662	-0.939398	-8.157356	-5.541070	1886.320190	0.000508	0.070377	3.470146	surprise
2	-645.410645	75.006981	-5.645598	11.208323	5.156332	7.834976	-700.848328	73.979218	13.752046	24.008165	2.642706	15.747820	-3.245348	6.640845	-6.408341	-4.687808	-0.684048	2.455816	-2.964346	
3	-700.848328	73.979218	13.752046	24.008165	2.642706	15.747820	-800.919861	50.396084	6.960778	13.710006	-5.116372	4.601861	-7.781662	3.272309	-11.155941	-1.797051	-3.456108	-1.959189	-1.131546	
4	-800.919861	50.396084	6.960778	13.710006	-5.116372	4.601861	-7.781662	3.272309	-11.155941	-1.797051	-3.456108	-1.959189	-1.131546	-2.165839	3.389515	1975.916504	0.001157	0.094916	4.070729	fear

```
3 -0.750196 -2.388092 1269.823853 0.000024 0.069154 3.937271      disgust
4 -3.742565 -3.461024 1825.969971 0.000003 0.060490 3.737062      calm
```

```
[30]: feature_df['EmotionLabel'].value_counts()
```

```
[30]: EmotionLabel
surprise    282
fear        273
calm        273
disgust     270
happy       269
angry       256
sad         252
neutral     125
Name: count, dtype: int64
```

```
[31]: feature_df.describe()
```

```
[31]:          MFCC_1      MFCC_2      MFCC_3      MFCC_4      MFCC_5 \
count  2000.000000  2000.000000  2000.000000  2000.000000  2000.000000
mean   -618.457886   65.781570   -4.643002   10.301273  -0.265238
std    100.004158   14.611405   11.708288   8.168470   6.887895
min   -873.242310   18.962200  -51.957912  -17.508692  -22.566322
25%  -693.353943   55.540034  -12.256225   4.729426  -5.063827
50%  -625.892120   66.068928  -3.692443  10.311200  -0.467768
75%  -553.163635   75.982845   3.577858  15.233767  4.873952
max  -333.377960  110.981491  22.603916  36.563427  21.130016

          MFCC_6      MFCC_7      MFCC_8      MFCC_9      MFCC_10 \
count  2000.000000  2000.000000  2000.000000  2000.000000  2000.000000
mean    8.167881  -8.399657   0.961017  -7.083739  -5.577426
std     7.151240   6.026907   5.148296   4.875229   4.356740
min   -11.918347  -29.964558  -16.975168  -21.486059  -21.439531
25%    2.795366  -12.362157  -2.576894  -10.732538  -8.760663
50%    8.558703  -8.973296   0.830992  -7.637449  -5.630704
75%   13.434915  -4.454705   4.362810  -3.310813  -2.199036
max   25.823013  10.092591  16.410280   6.087853   7.422122

          MFCC_11     MFCC_12     MFCC_13     MFCC_14     MFCC_15 \
count  2000.000000  2000.000000  2000.000000  2000.000000  2000.000000
mean   -4.066771  -1.930307  -1.759953  -3.111051  -2.970052
std    3.731323   3.257063   3.948246   3.439200   3.347444
min   -17.051992 -15.883946 -13.192415 -13.353581 -13.080017
25%   -6.417119  -4.051571  -4.960642  -5.332899  -5.221140
50%   -4.095771  -2.142579  -1.592526  -3.305322  -3.211582
75%   -1.692411   0.252324   1.265775  -1.033285  -0.887127
max    9.350845  18.046015  13.240598   9.045076  18.721136
```

	Pitch	Energy	ZCR	Duration
count	2000.000000	2.000000e+03	2000.000000	2000.000000
mean	1701.023193	7.585760e-04	0.069072	3.702966
std	220.666077	2.144486e-03	0.017882	0.334563
min	894.840393	4.249464e-07	0.029217	2.936271
25%	1568.141815	2.588635e-05	0.057052	3.470146
50%	1763.358093	9.584845e-05	0.066108	3.670333
75%	1868.641602	3.804911e-04	0.079790	3.870542
max	2072.602539	2.315510e-02	0.168519	5.271937

```
[32]: feature_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 2000 entries, 0 to 1999
Data columns (total 20 columns):
 #   Column           Non-Null Count  Dtype  
 ---  --  
 0    MFCC_1          2000 non-null   float32 
 1    MFCC_2          2000 non-null   float32 
 2    MFCC_3          2000 non-null   float32 
 3    MFCC_4          2000 non-null   float32 
 4    MFCC_5          2000 non-null   float32 
 5    MFCC_6          2000 non-null   float32 
 6    MFCC_7          2000 non-null   float32 
 7    MFCC_8          2000 non-null   float32 
 8    MFCC_9          2000 non-null   float32 
 9    MFCC_10         2000 non-null   float32 
 10   MFCC_11         2000 non-null   float32 
 11   MFCC_12         2000 non-null   float32 
 12   MFCC_13         2000 non-null   float32 
 13   MFCC_14         2000 non-null   float32 
 14   MFCC_15         2000 non-null   float32 
 15   Pitch           2000 non-null   float32 
 16   Energy          2000 non-null   float32 
 17   ZCR             2000 non-null   float64  
 18   Duration        2000 non-null   float64  
 19   EmotionLabel    2000 non-null   object  
dtypes: float32(17), float64(2), object(1)
memory usage: 179.8+ KB
```

7.2 Label Encoding

```
[12]: # Encode emotion labels as integers
label_encoder = LabelEncoder()
feature_df['EmotionEncoded'] = label_encoder.
    ↪fit_transform(feature_df['EmotionLabel'])
```

```
# Optional: Display label-to-integer mapping
emotion_label_map = dict(zip(label_encoder.classes_, label_encoder.
    ↪transform(label_encoder.classes_)))
emotion_label_map
```

```
[12]: {'angry': np.int64(0),
       'calm': np.int64(1),
       'disgust': np.int64(2),
       'fear': np.int64(3),
       'happy': np.int64(4),
       'neutral': np.int64(5),
       'sad': np.int64(6),
       'surprise': np.int64(7)}
```

8 Modelling and Evaluation

```
[13]: # Updated dictionary of ML models
ml_models = {
    "Logistic Regression": LogisticRegression(max_iter=1000),
    "Random Forest": RandomForestClassifier(),
    "Decision Tree": DecisionTreeClassifier(),
    "Gradient Boosting": GradientBoostingClassifier(),
    "HistGradient Boosting": HistGradientBoostingClassifier(),
    "XGBoost": XGBClassifier(use_label_encoder=False, eval_metric='mlogloss',
    ↪verbosity=0),
    "CatBoost": CatBoostClassifier(verbose=0),
    "K-Nearest Neighbors": KNeighborsClassifier(),
    "Neural Network (MLP)": MLPClassifier(max_iter=500),
    "AdaBoost": AdaBoostClassifier(),
    "Bagging": BaggingClassifier(),
    "Naive Bayes": GaussianNB(),
    "QDA": QuadraticDiscriminantAnalysis()
}
```

```
[14]: def train_evaluate_and_plot(X_train, X_test, y_train, y_test, label_suffix=""):
    """
    Trains multiple ML models, evaluates them on both training and testing data,
    and visualizes performance using confusion matrices and ROC curves.
    """
    evaluation_results = []
    color_map = cm.get_cmap('tab10') # For distinct ROC colors

    for idx, (model_name, model) in enumerate(ml_models.items()):
        print(f"\nTraining: {model_name + label_suffix}")
        model.fit(X_train, y_train)
```

```

# Make predictions
y_pred_train = model.predict(X_train)
y_pred_test = model.predict(X_test)
y_proba_test = model.predict_proba(X_test) if hasattr(model, □
↪"predict_proba") else None

# Evaluation on training data
evaluation_results.append({
    "Model": model_name + label_suffix,
    "Set": "Train",
    "Accuracy": accuracy_score(y_train, y_pred_train),
    "Loss": 1 - accuracy_score(y_train, y_pred_train),
    "Precision": precision_score(y_train, y_pred_train, □
↪average='weighted', zero_division=0),
    "Recall": recall_score(y_train, y_pred_train, average='weighted'),
    "F1 Score": f1_score(y_train, y_pred_train, average='weighted')
})

# Evaluation on test data
evaluation_results.append({
    "Model": model_name + label_suffix,
    "Set": "Test",
    "Accuracy": accuracy_score(y_test, y_pred_test),
    "Loss": 1 - accuracy_score(y_test, y_pred_test),
    "Precision": precision_score(y_test, y_pred_test, □
↪average='weighted', zero_division=0),
    "Recall": recall_score(y_test, y_pred_test, average='weighted'),
    "F1 Score": f1_score(y_test, y_pred_test, average='weighted')
})

# Visualization
fig, axes = plt.subplots(1, 2, figsize=(14, 5))

# Confusion matrix
cmatrix = confusion_matrix(y_test, y_pred_test)
sns.heatmap(cmatrix, annot=True, fmt="d", cmap="Blues",
            xticklabels=class_names, yticklabels=class_names,
            ax=axes[0], cbar=False, annot_kws={"size": 10})
axes[0].set_title(f'Confusion Matrix\n{model_name + label_suffix}', □
↪fontsize=12)
axes[0].set_xlabel("Predicted")
axes[0].set_ylabel("Actual")
axes[0].tick_params(axis='x', rotation=45)

# ROC Curve
if y_proba_test is not None:

```

```

        y_test_binarized = label_binarize(y_test, classes=np.unique(y))
        if y_proba_test.shape[1] == n_classes:
            for i in range(n_classes):
                fpr, tpr, _ = roc_curve(y_test_binarized[:, i], y_proba_test[:, i])
                roc_auc = auc(fpr, tpr)
                axes[1].plot(fpr, tpr, label=f'{class_names[i]}\n(AUC={roc_auc:.2f})',
                              color=color_map(i % 10))
            axes[1].plot([0, 1], [0, 1], 'k--', label='Random Guess')
            axes[1].set_title(f'ROC Curve\n{model_name + label_suffix}', fontsize=12)
            axes[1].set_xlabel("False Positive Rate")
            axes[1].set_ylabel("True Positive Rate")
            axes[1].legend(fontsize=9)
            axes[1].grid(True)
        else:
            axes[1].axis('off')
            axes[1].text(0.5, 0.5, 'No Probability Output\nUnavailable for ROC',
                         ha='center', va='center', fontsize=12)

    plt.tight_layout()
    plt.show()

    return pd.DataFrame(evaluation_results)

```

8.1 Modelling and Evaluation without *RobustScaler*

8.1.1 Split Train and Test Data without *RobustScaler*

```
[15]: X = feature_df.drop(['EmotionLabel', 'EmotionEncoded'], axis=1)
y = feature_df['EmotionEncoded']

class_names = label_encoder.classes_
n_classes = len(class_names)

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

```
[16]: X_train.shape
```

```
[16]: (1600, 19)
```

```
[17]: X_test.shape
```

```
[17]: (400, 19)
```

```
[18]: y_train.shape
```

```
[18]: (1600,)
```

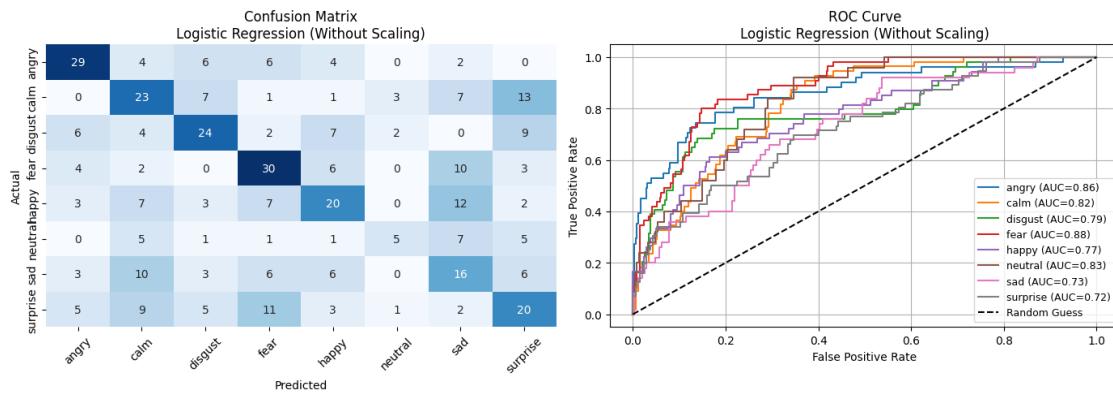
```
[19]: y_test.shape
```

```
[19]: (400,)
```

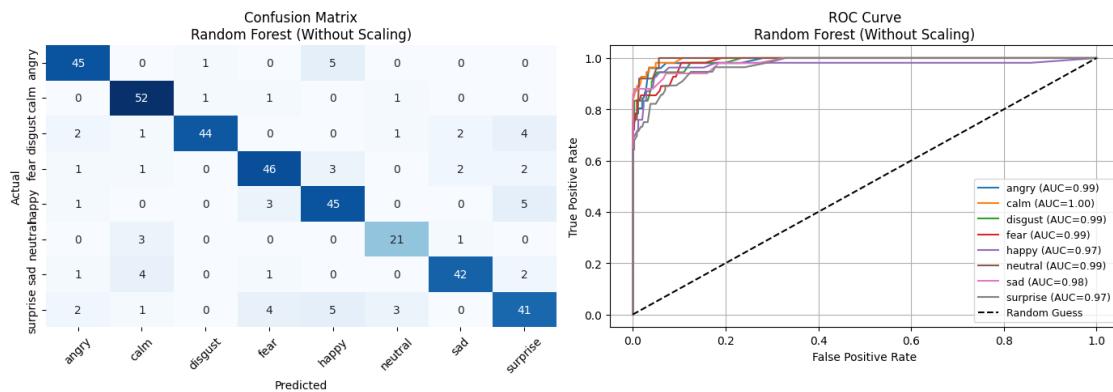
8.1.2 Train models and plot results without *RobustScaler*

```
[20]: results_df = train_evaluate_and_plot(X_train, X_test, y_train, y_test, label_suffix=" (Without Scaling)")
```

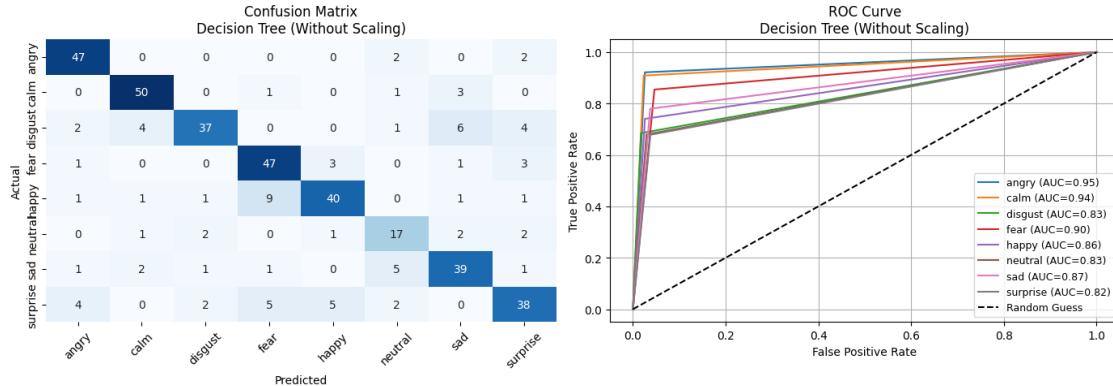
Training: Logistic Regression (Without Scaling)



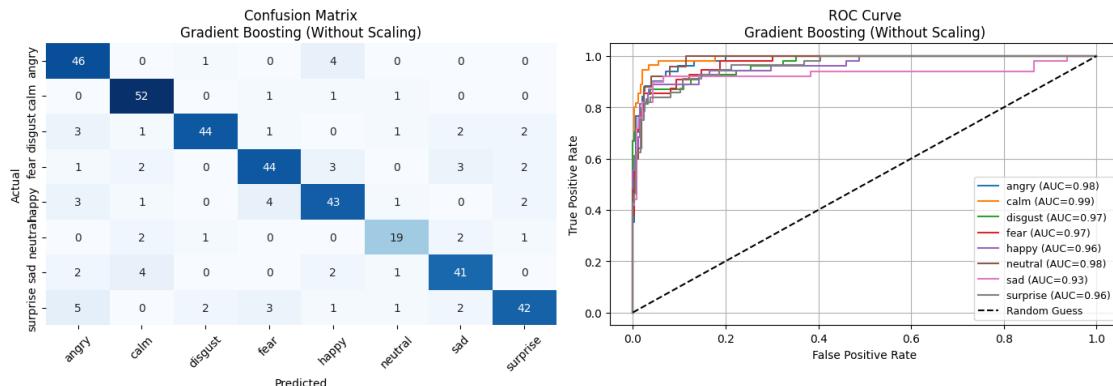
Training: Random Forest (Without Scaling)



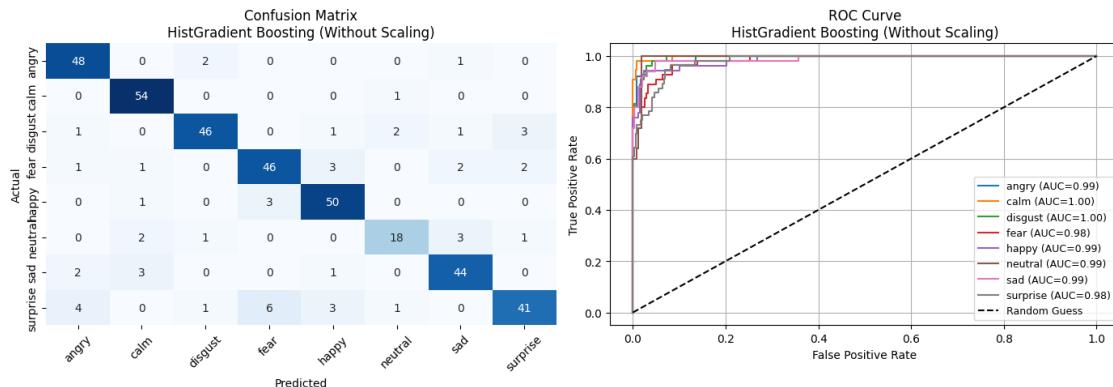
Training: Decision Tree (Without Scaling)



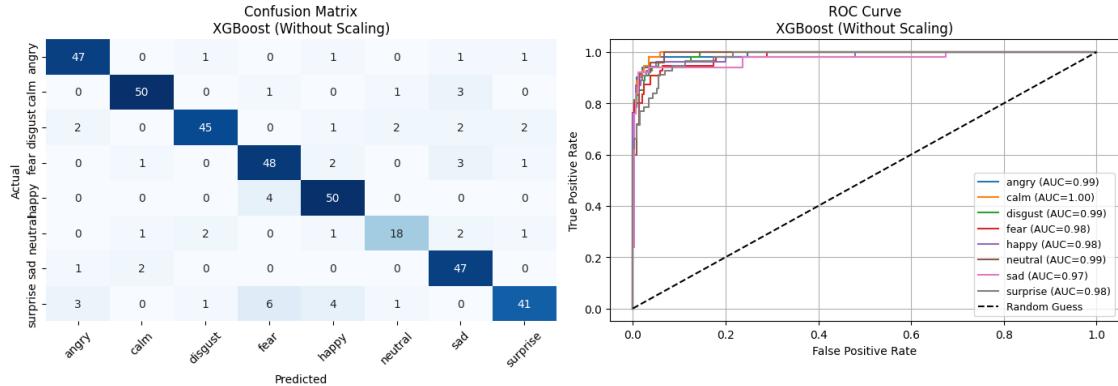
Training: Gradient Boosting (Without Scaling)



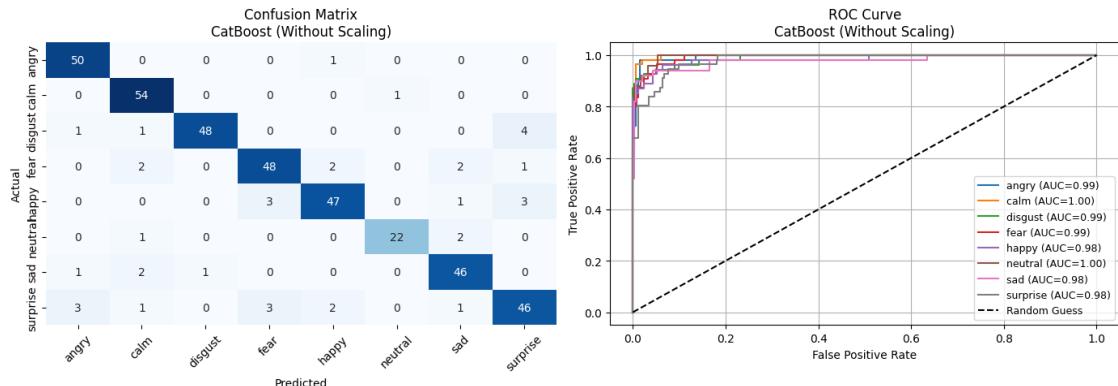
Training: HistGradient Boosting (Without Scaling)



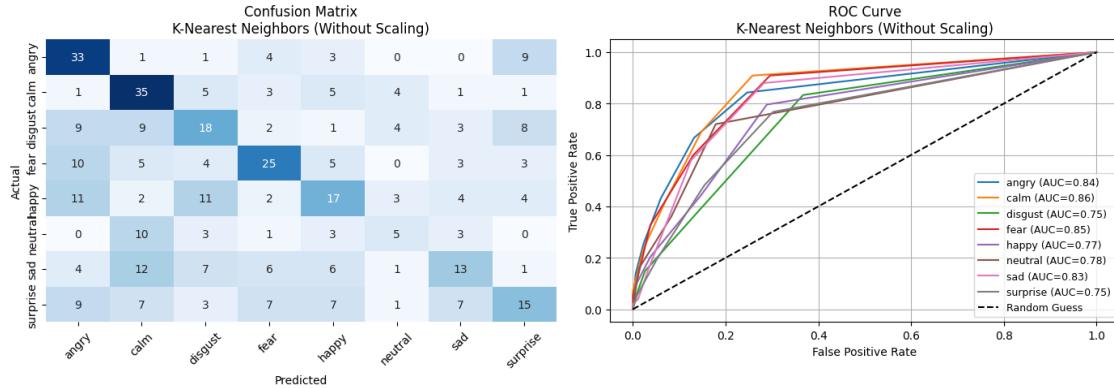
Training: XGBoost (Without Scaling)



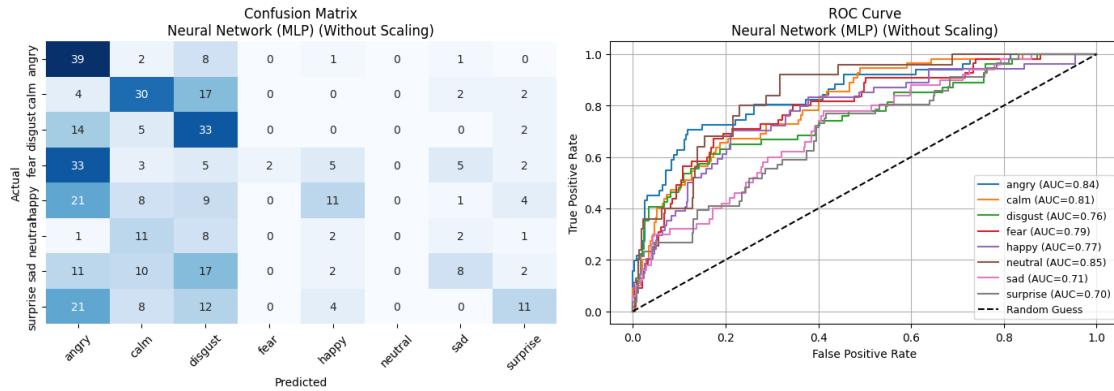
Training: CatBoost (Without Scaling)



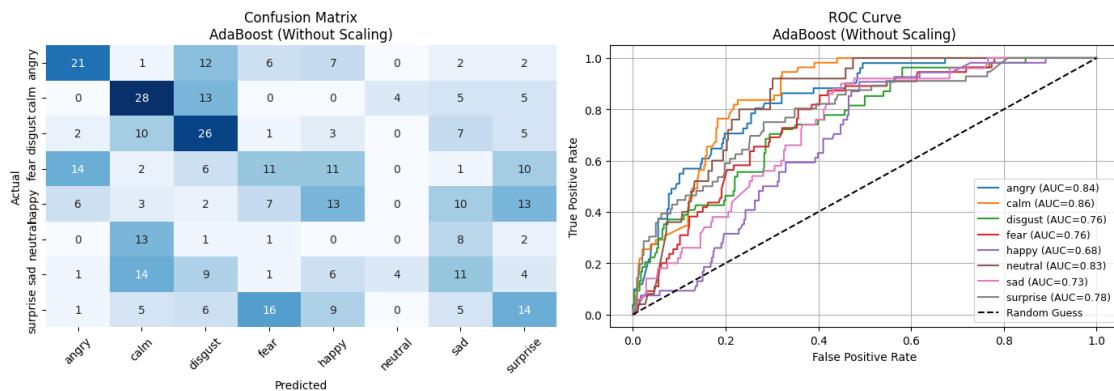
Training: K-Nearest Neighbors (Without Scaling)



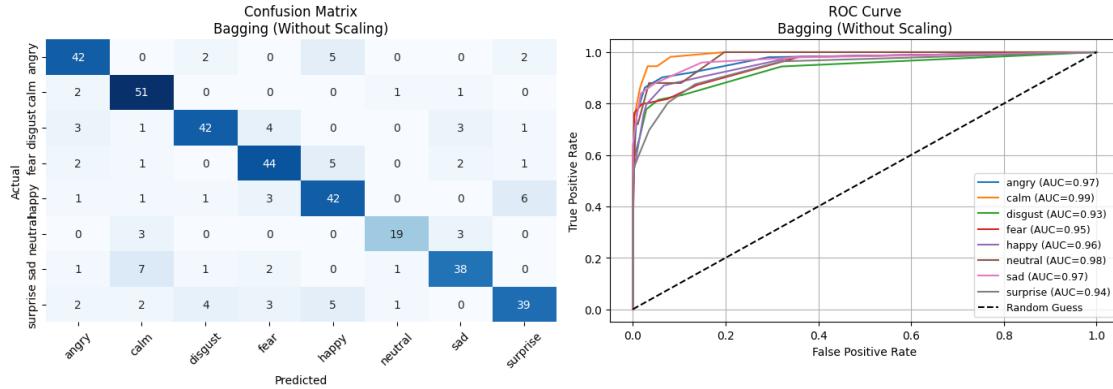
Training: Neural Network (MLP) (Without Scaling)



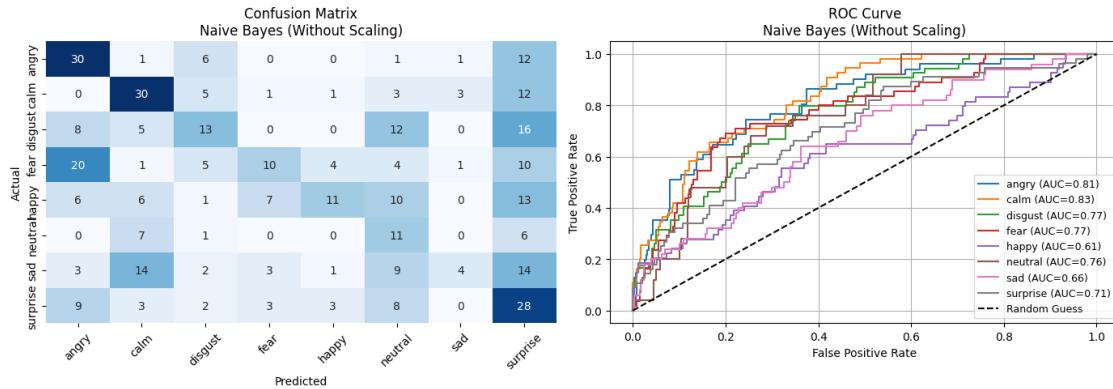
Training: AdaBoost (Without Scaling)



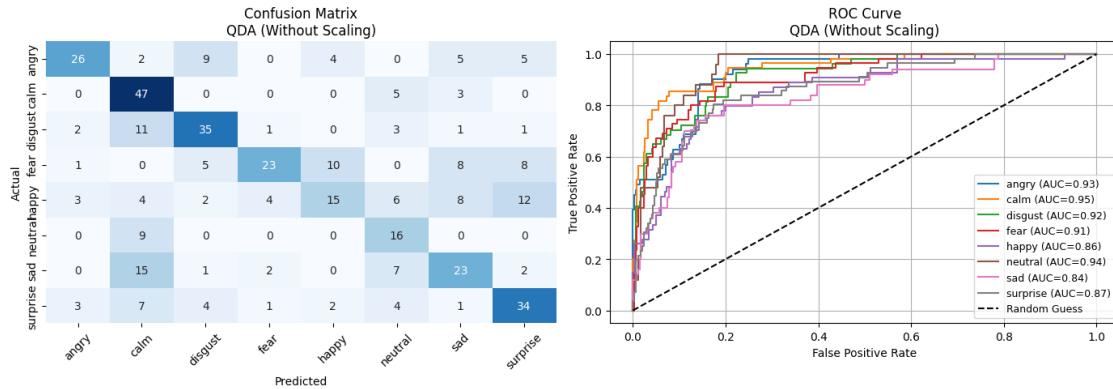
Training: Bagging (Without Scaling)



Training: Naive Bayes (Without Scaling)



Training: QDA (Without Scaling)



8.2 Modelling and Evaluation with *RobustScaler*

8.2.1 Split Train and Test Data with *RobustScaler*

```
[22]: from sklearn.preprocessing import RobustScaler

# Apply robust scaling to handle outliers better than standard scaling
robust_scaler = RobustScaler()
X_robust_scaled = robust_scaler.fit_transform(X)

# Train-test split after scaling
X_train_robust, X_test_robust, y_train_robust, y_test_robust = train_test_split(
    X_robust_scaled, y, test_size=0.2, random_state=42, stratify=y
)
```

```
[23]: X_train_robust.shape
```

```
[23]: (1600, 19)
```

```
[24]: X_test_robust.shape
```

```
[24]: (400, 19)
```

```
[25]: y_train_robust.shape
```

```
[25]: (1600,)
```

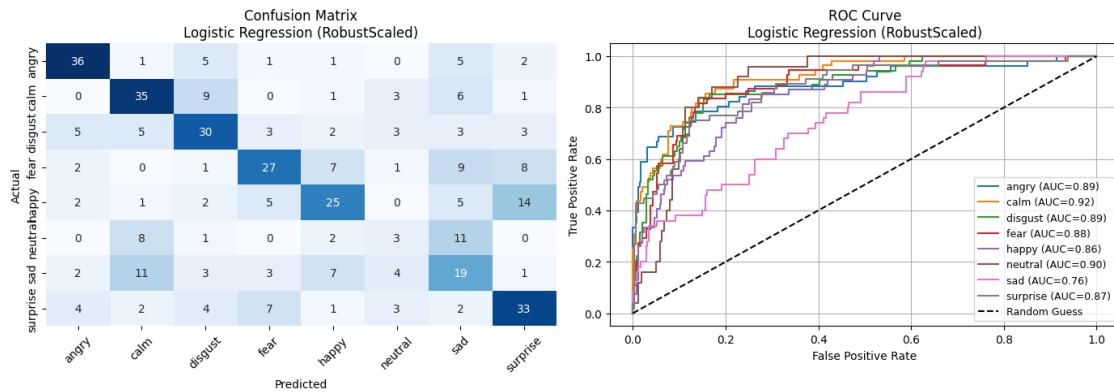
```
[26]: y_test_robust.shape
```

```
[26]: (400,)
```

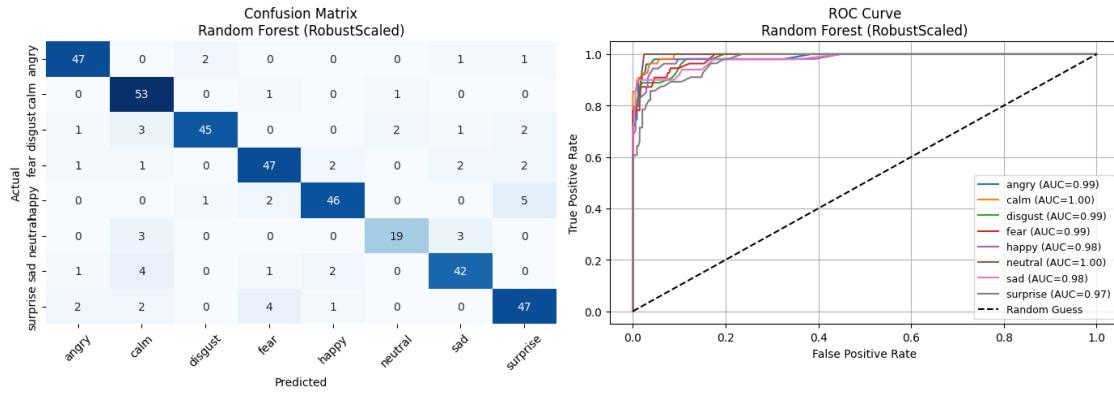
8.2.2 Train models and plot results with *RobustScaler*

```
[27]: results_robust = train_evaluate_and_plot(X_train_robust, X_test_robust, y_train_robust, y_test_robust, label_suffix=" (RobustScaled)")
```

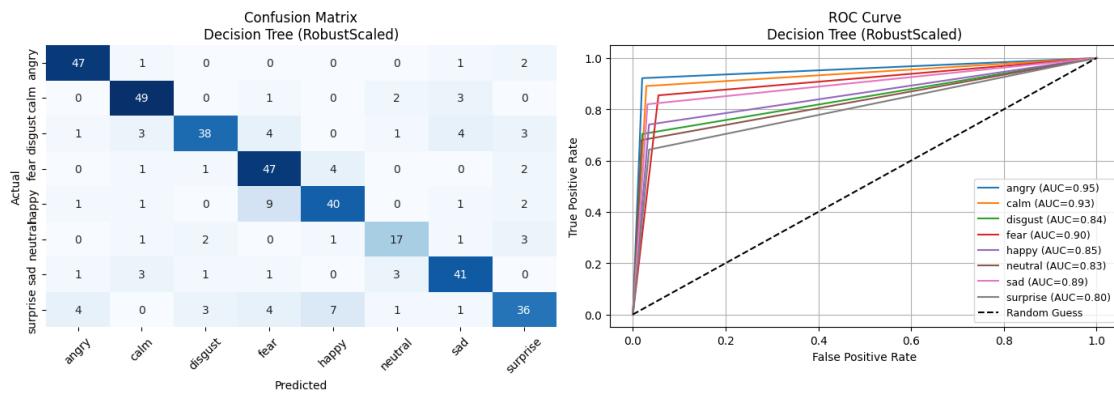
Training: Logistic Regression (RobustScaled)



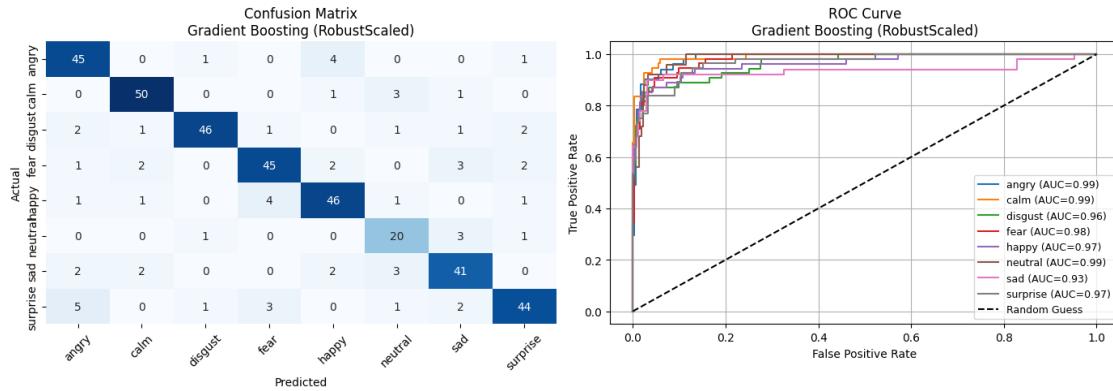
Training: Random Forest (RobustScaled)



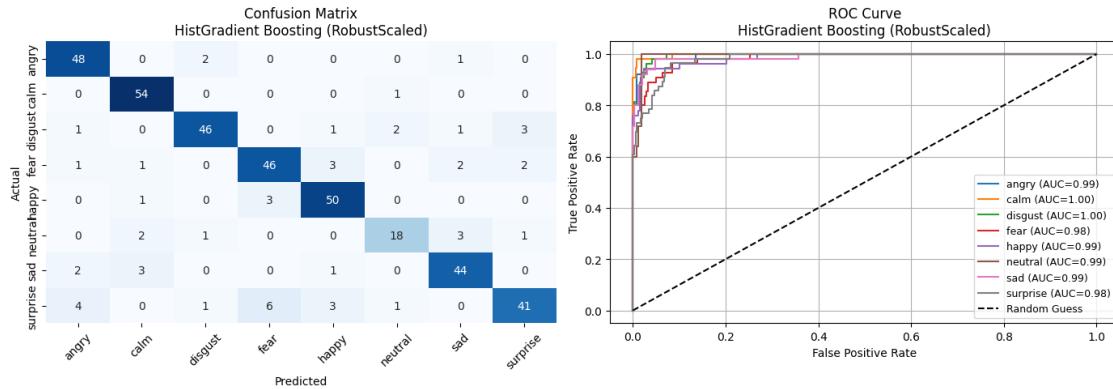
Training: Decision Tree (RobustScaled)



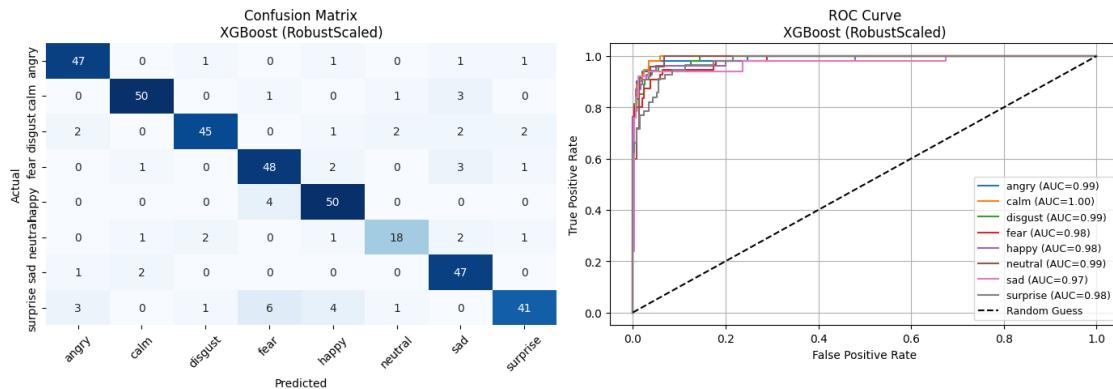
Training: Gradient Boosting (RobustScaled)



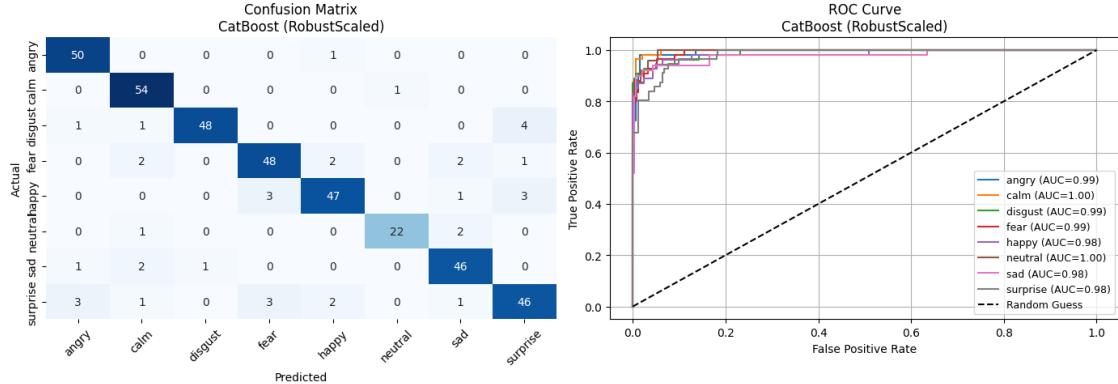
Training: HistGradient Boosting (RobustScaled)



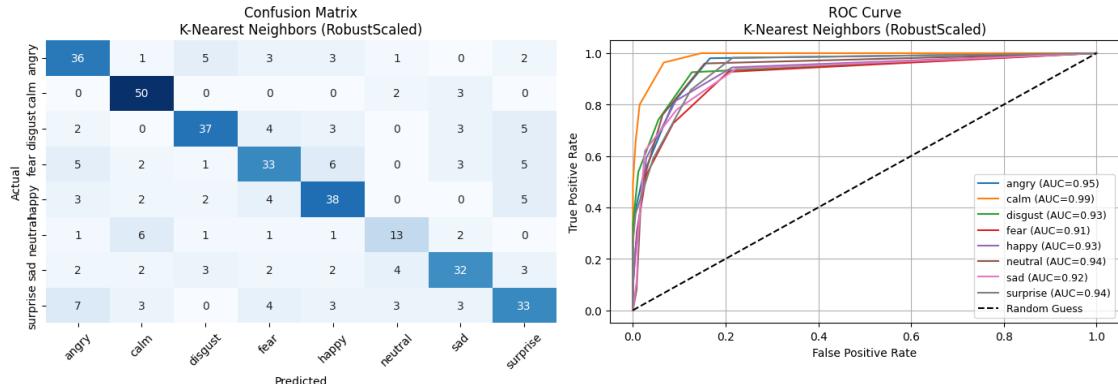
Training: XGBoost (RobustScaled)



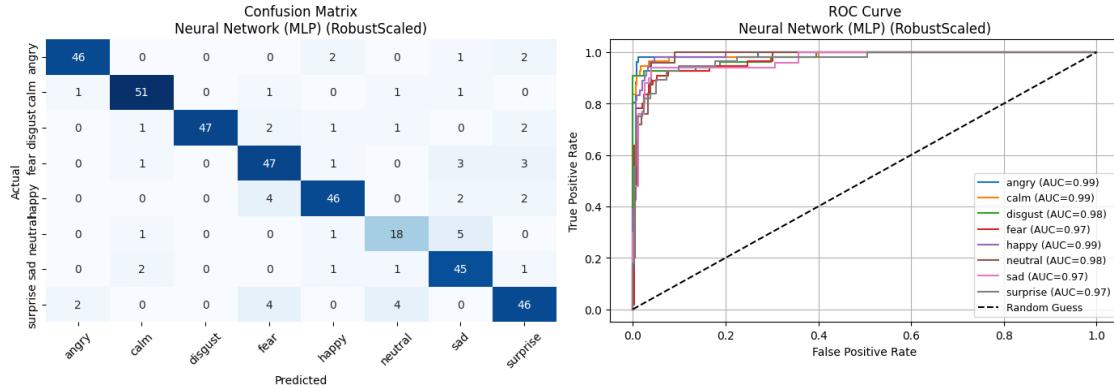
Training: CatBoost (RobustScaled)



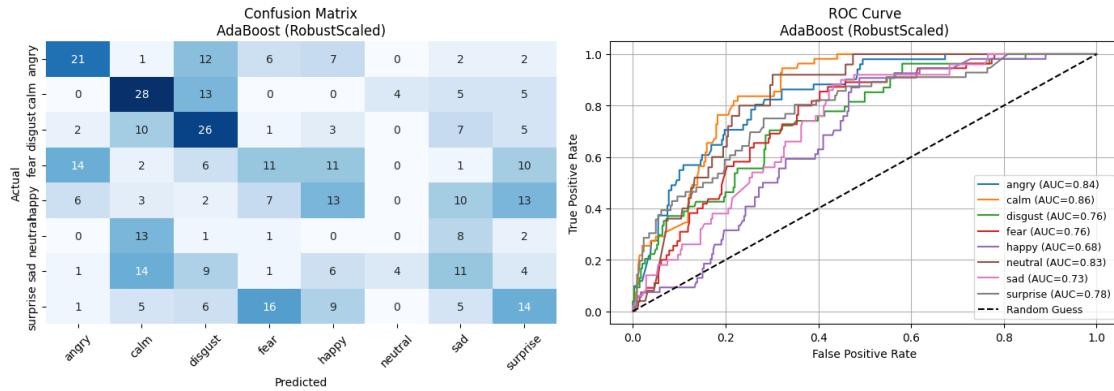
Training: K-Nearest Neighbors (RobustScaled)



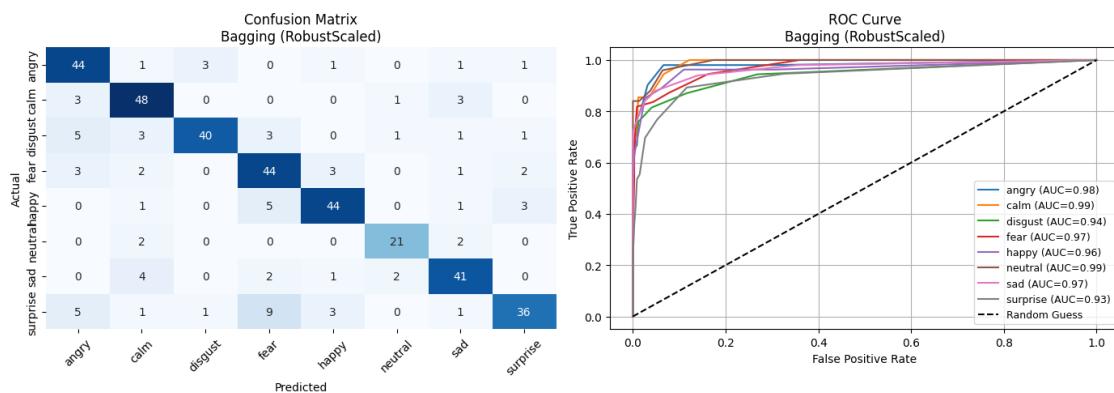
Training: Neural Network (MLP) (RobustScaled)



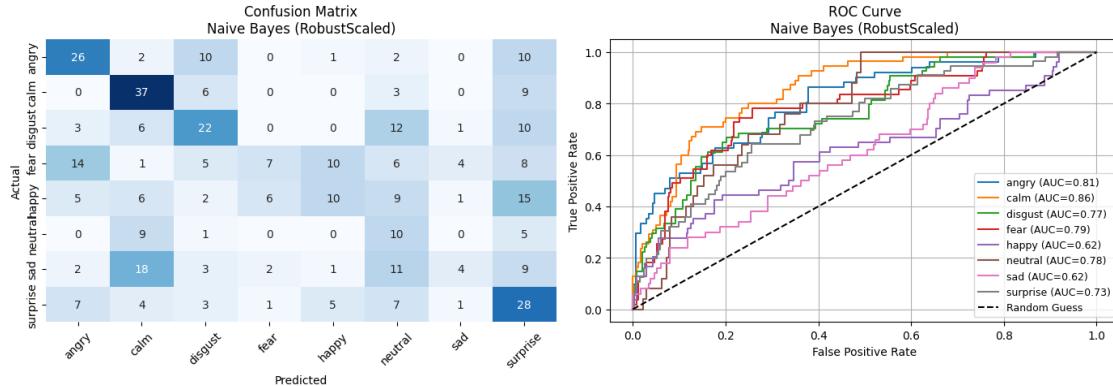
Training: AdaBoost (RobustScaled)



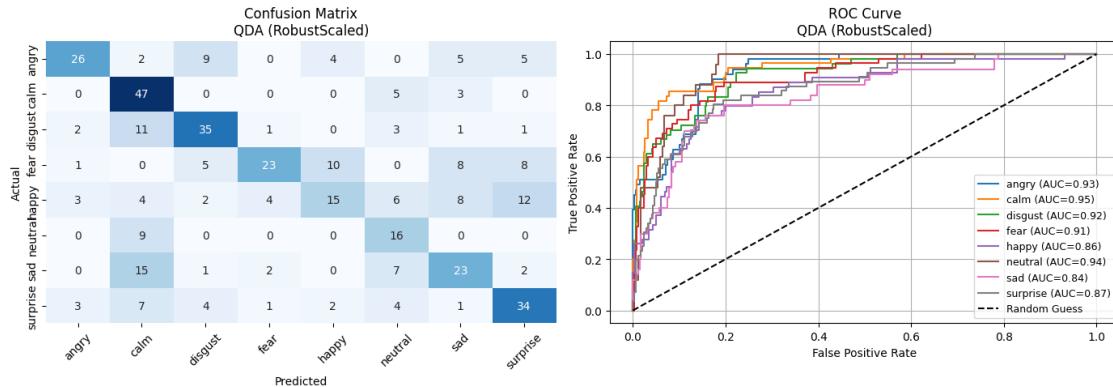
Training: Bagging (RobustScaled)



Training: Naive Bayes (RobustScaled)



Training: QDA (RobustScaled)



9 Visualization of all models (without *RobustScaler* and with *RobustScaler*)

```
[28]: # Combine with previous results
all_model_results = pd.concat([results_df, results_robust])
```

```
[29]: all_model_results
```

	Model	Set	Accuracy	Loss	\
0	Logistic Regression (Without Scaling)	Train	0.452500	0.547500	
1	Logistic Regression (Without Scaling)	Test	0.417500	0.582500	
2	Random Forest (Without Scaling)	Train	1.000000	0.000000	

3	Random Forest (Without Scaling)	Test	0.840000	0.160000
4	Decision Tree (Without Scaling)	Train	1.000000	0.000000
5	Decision Tree (Without Scaling)	Test	0.787500	0.212500
6	Gradient Boosting (Without Scaling)	Train	0.994375	0.005625
7	Gradient Boosting (Without Scaling)	Test	0.827500	0.172500
8	HistGradient Boosting (Without Scaling)	Train	1.000000	0.000000
9	HistGradient Boosting (Without Scaling)	Test	0.867500	0.132500
10	XGBoost (Without Scaling)	Train	1.000000	0.000000
11	XGBoost (Without Scaling)	Test	0.865000	0.135000
12	CatBoost (Without Scaling)	Train	1.000000	0.000000
13	CatBoost (Without Scaling)	Test	0.902500	0.097500
14	K-Nearest Neighbors (Without Scaling)	Train	0.624375	0.375625
15	K-Nearest Neighbors (Without Scaling)	Test	0.402500	0.597500
16	Neural Network (MLP) (Without Scaling)	Train	0.378750	0.621250
17	Neural Network (MLP) (Without Scaling)	Test	0.335000	0.665000
18	AdaBoost (Without Scaling)	Train	0.393750	0.606250
19	AdaBoost (Without Scaling)	Test	0.310000	0.690000
20	Bagging (Without Scaling)	Train	0.995625	0.004375
21	Bagging (Without Scaling)	Test	0.792500	0.207500
22	Naive Bayes (Without Scaling)	Train	0.365000	0.635000
23	Naive Bayes (Without Scaling)	Test	0.342500	0.657500
24	QDA (Without Scaling)	Train	0.652500	0.347500
25	QDA (Without Scaling)	Test	0.547500	0.452500
0	Logistic Regression (RobustScaled)	Train	0.568125	0.431875
1	Logistic Regression (RobustScaled)	Test	0.520000	0.480000
2	Random Forest (RobustScaled)	Train	1.000000	0.000000
3	Random Forest (RobustScaled)	Test	0.865000	0.135000
4	Decision Tree (RobustScaled)	Train	1.000000	0.000000
5	Decision Tree (RobustScaled)	Test	0.787500	0.212500
6	Gradient Boosting (RobustScaled)	Train	0.996250	0.003750
7	Gradient Boosting (RobustScaled)	Test	0.842500	0.157500
8	HistGradient Boosting (RobustScaled)	Train	1.000000	0.000000
9	HistGradient Boosting (RobustScaled)	Test	0.867500	0.132500
10	XGBoost (RobustScaled)	Train	1.000000	0.000000
11	XGBoost (RobustScaled)	Test	0.865000	0.135000
12	CatBoost (RobustScaled)	Train	1.000000	0.000000
13	CatBoost (RobustScaled)	Test	0.902500	0.097500
14	K-Nearest Neighbors (RobustScaled)	Train	0.835000	0.165000
15	K-Nearest Neighbors (RobustScaled)	Test	0.680000	0.320000
16	Neural Network (MLP) (RobustScaled)	Train	0.990000	0.010000
17	Neural Network (MLP) (RobustScaled)	Test	0.865000	0.135000
18	AdaBoost (RobustScaled)	Train	0.393750	0.606250
19	AdaBoost (RobustScaled)	Test	0.310000	0.690000
20	Bagging (RobustScaled)	Train	0.994375	0.005625
21	Bagging (RobustScaled)	Test	0.795000	0.205000
22	Naive Bayes (RobustScaled)	Train	0.393750	0.606250
23	Naive Bayes (RobustScaled)	Test	0.360000	0.640000

24		QDA (RobustScaled)	Train	0.652500	0.347500
25		QDA (RobustScaled)	Test	0.547500	0.452500

	Precision	Recall	F1 Score
0	0.451696	0.452500	0.447965
1	0.422589	0.417500	0.415770
2	1.000000	1.000000	1.000000
3	0.843010	0.840000	0.839994
4	1.000000	1.000000	1.000000
5	0.790500	0.787500	0.786191
6	0.994391	0.994375	0.994375
7	0.830453	0.827500	0.826875
8	1.000000	1.000000	1.000000
9	0.867693	0.867500	0.865608
10	1.000000	1.000000	1.000000
11	0.867844	0.865000	0.863824
12	1.000000	1.000000	1.000000
13	0.903736	0.902500	0.902071
14	0.624170	0.624375	0.618858
15	0.394742	0.402500	0.389809
16	0.489974	0.378750	0.333952
17	0.442672	0.335000	0.282892
18	0.381748	0.393750	0.380383
19	0.291646	0.310000	0.297017
20	0.995651	0.995625	0.995627
21	0.794667	0.792500	0.791570
22	0.406005	0.365000	0.350735
23	0.396305	0.342500	0.322704
24	0.693805	0.652500	0.645363
25	0.574292	0.547500	0.539424
0	0.563885	0.568125	0.563541
1	0.519230	0.520000	0.517310
2	1.000000	1.000000	1.000000
3	0.868043	0.865000	0.864770
4	1.000000	1.000000	1.000000
5	0.788758	0.787500	0.785467
6	0.996258	0.996250	0.996247
7	0.845990	0.842500	0.843149
8	1.000000	1.000000	1.000000
9	0.867693	0.867500	0.865608
10	1.000000	1.000000	1.000000
11	0.867844	0.865000	0.863824
12	1.000000	1.000000	1.000000
13	0.903736	0.902500	0.902071
14	0.839108	0.835000	0.834445
15	0.678100	0.680000	0.677265
16	0.990020	0.990000	0.989987

```

17  0.869447  0.865000  0.865985
18  0.381748  0.393750  0.380383
19  0.291646  0.310000  0.297017
20  0.994400  0.994375  0.994372
21  0.803141  0.795000  0.794527
22  0.440751  0.393750  0.377070
23  0.384298  0.360000  0.334971
24  0.693805  0.652500  0.645363
25  0.574292  0.547500  0.539424

```

9.1 Visualization Using Grouped Horizontal Bar Plot

```
[31]: # Filter only the test and train results
filtered_results = all_model_results.copy()

# Extract the base model names without scaling suffix
filtered_results['BaseModel'] = filtered_results['Model'].str.replace(r' \(.+*\)\)', '', regex=True)
filtered_results['Scaling'] = filtered_results['Model'].str.extract(r'\((.*?)+\)\)[0].fillna("No Scaling")

# Melt the results DataFrame to long format for plotting
melted_results = pd.melt(
    filtered_results,
    id_vars=['BaseModel', 'Scaling', 'Set'],
    value_vars=['Accuracy', 'Loss', 'Precision', 'Recall', 'F1 Score'],
    var_name='Metric',
    value_name='Value'
)

# Convert to percentage for consistency
melted_results['Value'] = melted_results['Value'] * 100

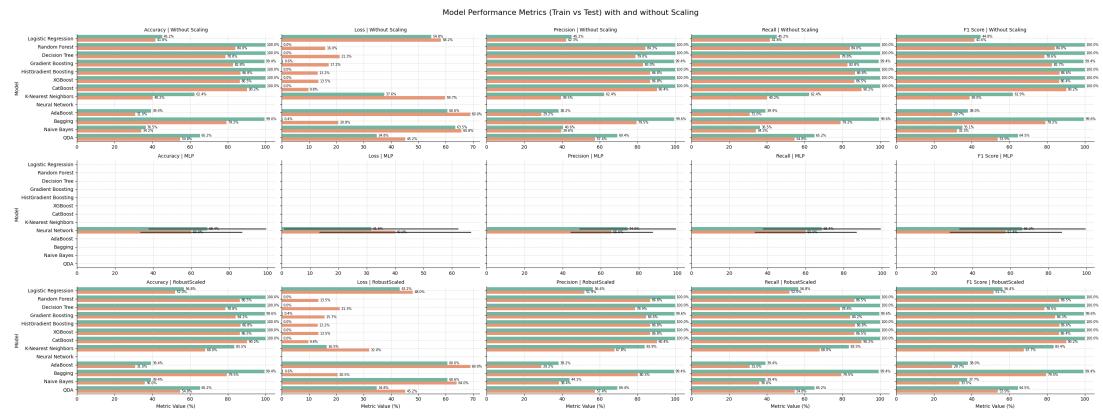
# Create a FacetGrid for better separation
g = sns.catplot(
    data=melted_results,
    kind="bar",
    x="Value",
    y="BaseModel",
    hue="Set",
    col="Metric",
    row="Scaling",
    height=4,
    aspect=1.6,
    palette="Set2",
    sharex=False
)
```

```

)
# Format each axis
g.set_titles("{col_name} | {row_name}")
g.set_axis_labels("Metric Value (%)", "Model")
for ax in g.axes.flat:
    ax.grid(True, linestyle='--', alpha=0.5)
    for container in ax.containers:
        ax.bar_label(container, fmt='%.1f%%', label_type='edge', padding=3, fontsize=7)

plt.subplots_adjust(top=0.92)
g.fig.suptitle("Model Performance Metrics (Train vs Test) with and without Scaling", fontsize=16)
plt.show()

```



9.2 Line Plot: Metric Trends per Model

```

[33]: line_data = all_model_results.copy()
line_data['Model (Clean)'] = line_data['Model'].str.replace(r' \((.*?)\)', '', regex=True)
line_data['Scaling'] = line_data['Model'].str.extract(r'\((.*?)\)')[0].fillna('No Scaling')

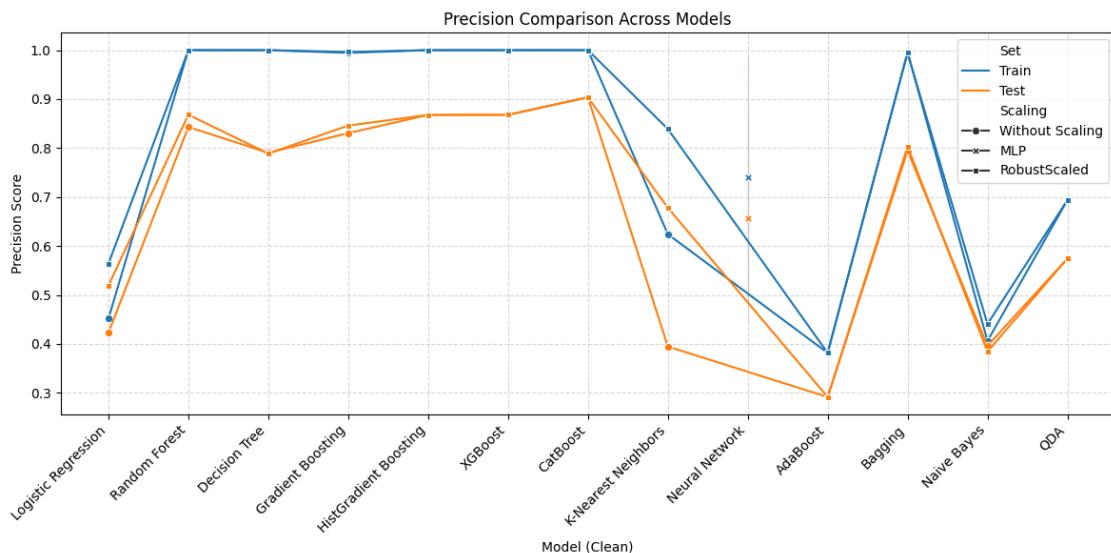
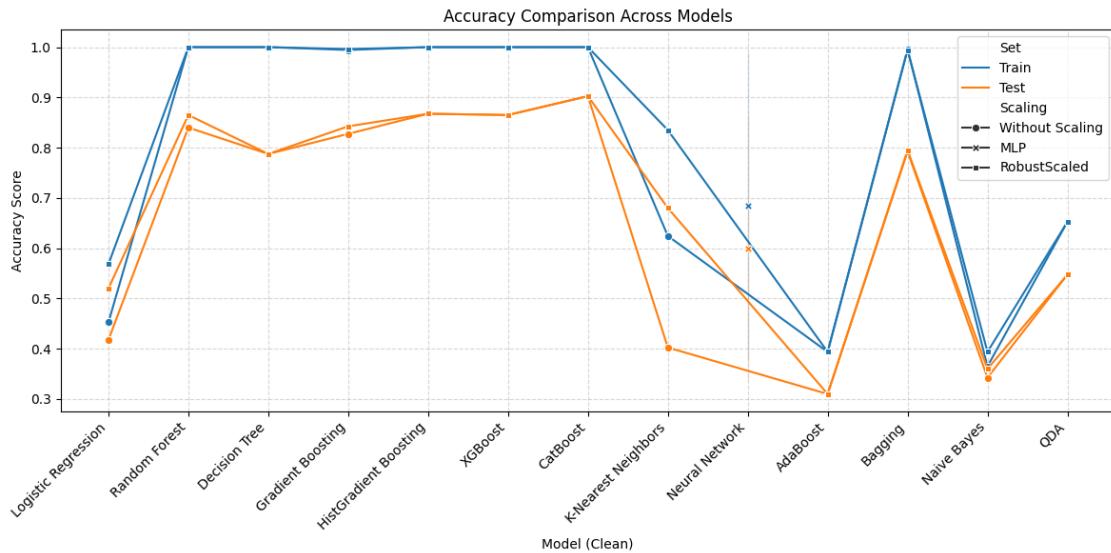
# Plot for each metric
for metric in ['Accuracy', 'Precision', 'Recall', 'F1 Score']:
    plt.figure(figsize=(12, 6))
    sns.lineplot(data=line_data, x='Model (Clean)', y=metric, hue='Set', style='Scaling', markers=True, dashes=False)
    plt.title(f'{metric} Comparison Across Models')
    plt.ylabel(f'{metric} Score')
    plt.xticks(rotation=45, ha='right')

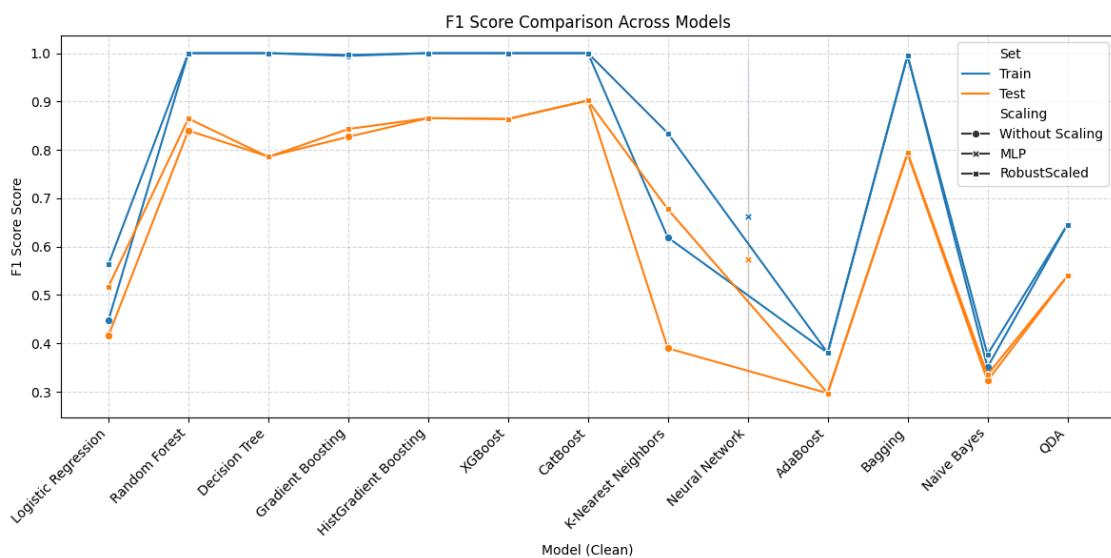
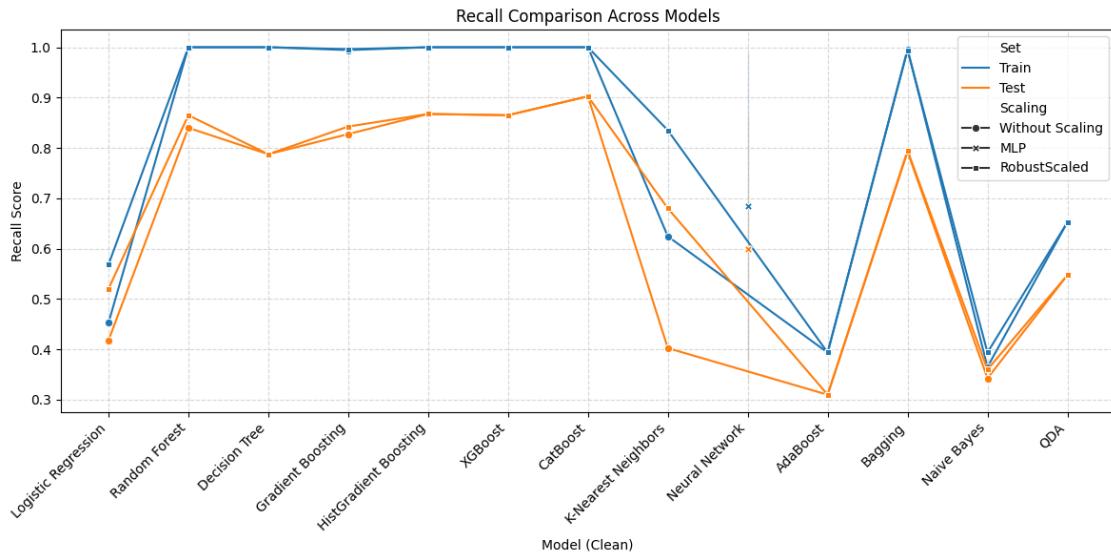
```

```

plt.grid(True, linestyle='--', alpha=0.5)
plt.tight_layout()
plt.show()

```





9.3 Heatmap of Metrics

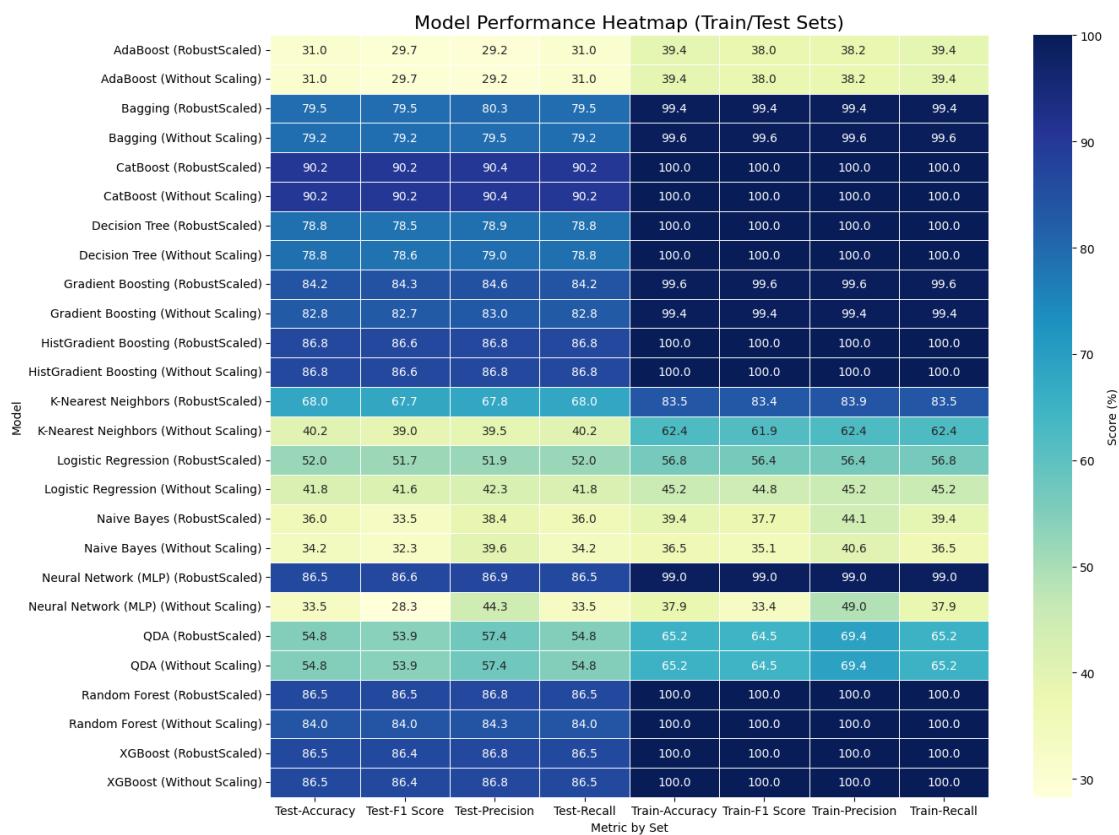
```
[34]: # Prepare data pivoted by model and metric
heatmap_data = all_model_results.pivot_table(
    index='Model',
    columns='Set',
    values=['Accuracy', 'Precision', 'Recall', 'F1 Score']
)
```

```

# Normalize to percentage
heatmap_data *= 100

# Plot
plt.figure(figsize=(14, 10))
sns.heatmap(heatmap_data.swaplevel(axis=1).sort_index(axis=1),
            annot=True, fmt=".1f", cmap="YlGnBu", linewidths=0.5, cbar_kws={'label': 'Score (%)'})
plt.title("Model Performance Heatmap (Train/Test Sets)", fontsize=16)
plt.ylabel("Model")
plt.xlabel("Metric by Set")
plt.tight_layout()
plt.show()

```



10 Deep Learning Modelling and Evaluation

[35]: # One-hot encode the robust scaled targets
y_train_robust_nn = to_categorical(y_train_robust)
y_test_robust_nn = to_categorical(y_test_robust)

```
[36]: # Store training histories for later plotting/comparison
nn_training_histories = []
```

10.1 Model 1: Basic NN with Dropout

```
[37]: basic_nn = Sequential([
    Dense(128, activation='relu', input_shape=(X_train_robust.shape[1],)),
    Dropout(0.3),
    Dense(64, activation='relu'),
    Dropout(0.3),
    Dense(y_train_robust_nn.shape[1], activation='softmax')
])

basic_nn.compile(optimizer='adam', loss='categorical_crossentropy',
                  metrics=['accuracy'])

history_basic = basic_nn.fit(
    X_train_robust, y_train_robust_nn,
    validation_data=(X_test_robust, y_test_robust_nn),
    epochs=50, batch_size=16, verbose=1
)

nn_training_histories.append(('BasicNN_Dropout', history_basic))
```

```
Epoch 1/50
100/100      2s 8ms/step -
accuracy: 0.1784 - loss: 2.0460 - val_accuracy: 0.3400 - val_loss: 1.7581
Epoch 2/50
100/100      1s 5ms/step -
accuracy: 0.3545 - loss: 1.7120 - val_accuracy: 0.4125 - val_loss: 1.5697
Epoch 3/50
100/100      1s 5ms/step -
accuracy: 0.4066 - loss: 1.5420 - val_accuracy: 0.4525 - val_loss: 1.4570
Epoch 4/50
100/100      0s 5ms/step -
accuracy: 0.4560 - loss: 1.4724 - val_accuracy: 0.4800 - val_loss: 1.3918
Epoch 5/50
100/100      1s 5ms/step -
accuracy: 0.4390 - loss: 1.4565 - val_accuracy: 0.5050 - val_loss: 1.3533
Epoch 6/50
100/100      1s 6ms/step -
accuracy: 0.5005 - loss: 1.3455 - val_accuracy: 0.5275 - val_loss: 1.3192
Epoch 7/50
100/100      0s 4ms/step -
accuracy: 0.5039 - loss: 1.2945 - val_accuracy: 0.5075 - val_loss: 1.2738
Epoch 8/50
100/100      0s 3ms/step -
```

```
accuracy: 0.5422 - loss: 1.2167 - val_accuracy: 0.5425 - val_loss: 1.2321
Epoch 9/50
100/100          0s 4ms/step -
accuracy: 0.5526 - loss: 1.2128 - val_accuracy: 0.5550 - val_loss: 1.2152
Epoch 10/50
100/100          1s 3ms/step -
accuracy: 0.5417 - loss: 1.1998 - val_accuracy: 0.5800 - val_loss: 1.1866
Epoch 11/50
100/100          0s 3ms/step -
accuracy: 0.5796 - loss: 1.1888 - val_accuracy: 0.5950 - val_loss: 1.1578
Epoch 12/50
100/100          1s 3ms/step -
accuracy: 0.5995 - loss: 1.1241 - val_accuracy: 0.5750 - val_loss: 1.1375
Epoch 13/50
100/100          0s 3ms/step -
accuracy: 0.5950 - loss: 1.0976 - val_accuracy: 0.5925 - val_loss: 1.1234
Epoch 14/50
100/100          1s 3ms/step -
accuracy: 0.6198 - loss: 1.0700 - val_accuracy: 0.6100 - val_loss: 1.0880
Epoch 15/50
100/100          1s 3ms/step -
accuracy: 0.6036 - loss: 1.0645 - val_accuracy: 0.6225 - val_loss: 1.0653
Epoch 16/50
100/100          1s 3ms/step -
accuracy: 0.6423 - loss: 1.0349 - val_accuracy: 0.6150 - val_loss: 1.0467
Epoch 17/50
100/100          1s 3ms/step -
accuracy: 0.6443 - loss: 1.0157 - val_accuracy: 0.6475 - val_loss: 1.0312
Epoch 18/50
100/100          1s 3ms/step -
accuracy: 0.6538 - loss: 0.9634 - val_accuracy: 0.6375 - val_loss: 1.0109
Epoch 19/50
100/100          1s 3ms/step -
accuracy: 0.6634 - loss: 0.9385 - val_accuracy: 0.6625 - val_loss: 0.9832
Epoch 20/50
100/100          0s 3ms/step -
accuracy: 0.6534 - loss: 0.9768 - val_accuracy: 0.6900 - val_loss: 0.9570
Epoch 21/50
100/100          1s 3ms/step -
accuracy: 0.6886 - loss: 0.9089 - val_accuracy: 0.6800 - val_loss: 0.9538
Epoch 22/50
100/100          1s 3ms/step -
accuracy: 0.6771 - loss: 0.8939 - val_accuracy: 0.6750 - val_loss: 0.9492
Epoch 23/50
100/100          0s 3ms/step -
accuracy: 0.6938 - loss: 0.8903 - val_accuracy: 0.6725 - val_loss: 0.9350
Epoch 24/50
100/100          0s 3ms/step -
```

```
accuracy: 0.7063 - loss: 0.8457 - val_accuracy: 0.6675 - val_loss: 0.9334
Epoch 25/50
100/100      1s 3ms/step -
accuracy: 0.6810 - loss: 0.8750 - val_accuracy: 0.6925 - val_loss: 0.9177
Epoch 26/50
100/100      0s 3ms/step -
accuracy: 0.7014 - loss: 0.8333 - val_accuracy: 0.7050 - val_loss: 0.8930
Epoch 27/50
100/100      1s 5ms/step -
accuracy: 0.6884 - loss: 0.8455 - val_accuracy: 0.6975 - val_loss: 0.8835
Epoch 28/50
100/100      1s 5ms/step -
accuracy: 0.6843 - loss: 0.8746 - val_accuracy: 0.7100 - val_loss: 0.8665
Epoch 29/50
100/100      1s 5ms/step -
accuracy: 0.7133 - loss: 0.8138 - val_accuracy: 0.7075 - val_loss: 0.8604
Epoch 30/50
100/100      1s 5ms/step -
accuracy: 0.6942 - loss: 0.8265 - val_accuracy: 0.7075 - val_loss: 0.8575
Epoch 31/50
100/100      1s 5ms/step -
accuracy: 0.7055 - loss: 0.7903 - val_accuracy: 0.7125 - val_loss: 0.8581
Epoch 32/50
100/100      0s 3ms/step -
accuracy: 0.7084 - loss: 0.8106 - val_accuracy: 0.7300 - val_loss: 0.8074
Epoch 34/50
100/100      0s 3ms/step -
accuracy: 0.7381 - loss: 0.7472 - val_accuracy: 0.7300 - val_loss: 0.8188
Epoch 35/50
100/100      1s 3ms/step -
accuracy: 0.7407 - loss: 0.7171 - val_accuracy: 0.7275 - val_loss: 0.8033
Epoch 36/50
100/100      0s 3ms/step -
accuracy: 0.7267 - loss: 0.7643 - val_accuracy: 0.7375 - val_loss: 0.7851
Epoch 37/50
100/100      1s 3ms/step -
accuracy: 0.7492 - loss: 0.7355 - val_accuracy: 0.7500 - val_loss: 0.7881
Epoch 38/50
100/100      1s 3ms/step -
accuracy: 0.7304 - loss: 0.7140 - val_accuracy: 0.7325 - val_loss: 0.7689
Epoch 39/50
100/100      1s 3ms/step -
accuracy: 0.7378 - loss: 0.7618 - val_accuracy: 0.7325 - val_loss: 0.7655
Epoch 40/50
100/100      1s 3ms/step -
```

```

accuracy: 0.7477 - loss: 0.6822 - val_accuracy: 0.7475 - val_loss: 0.7667
Epoch 41/50
100/100      1s 3ms/step -
accuracy: 0.7488 - loss: 0.7010 - val_accuracy: 0.7525 - val_loss: 0.7508
Epoch 42/50
100/100      1s 3ms/step -
accuracy: 0.7657 - loss: 0.6715 - val_accuracy: 0.7300 - val_loss: 0.7460
Epoch 43/50
100/100      0s 3ms/step -
accuracy: 0.7534 - loss: 0.6491 - val_accuracy: 0.7625 - val_loss: 0.7412
Epoch 44/50
100/100      1s 3ms/step -
accuracy: 0.7545 - loss: 0.6897 - val_accuracy: 0.7675 - val_loss: 0.7304
Epoch 45/50
100/100      0s 4ms/step -
accuracy: 0.7718 - loss: 0.6353 - val_accuracy: 0.7725 - val_loss: 0.7267
Epoch 46/50
100/100      1s 10ms/step -
accuracy: 0.7782 - loss: 0.6478 - val_accuracy: 0.7475 - val_loss: 0.7209
Epoch 47/50
100/100      2s 17ms/step -
accuracy: 0.7678 - loss: 0.6626 - val_accuracy: 0.7525 - val_loss: 0.7020
Epoch 48/50
100/100      3s 26ms/step -
accuracy: 0.7789 - loss: 0.6254 - val_accuracy: 0.7650 - val_loss: 0.7024
Epoch 49/50
100/100      3s 3ms/step -
accuracy: 0.7857 - loss: 0.6316 - val_accuracy: 0.7625 - val_loss: 0.6811
Epoch 50/50
100/100      1s 3ms/step -
accuracy: 0.7716 - loss: 0.6155 - val_accuracy: 0.7550 - val_loss: 0.6790

```

10.2 Model 2: Deeper Network with Regularized Dropout

```
[38]: deep_nn = Sequential([
    Dense(256, activation='relu', input_shape=(X_train_robust.shape[1],)),
    Dropout(0.4),
    Dense(128, activation='relu'),
    Dropout(0.3),
    Dense(64, activation='relu'),
    Dropout(0.3),
    Dense(y_train_robust_nn.shape[1], activation='softmax')
])

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

```

history_deep = deep_nn.fit(
    X_train_robust, y_train_robust_nn,
    validation_data=(X_test_robust, y_test_robust_nn),
    epochs=50, batch_size=16, verbose=1
)

nn_training_histories.append(('DeepNN_Regularized', history_deep))

```

```

Epoch 1/50
100/100      3s 9ms/step -
accuracy: 0.2079 - loss: 2.0363 - val_accuracy: 0.3500 - val_loss: 1.7651
Epoch 2/50
100/100      1s 6ms/step -
accuracy: 0.3569 - loss: 1.7544 - val_accuracy: 0.4525 - val_loss: 1.5023
Epoch 3/50
100/100      1s 4ms/step -
accuracy: 0.4208 - loss: 1.5360 - val_accuracy: 0.4600 - val_loss: 1.4205
Epoch 4/50
100/100      1s 4ms/step -
accuracy: 0.4867 - loss: 1.4167 - val_accuracy: 0.5250 - val_loss: 1.3206
Epoch 5/50
100/100      1s 4ms/step -
accuracy: 0.4722 - loss: 1.3644 - val_accuracy: 0.5325 - val_loss: 1.2736
Epoch 6/50
100/100      0s 4ms/step -
accuracy: 0.5212 - loss: 1.2692 - val_accuracy: 0.5725 - val_loss: 1.2064
Epoch 7/50
100/100      0s 3ms/step -
accuracy: 0.5391 - loss: 1.2472 - val_accuracy: 0.5975 - val_loss: 1.1505
Epoch 8/50
100/100      1s 3ms/step -
accuracy: 0.5594 - loss: 1.2295 - val_accuracy: 0.6150 - val_loss: 1.1169
Epoch 9/50
100/100      0s 4ms/step -
accuracy: 0.6034 - loss: 1.1199 - val_accuracy: 0.6200 - val_loss: 1.0630
Epoch 10/50
100/100      0s 4ms/step -
accuracy: 0.5855 - loss: 1.0904 - val_accuracy: 0.6400 - val_loss: 1.0281
Epoch 11/50
100/100      1s 3ms/step -
accuracy: 0.6030 - loss: 1.0350 - val_accuracy: 0.6500 - val_loss: 1.0122
Epoch 12/50
100/100      0s 4ms/step -
accuracy: 0.6162 - loss: 1.0215 - val_accuracy: 0.6500 - val_loss: 0.9718
Epoch 13/50
100/100      0s 4ms/step -
accuracy: 0.6172 - loss: 1.0209 - val_accuracy: 0.6625 - val_loss: 0.9261

```

```
Epoch 14/50
100/100      1s 4ms/step -
accuracy: 0.6670 - loss: 0.9016 - val_accuracy: 0.6750 - val_loss: 0.9317
Epoch 15/50
100/100      1s 4ms/step -
accuracy: 0.6570 - loss: 0.9208 - val_accuracy: 0.6925 - val_loss: 0.8949
Epoch 16/50
100/100      0s 4ms/step -
accuracy: 0.6726 - loss: 0.9014 - val_accuracy: 0.6900 - val_loss: 0.8745
Epoch 17/50
100/100      1s 4ms/step -
accuracy: 0.6897 - loss: 0.8537 - val_accuracy: 0.7025 - val_loss: 0.8549
Epoch 18/50
100/100      1s 4ms/step -
accuracy: 0.7022 - loss: 0.8664 - val_accuracy: 0.7100 - val_loss: 0.8398
Epoch 19/50
100/100      0s 4ms/step -
accuracy: 0.7157 - loss: 0.8001 - val_accuracy: 0.7225 - val_loss: 0.8016
Epoch 20/50
100/100      0s 4ms/step -
accuracy: 0.7247 - loss: 0.7905 - val_accuracy: 0.7175 - val_loss: 0.7952
Epoch 21/50
100/100      1s 4ms/step -
accuracy: 0.6918 - loss: 0.8045 - val_accuracy: 0.7450 - val_loss: 0.7450
Epoch 22/50
100/100      1s 4ms/step -
accuracy: 0.7101 - loss: 0.7833 - val_accuracy: 0.7475 - val_loss: 0.7503
Epoch 23/50
100/100      1s 5ms/step -
accuracy: 0.7407 - loss: 0.7444 - val_accuracy: 0.7475 - val_loss: 0.7124
Epoch 24/50
100/100      1s 6ms/step -
accuracy: 0.7494 - loss: 0.7224 - val_accuracy: 0.7350 - val_loss: 0.7113
Epoch 25/50
100/100      1s 5ms/step -
accuracy: 0.7385 - loss: 0.7120 - val_accuracy: 0.7800 - val_loss: 0.7027
Epoch 26/50
100/100      1s 6ms/step -
accuracy: 0.7549 - loss: 0.6862 - val_accuracy: 0.7700 - val_loss: 0.6787
Epoch 27/50
100/100      1s 3ms/step -
accuracy: 0.7543 - loss: 0.6707 - val_accuracy: 0.7725 - val_loss: 0.6535
Epoch 28/50
100/100      0s 4ms/step -
accuracy: 0.7632 - loss: 0.6401 - val_accuracy: 0.7725 - val_loss: 0.6444
Epoch 29/50
100/100      1s 3ms/step -
accuracy: 0.7891 - loss: 0.6118 - val_accuracy: 0.7825 - val_loss: 0.6208
```

```
Epoch 30/50
100/100      0s 4ms/step -
accuracy: 0.7840 - loss: 0.6460 - val_accuracy: 0.7525 - val_loss: 0.6506
Epoch 31/50
100/100      0s 3ms/step -
accuracy: 0.7848 - loss: 0.6227 - val_accuracy: 0.7925 - val_loss: 0.6238
Epoch 32/50
100/100      0s 3ms/step -
accuracy: 0.8028 - loss: 0.5872 - val_accuracy: 0.7600 - val_loss: 0.6002
Epoch 33/50
100/100      0s 4ms/step -
accuracy: 0.7803 - loss: 0.5998 - val_accuracy: 0.8000 - val_loss: 0.5754
Epoch 34/50
100/100      0s 3ms/step -
accuracy: 0.8035 - loss: 0.5372 - val_accuracy: 0.8000 - val_loss: 0.5635
Epoch 35/50
100/100      0s 3ms/step -
accuracy: 0.8193 - loss: 0.5301 - val_accuracy: 0.8050 - val_loss: 0.5597
Epoch 36/50
100/100      1s 4ms/step -
accuracy: 0.8148 - loss: 0.5315 - val_accuracy: 0.7925 - val_loss: 0.5675
Epoch 37/50
100/100      1s 4ms/step -
accuracy: 0.8164 - loss: 0.5265 - val_accuracy: 0.8100 - val_loss: 0.5325
Epoch 38/50
100/100      0s 4ms/step -
accuracy: 0.8226 - loss: 0.5230 - val_accuracy: 0.7950 - val_loss: 0.5504
Epoch 39/50
100/100      0s 3ms/step -
accuracy: 0.8100 - loss: 0.5439 - val_accuracy: 0.7975 - val_loss: 0.5249
Epoch 40/50
100/100      0s 4ms/step -
accuracy: 0.8095 - loss: 0.5360 - val_accuracy: 0.7875 - val_loss: 0.5589
Epoch 41/50
100/100      0s 4ms/step -
accuracy: 0.8284 - loss: 0.4877 - val_accuracy: 0.8200 - val_loss: 0.5228
Epoch 42/50
100/100      0s 4ms/step -
accuracy: 0.8408 - loss: 0.5087 - val_accuracy: 0.8200 - val_loss: 0.5066
Epoch 43/50
100/100      1s 3ms/step -
accuracy: 0.8305 - loss: 0.5048 - val_accuracy: 0.8275 - val_loss: 0.4848
Epoch 44/50
100/100      0s 4ms/step -
accuracy: 0.8424 - loss: 0.4625 - val_accuracy: 0.8325 - val_loss: 0.4611
Epoch 45/50
100/100      1s 4ms/step -
accuracy: 0.8291 - loss: 0.5086 - val_accuracy: 0.8275 - val_loss: 0.4730
```

```

Epoch 46/50
100/100      0s 4ms/step -
accuracy: 0.8092 - loss: 0.5102 - val_accuracy: 0.8425 - val_loss: 0.4534
Epoch 47/50
100/100      0s 4ms/step -
accuracy: 0.8462 - loss: 0.4460 - val_accuracy: 0.8500 - val_loss: 0.4428
Epoch 48/50
100/100      1s 3ms/step -
accuracy: 0.8308 - loss: 0.4643 - val_accuracy: 0.8375 - val_loss: 0.4573
Epoch 49/50
100/100      1s 6ms/step -
accuracy: 0.8534 - loss: 0.4352 - val_accuracy: 0.8450 - val_loss: 0.4623
Epoch 50/50
100/100      1s 6ms/step -
accuracy: 0.8618 - loss: 0.3975 - val_accuracy: 0.8550 - val_loss: 0.4530

```

We compared multiple ML models:

Classical ML models: Logistic Regression, Random Forest, Extra Trees, SVM (Linear & RBF), KNN, XGBoost, LightGBM, AdaBoost, Naive Bayes, etc.

Neural Networks:

Shallow and deep fully-connected NNs with Dropout and Batch Normalization

Trained using categorical crossentropy loss and softmax activation

Model evaluation included:

Accuracy, Precision, Recall, F1 Score

Confusion matrices

ROC-AUC curves

11 Visualization of Deep Learning Models

```
[39]: # color cycle
custom_colors = itertools.cycle(['#00BFC4', '#F8766D', '#7CAE00', '#C77CFF',
                                '#FF61C3', '#00BA38', '#619cff'])

plt.figure(figsize=(14, 5))

# Accuracy Plot
plt.subplot(1, 2, 1)
for model_name, hist in nn_training_histories:
    color = next(custom_colors)
    train_acc = hist.history['accuracy']
    val_acc = hist.history['val_accuracy']
    plt.plot(train_acc, linestyle='--', label=f'{model_name} Train Acc' +
             f'({train_acc[-1]*100:.2f}%)', color=color)
```

```

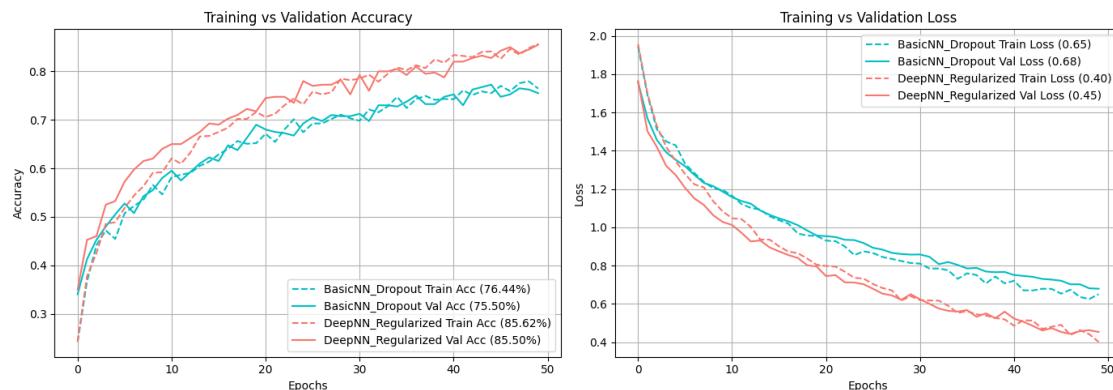
plt.plot(val_acc, linestyle='-', label=f'{model_name} Val Acc' + 
         f'({val_acc[-1]*100:.2f}%)', color=color)
plt.title('Training vs Validation Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
plt.grid(True)

# color cycle for Loss Plot
custom_colors = itertools.cycle(['#00BFC4', '#F8766D', '#7CAE00', '#C77CFF', '#FF61C3', '#00BA38', '#619cff'])

# Loss Plot
plt.subplot(1, 2, 2)
for model_name, hist in nn_training_histories:
    color = next(custom_colors)
    train_loss = hist.history['loss']
    val_loss = hist.history['val_loss']
    plt.plot(train_loss, linestyle='--', label=f'{model_name} Train Loss' + 
             f'({train_loss[-1]:.2f})', color=color)
    plt.plot(val_loss, linestyle='-', label=f'{model_name} Val Loss' + 
             f'({val_loss[-1]:.2f})', color=color)
plt.title('Training vs Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()
plt.grid(True)

plt.tight_layout()
plt.show()

```

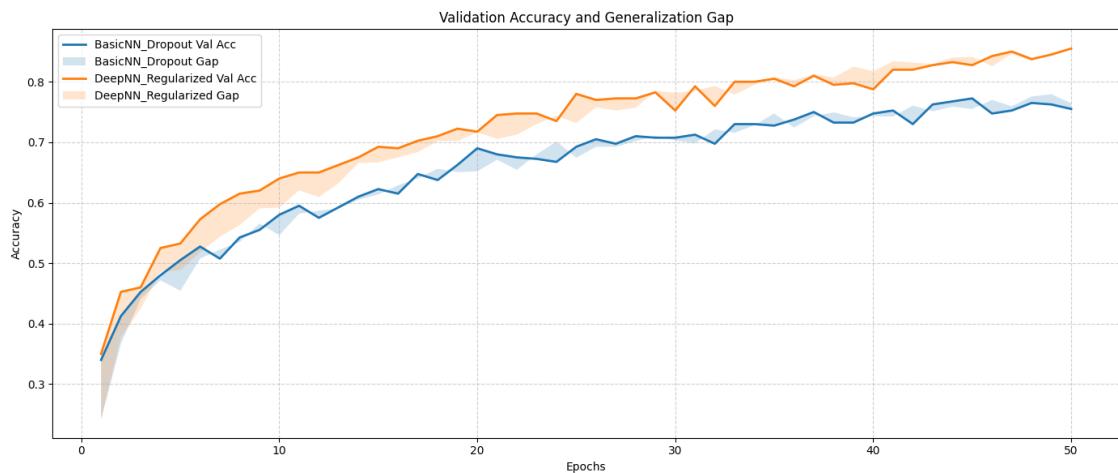


11.1 Area Plot (Shaded Epoch Curves)

```
[41]: plt.figure(figsize=(14, 6))

for model_name, hist in nn_training_histories:
    epochs = range(1, len(hist.history['accuracy']) + 1)
    plt.plot(epochs, hist.history['val_accuracy'], label=f'{model_name} Val Acc', linewidth=2)
    plt.fill_between(epochs, hist.history['accuracy'], hist.history['val_accuracy'], alpha=0.2, label=f'{model_name} Gap')

plt.title('Validation Accuracy and Generalization Gap')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
plt.grid(True, linestyle='--', alpha=0.6)
plt.tight_layout()
plt.show()
```



11.2 Combined Line Plot per Model

```
[42]: num_models = len(nn_training_histories)
fig, axes = plt.subplots(num_models, 1, figsize=(12, 4 * num_models), sharex=True)

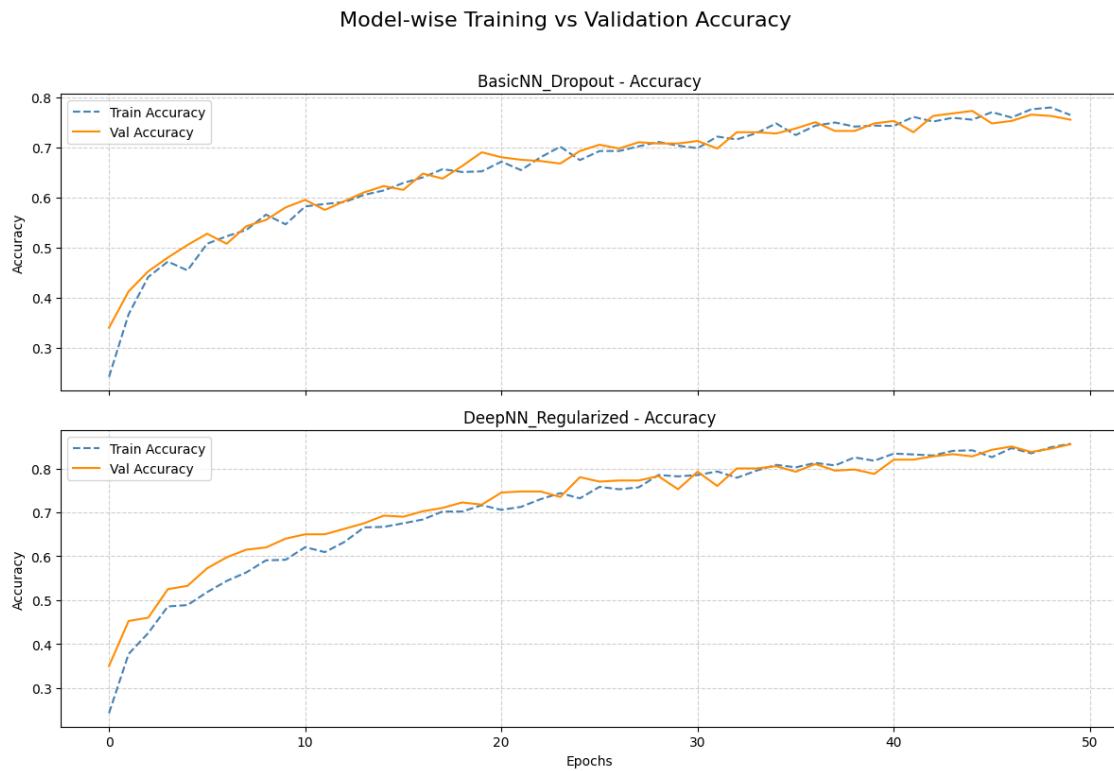
for i, (model_name, hist) in enumerate(nn_training_histories):
    ax = axes[i]
    ax.plot(hist.history['accuracy'], label='Train Accuracy', linestyle='--', color='steelblue')
```

```

    ax.plot(hist.history['val_accuracy'], label='Val Accuracy', linestyle='--', color='darkorange')
    ax.set_title(f'{model_name} - Accuracy')
    ax.set_ylabel('Accuracy')
    ax.grid(True, linestyle='--', alpha=0.6)
    ax.legend()

axes[-1].set_xlabel('Epochs')
plt.suptitle('Model-wise Training vs Validation Accuracy', fontsize=16, y=1.02)
plt.tight_layout()
plt.show()

```



12 Evaluation and Results

Best ML Model: **CatBoost** (Robust Scaled)

Test Accuracy: 90.25%

Test F1 Score: 0.902

Best DL Model: **Deeper Neural Network with Regularized Dropout**

Validation Accuracy: 85.5%

Validation Loss: 0.4530

Model Type	Model Name	Accuracy	F1 Score
Classical ML	CatBoost (Robust Scaled)	90.25%	0.902
Deep Learning	Deeper Neural Net (Reg. Dropout)	85.50%	~0.85

Recommended Final Model: CatBoost (Classical ML)

CatBoost outperformed all other models, including deep learning, in both accuracy and F1 score.

It also requires significantly less training time and computational resources than deep neural networks.

Additionally, it handles categorical data, noise, and overfitting effectively with minimal hyperparameter tuning.

13 Deployment

Hypothetical Deployment Scenario:

Emotion detection integrated into a real-time voice assistant or chatbot

Backend service using FastAPI or Flask serving the model

Frontend: Live audio input with feedback on predicted emotion

14 Discussion and Conclusions

The project successfully demonstrated the ability of machines to learn emotional patterns in human speech using both classical and deep learning models. Among all the models evaluated:

The CatBoost classifier emerged as the most effective, achieving 90.25% accuracy and 0.902 F1 score, confirming its capability to handle complex audio feature representations.

The Deeper Neural Network with regularized dropout also performed competitively with 85.5% accuracy, validating the potential of deep learning for more nuanced emotional modeling with further tuning.

Key Takeaways:

Acoustic features (MFCCs, energy, pitch, ZCR) can robustly represent emotional patterns in speech.

Ensemble tree-based models, especially CatBoost and XGBoost, are highly effective for emotion classification from structured audio features.

Deep learning models show promising results and generalize well with regularization and sufficient data but require more training time and fine-tuning.

The use of RobustScaler preprocessing contributed to more stable and higher-performing models across the board.

Future Work:

Deploy the CatBoost model with a simple Flask API for real-time emotion detection.

Incorporate more diverse datasets (e.g., CREMA-D, TESS) for generalizability.

Explore audio-based Transformers or CNN-RNN hybrid models for end-to-end learning from raw waveforms.

15 Save the file as PDF

```
[44]: !apt-get update  
!apt-get install pandoc  
!apt-get install inkscape  
!apt-get install texlive-xetex texlive-fonts-recommended texlive-latex-extra  
  
0% [Working] Get:1 http://security.ubuntu.com/ubuntu jammy-security InRelease [129 kB]  
0% [Waiting for headers] [1 InRelease 12.7 kB/129 kB 10%] [Connected to cloud.r  
Hit:2 http://archive.ubuntu.com/ubuntu jammy InRelease  
0% [1 InRelease 43.1 kB/129 kB 33%] [Connected to cloud.r-project.org (108.157.  
Get:3 http://archive.ubuntu.com/ubuntu jammy-updates InRelease [128 kB]  
Get:4 https://cloud.r-project.org/bin/linux/ubuntu jammy-cran40/ InRelease  
[3,632 B]  
Hit:5 https://developer.download.nvidia.com/compute/cuda/repos/ubuntu2204/x86_64  
InRelease  
Get:6 http://archive.ubuntu.com/ubuntu jammy-backports InRelease [127 kB]  
Get:7 https://r2u.stat.illinois.edu/ubuntu jammy InRelease [6,555 B]  
Hit:8 https://ppa.launchpadcontent.net/deadsnakes/ppa/ubuntu jammy InRelease  
Hit:9 https://ppa.launchpadcontent.net/graphics-drivers/ppa/ubuntu jammy  
InRelease  
Get:10 http://security.ubuntu.com/ubuntu jammy-security/restricted amd64  
Packages [4,532 kB]  
Hit:11 https://ppa.launchpadcontent.net/ubuntugis/ppa/ubuntu jammy InRelease  
Get:12 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 Packages [3,340  
kB]  
Get:13 http://security.ubuntu.com/ubuntu jammy-security/universe amd64 Packages  
[1,253 kB]  
Get:14 http://security.ubuntu.com/ubuntu jammy-security/main amd64 Packages  
[3,024 kB]  
Get:15 http://archive.ubuntu.com/ubuntu jammy-updates/restricted amd64 Packages  
[4,703 kB]  
Get:16 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64 Packages  
[1,561 kB]  
Get:17 https://r2u.stat.illinois.edu/ubuntu jammy/main all Packages [9,056 kB]  
Get:18 https://r2u.stat.illinois.edu/ubuntu jammy/main amd64 Packages [2,747 kB]  
Fetched 30.6 MB in 3s (9,727 kB/s)  
Reading package lists... Done  
W: Skipping acquire of configured file 'main/source/Sources' as repository  
'https://r2u.stat.illinois.edu/ubuntu jammy InRelease' does not seem to provide
```

```
it (sources.list entry misspelt?)  
Reading package lists... Done  
Building dependency tree... Done  
Reading state information... Done  
The following additional packages will be installed:  
  libcmark-gfm-extensions0.29.0.gfm.3 libcmark-gfm0.29.0.gfm.3 pandoc-data  
Suggested packages:  
  texlive-latex-recommended texlive-xetex texlive-luatex pandoc-citeproc  
  texlive-latex-extra context wkhtmltopdf librsvg2-bin groff ghc nodejs php  
  python ruby libjs-mathjax libjs-katex citation-style-language-styles  
The following NEW packages will be installed:  
  libcmark-gfm-extensions0.29.0.gfm.3 libcmark-gfm0.29.0.gfm.3 pandoc  
  pandoc-data  
0 upgraded, 4 newly installed, 0 to remove and 37 not upgraded.  
Need to get 20.6 MB of archives.  
After this operation, 156 MB of additional disk space will be used.  
Get:1 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libcmark-  
gfm0.29.0.gfm.3 amd64 0.29.0.gfm.3-3 [115 kB]  
Get:2 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libcmark-gfm-  
extensions0.29.0.gfm.3 amd64 0.29.0.gfm.3-3 [25.1 kB]  
Get:3 http://archive.ubuntu.com/ubuntu jammy/universe amd64 pandoc-data all  
2.9.2.1-3ubuntu2 [81.8 kB]  
Get:4 http://archive.ubuntu.com/ubuntu jammy/universe amd64 pandoc amd64  
2.9.2.1-3ubuntu2 [20.3 MB]  
Fetched 20.6 MB in 0s (43.0 MB/s)  
Selecting previously unselected package libcmark-gfm0.29.0.gfm.3:amd64.  
(Reading database ... 126319 files and directories currently installed.)  
Preparing to unpack .../libcmark-gfm0.29.0.gfm.3_0.29.0.gfm.3-3_amd64.deb ...  
Unpacking libcmark-gfm0.29.0.gfm.3:amd64 (0.29.0.gfm.3-3) ...  
Selecting previously unselected package libcmark-gfm-  
extensions0.29.0.gfm.3:amd64.  
Preparing to unpack .../libcmark-gfm-  
extensions0.29.0.gfm.3_0.29.0.gfm.3-3_amd64.deb ...  
Unpacking libcmark-gfm-extensions0.29.0.gfm.3:amd64 (0.29.0.gfm.3-3) ...  
Selecting previously unselected package pandoc-data.  
Preparing to unpack .../pandoc-data_2.9.2.1-3ubuntu2_all.deb ...  
Unpacking pandoc-data (2.9.2.1-3ubuntu2) ...  
Selecting previously unselected package pandoc.  
Preparing to unpack .../pandoc_2.9.2.1-3ubuntu2_amd64.deb ...  
Unpacking pandoc (2.9.2.1-3ubuntu2) ...  
Setting up libcmark-gfm0.29.0.gfm.3:amd64 (0.29.0.gfm.3-3) ...  
Setting up libcmark-gfm-extensions0.29.0.gfm.3:amd64 (0.29.0.gfm.3-3) ...  
Setting up pandoc-data (2.9.2.1-3ubuntu2) ...  
Setting up pandoc (2.9.2.1-3ubuntu2) ...  
Processing triggers for man-db (2.10.2-1) ...  
Processing triggers for libc-bin (2.35-0ubuntu3.8) ...  
/sbin/ldconfig.real: /usr/local/lib/libtbb.so.12 is not a symbolic link
```

```
/sbin/ldconfig.real: /usr/local/lib/libtcm_debug.so.1 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libur_loader.so.0 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libur_adapter_opencl.so.0 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libhwloc.so.15 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libtbbbind_2_5.so.3 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libtbbbind_2_0.so.3 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libtcm.so.1 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libtbbmalloc.so.2 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libumf.so.0 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libur_adapter_level_zero.so.0 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libtbbbind.so.3 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libtbbmalloc_proxy.so.2 is not a symbolic link

Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  aspell aspell-en dictionaries-common enchant-2 fig2dev fonts-droid-fallback
  fonts-noto-mono fonts-urw-base35 gawk ghostscript glib-networking
  glib-networking-common glib-networking-services gsettings-desktop-schemas
  gsfonts hunspell-en-us imagemagick imagemagick-6-common imagemagick-6.q16
  lib2geom1.1.0 libaspell15 libatkmm-1.6-1v5 libcairomm-1.0-1v5 libcdr-0.1-1
  libdbus-glib-1-2 libdjvuibre-text libdjvuibre21 libenchant-2-2
  libfftw3-double3 libglibmm-2.4-1v5 libgs9 libgs9-common libgs127
  libgslcblas0 libgspell-1-2 libgspell-1-common libgtkmm-3.0-1v5
  libhunspell-1.7-0 libidn12 libijs-0.35 libimage-magick-perl
  libimage-magick-q16-perl libjbig2dec0 libjxr-tools libjxr0 liblqr-1-0
  libmagick++-6.q16-8 libmagickcore-6.q16-6 libmagickcore-6.q16-6-extra
  libmagickwand-6.q16-6 libnetpbm10 libpangomm-1.4-1v5 libpoppler-glib8
  libpotrace0 libproxy1v5 librevenge-0.0-0 librsvg2-common libsigc++-2.0-0v5
  libsoup2.4-1 libsoup2.4-common libtext-iconv-perl libvisio-0.1-1
  libwmf-0.2-7 libwmf-bin libwmflite-0.2-7 libwpd-0.10-10 libwpg-0.3-3 netpbm
  poppler-data python3-bs4 python3-chardet python3-html5lib python3-lxml
  python3-numpy python3-scour python3-soupsieve python3-webencodings
```

```

session-migration
Suggested packages:
  aspell-doc spellutils wordlist xfig fonts-noto fonts-freefont-otf
  | fonts-freefont-ttf fonts-texgyre gawk-doc ghostscript-x hunspell
  openoffice.org-hunspell | openoffice.org-core imagemagick-doc autotrace
  cups-bsd | lpr | lprng enscript gimp gnuplot grads hp2xx html2ps mplayer
  povray radiance sane-utils texlive-base-bin ufraw-batch dia
  inkscape-tutorials libsvg-perl pstoedit python3-uniconvertor ruby
  libenchant-2-voikko libfftw3-bin libfftw3-dev gsl-ref-psdoc | gsl-doc-pdf
  | gsl-doc-info | gsl-ref-html libwmf-0.2-7-gtk poppler-utils
  fonts-japanese-mincho | fonts-ipafont-mincho fonts-japanese-gothic
  | fonts-ipafont-gothic fonts-aphic-ukai fonts-aphic-uming fonts-nanum
  python3-genshi python-lxml-doc python-numpy-doc python3-pytest
The following NEW packages will be installed:
  aspell aspell-en dictionaries-common enchant-2 fig2dev fonts-droid-fallback
  fonts-noto-mono fonts-urw-base35 gawk ghostscript glib-networking
  glib-networking-common glib-networking-services gsettings-desktop-schemas
  gsfonts hunspell-en-us imagemagick imagemagick-6-common imagemagick-6.q16
  inkscape lib2geom1.1.0 libaspell15 libatkmm-1.6-1v5 libcairomm-1.0-1v5
  libcdr-0.1-1 libdbus-glib-1-2 libdjvuibre-text libdjvuibre21
  libenchant-2-2 libfftw3-double3 libglibmm-2.4-1v5 libgs9 libgs9-common
  libgs127 libgslcblas0 libgspell-1-2 libgspell-1-common libgtkmm-3.0-1v5
  libhunspell-1.7-0 libidn12 libijs-0.35 libimage-magick-perl
  libimage-magick-q16-perl libjbig2dec0 libjxr-tools libjxr0 liblqr-1-0
  libmagick++-6.q16-8 libmagickcore-6.q16-6 libmagickcore-6.q16-6-extra
  libmagickwand-6.q16-6 libnetpbm10 libpangomm-1.4-1v5 libpoppler-glib8
  libpotrace0 libproxy1v5 librevenge-0.0-0 librsvg2-common libsigc++-2.0-0v5
  libsoup2.4-1 libsoup2.4-common libtext-iconv-perl libvisio-0.1-1
  libwmf-0.2-7 libwmf-bin libwmflite-0.2-7 libwpd-0.10-10 libwpg-0.3-3 netpbm
  poppler-data python3-bs4 python3-chardet python3-html5lib python3-lxml
  python3-numpy python3-scour python3-soupsieve python3-webencodings
  session-migration
0 upgraded, 79 newly installed, 0 to remove and 37 not upgraded.
Need to get 55.8 MB of archives.
After this operation, 228 MB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-droid-fallback all
 1:6.0.1r16-1.1build1 [1,805 kB]
Get:2 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 gawk amd64
 1:5.1.0-1ubuntu0.1 [447 kB]
Get:3 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64
  imagemagick-6-common all 8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5 [64.3 kB]
Get:4 http://archive.ubuntu.com/ubuntu jammy/main amd64 libfftw3-double3 amd64
  3.3.8-2ubuntu8 [770 kB]
Get:5 http://archive.ubuntu.com/ubuntu jammy/universe amd64 liblqr-1-0 amd64
  0.4.2-2.1 [27.7 kB]
Get:6 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64
  libmagickcore-6.q16-6 amd64 8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5 [1,795 kB]
Get:7 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64 libimage-

```

magick-q16-perl amd64 8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5 [108 kB]
Get:8 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64 libimage-magick-perl all 8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5 [53.9 kB]
Get:9 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64 libmagickwand-6.q16-6 amd64 8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5 [328 kB]
Get:10 http://archive.ubuntu.com/ubuntu jammy/main amd64 poppler-data all 0.4.11-1 [2,171 kB]
Get:11 http://archive.ubuntu.com/ubuntu jammy/main amd64 libtext-iconv-perl amd64 1.7-7build3 [14.3 kB]
Get:12 http://archive.ubuntu.com/ubuntu jammy/main amd64 libaspell15 amd64 0.60.8-4build1 [325 kB]
Get:13 http://archive.ubuntu.com/ubuntu jammy/main amd64 dictionaries-common all 1.28.14 [185 kB]
Get:14 http://archive.ubuntu.com/ubuntu jammy/main amd64 aspell amd64 0.60.8-4build1 [87.7 kB]
Get:15 http://archive.ubuntu.com/ubuntu jammy/main amd64 aspell-en all 2018.04.16-0-1 [299 kB]
Get:16 http://archive.ubuntu.com/ubuntu jammy/main amd64 hunspell-en-us all 1:2020.12.07-2 [280 kB]
Get:17 http://archive.ubuntu.com/ubuntu jammy/main amd64 libhunspell-1.7-0 amd64 1.7.0-4build1 [175 kB]
Get:18 http://archive.ubuntu.com/ubuntu jammy/main amd64 libenchant-2-2 amd64 2.3.2-1ubuntu2 [50.9 kB]
Get:19 http://archive.ubuntu.com/ubuntu jammy/main amd64 enchant-2 amd64 2.3.2-1ubuntu2 [13.0 kB]
Get:20 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-urw-base35 all 20200910-1 [6,367 kB]
Get:21 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libgs9-common all 9.55.0~dfsg1-0ubuntu5.11 [753 kB]
Get:22 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libidn12 amd64 1.38-4ubuntu1 [60.0 kB]
Get:23 http://archive.ubuntu.com/ubuntu jammy/main amd64 libijs-0.35 amd64 0.35-15build2 [16.5 kB]
Get:24 http://archive.ubuntu.com/ubuntu jammy/main amd64 libjbig2dec0 amd64 0.19-3build2 [64.7 kB]
Get:25 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libgs9 amd64 9.55.0~dfsg1-0ubuntu5.11 [5,031 kB]
Get:26 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 ghostscript amd64 9.55.0~dfsg1-0ubuntu5.11 [49.4 kB]
Get:27 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libnetpbm10 amd64 2:10.0-15.4 [59.1 kB]
Get:28 http://archive.ubuntu.com/ubuntu jammy/universe amd64 netpbm amd64 2:10.0-15.4 [1,007 kB]
Get:29 http://archive.ubuntu.com/ubuntu jammy/universe amd64 fig2dev amd64 1:3.2.8b-1 [440 kB]
Get:30 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-noto-mono all 20201225-1build1 [397 kB]
Get:31 http://archive.ubuntu.com/ubuntu jammy/main amd64 libproxy1v5 amd64

0.4.17-2 [51.9 kB]
Get:32 http://archive.ubuntu.com/ubuntu jammy/main amd64 glib-networking-common all 2.72.0-1 [3,718 B]
Get:33 http://archive.ubuntu.com/ubuntu jammy/main amd64 glib-networking-services amd64 2.72.0-1 [9,982 B]
Get:34 http://archive.ubuntu.com/ubuntu jammy/main amd64 session-migration amd64 0.3.6 [9,774 B]
Get:35 http://archive.ubuntu.com/ubuntu jammy/main amd64 gsettings-desktop-schemas all 42.0-1ubuntu1 [31.1 kB]
Get:36 http://archive.ubuntu.com/ubuntu jammy/main amd64 glib-networking amd64 2.72.0-1 [69.8 kB]
Get:37 http://archive.ubuntu.com/ubuntu jammy/universe amd64 gsfonts all 1:8.11+urwcyr1.0.7~pre44-4.5 [3,120 kB]
Get:38 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64 imagemagick-6.q16 amd64 8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5 [224 kB]
Get:39 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64 imagemagick amd64 8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5 [14.6 kB]
Get:40 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 librsvg2-common amd64 2.52.5+dfsg-3ubuntu0.2 [17.7 kB]
Get:41 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libgslcblas0 amd64 2.7.1+dfsg-3 [94.4 kB]
Get:42 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libgsl27 amd64 2.7.1+dfsg-3 [1,000 kB]
Get:43 http://archive.ubuntu.com/ubuntu jammy/universe amd64 lib2geom1.1.0 amd64 1.1-2build1 [346 kB]
Get:44 http://archive.ubuntu.com/ubuntu jammy/main amd64 libsigc++-2.0-0v5 amd64 2.10.4-2ubuntu3 [12.1 kB]
Get:45 http://archive.ubuntu.com/ubuntu jammy/main amd64 libglibmm-2.4-1v5 amd64 2.66.2-2 [645 kB]
Get:46 http://archive.ubuntu.com/ubuntu jammy/main amd64 libatkmm-1.6-1v5 amd64 2.28.2-1build1 [78.5 kB]
Get:47 http://archive.ubuntu.com/ubuntu jammy/main amd64 libcairoomm-1.0-1v5 amd64 1.12.2-4build3 [45.1 kB]
Get:48 http://archive.ubuntu.com/ubuntu jammy/main amd64 librevenge-0.0-0 amd64 0.0.4-6ubuntu7 [209 kB]
Get:49 http://archive.ubuntu.com/ubuntu jammy/main amd64 libcdr-0.1-1 amd64 0.1.6-2build2 [392 kB]
Get:50 http://archive.ubuntu.com/ubuntu jammy/main amd64 libdbus-glib-1-2 amd64 0.112-2build1 [65.4 kB]
Get:51 http://archive.ubuntu.com/ubuntu jammy/main amd64 libgspell-1-common all 1.9.1-4 [6,114 B]
Get:52 http://archive.ubuntu.com/ubuntu jammy/main amd64 libgspell-1-2 amd64 1.9.1-4 [56.5 kB]
Get:53 http://archive.ubuntu.com/ubuntu jammy/main amd64 libpangomm-1.4-1v5 amd64 2.46.2-1 [56.1 kB]
Get:54 http://archive.ubuntu.com/ubuntu jammy/main amd64 libgtkmm-3.0-1v5 amd64 3.24.5-1build1 [1,003 kB]
Get:55 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64

```
libmagick++-6.q16-8 amd64 8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5 [157 kB]
Get:56 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libpoppler-
glib8 amd64 22.02.0-2ubuntu0.8 [134 kB]
Get:57 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libpotrace0 amd64
1.16-2 [17.2 kB]
Get:58 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64
libsoup2.4-common all 2.74.2-3ubuntu0.5 [4,660 B]
Get:59 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libsoup2.4-1
amd64 2.74.2-3ubuntu0.5 [287 kB]
Get:60 http://archive.ubuntu.com/ubuntu jammy/main amd64 libvisio-0.1-1 amd64
0.1.7-1build5 [238 kB]
Get:61 http://archive.ubuntu.com/ubuntu jammy/main amd64 libwpd-0.10-10 amd64
0.10.3-2build1 [209 kB]
Get:62 http://archive.ubuntu.com/ubuntu jammy/main amd64 libwpg-0.3-3 amd64
0.3.3-1build3 [49.9 kB]
Get:63 http://archive.ubuntu.com/ubuntu jammy/universe amd64 inkscape amd64
1.1.2-3ubuntu1 [17.8 MB]
Get:64 http://archive.ubuntu.com/ubuntu jammy/main amd64 libdjvulibre-text all
3.5.28-2build2 [50.9 kB]
Get:65 http://archive.ubuntu.com/ubuntu jammy/main amd64 libdjvulibre21 amd64
3.5.28-2build2 [624 kB]
Get:66 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libjxr0 amd64
1.2~git20170615.f752187-5 [174 kB]
Get:67 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libjxr-tools amd64
1.2~git20170615.f752187-5 [16.0 kB]
Get:68 http://archive.ubuntu.com/ubuntu jammy/main amd64 libwmflite-0.2-7 amd64
0.2.12-5ubuntu1 [68.9 kB]
Get:69 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64
libmagickcore-6.q16-6-extra amd64 8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5 [70.1 kB]
Get:70 http://archive.ubuntu.com/ubuntu jammy/main amd64 libwmf-0.2-7 amd64
0.2.12-5ubuntu1 [94.2 kB]
Get:71 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libwmf-bin amd64
0.2.12-5ubuntu1 [34.3 kB]
Get:72 http://archive.ubuntu.com/ubuntu jammy/main amd64 python3-soupsieve all
2.3.1-1 [33.0 kB]
Get:73 http://archive.ubuntu.com/ubuntu jammy/main amd64 python3-bs4 all
4.10.0-2 [79.1 kB]
Get:74 http://archive.ubuntu.com/ubuntu jammy/main amd64 python3-chardet all
4.0.0-1 [98.0 kB]
Get:75 http://archive.ubuntu.com/ubuntu jammy/main amd64 python3-webencodings
all 0.5.1-4 [11.8 kB]
Get:76 http://archive.ubuntu.com/ubuntu jammy/main amd64 python3-html5lib all
1.1-3 [87.0 kB]
Get:77 http://archive.ubuntu.com/ubuntu jammy/main amd64 python3-lxml amd64
4.8.0-1build1 [1,150 kB]
Get:78 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 python3-numpy
amd64 1:1.21.5-1ubuntu22.04.1 [3,467 kB]
Get:79 http://archive.ubuntu.com/ubuntu jammy/universe amd64 python3-scour all
```

```
0.38.2-2 [49.4 kB]
Fetched 55.8 MB in 2s (26.9 MB/s)
Extracting templates from packages: 100%
Preconfiguring packages ...
Selecting previously unselected package fonts-droid-fallback.
(Reading database ... 126544 files and directories currently installed.)
Preparing to unpack .../00-fonts-droid-fallback_1%3a6.0.1r16-1.1build1_all.deb
...
Unpacking fonts-droid-fallback (1:6.0.1r16-1.1build1) ...
Selecting previously unselected package gawk.
Preparing to unpack .../01-gawk_1%3a5.1.0-1ubuntu0.1_amd64.deb ...
Unpacking gawk (1:5.1.0-1ubuntu0.1) ...
Selecting previously unselected package imagemagick-6-common.
Preparing to unpack
.../02-imagemagick-6-common_8%3a6.9.11.60+dfsg-1.3ubuntu0.22.04.5_all.deb ...
Unpacking imagemagick-6-common (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Selecting previously unselected package libfftw3-double3:amd64.
Preparing to unpack .../03-libfftw3-double3_3.3.8-2ubuntu8_amd64.deb ...
Unpacking libfftw3-double3:amd64 (3.3.8-2ubuntu8) ...
Selecting previously unselected package liblqr-1-0:amd64.
Preparing to unpack .../04-liblqr-1-0_0.4.2-2.1_amd64.deb ...
Unpacking liblqr-1-0:amd64 (0.4.2-2.1) ...
Selecting previously unselected package libmagickcore-6.q16-6:amd64.
Preparing to unpack
.../05-libmagickcore-6.q16-6_8%3a6.9.11.60+dfsg-1.3ubuntu0.22.04.5_amd64.deb ...
Unpacking libmagickcore-6.q16-6:amd64 (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Selecting previously unselected package libimage-magick-q16-perl.
Preparing to unpack .../06-libimage-
magick-q16-perl_8%3a6.9.11.60+dfsg-1.3ubuntu0.22.04.5_amd64.deb ...
Unpacking libimage-magick-q16-perl (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Selecting previously unselected package libimage-magick-perl.
Preparing to unpack .../07-libimage-magick-
perl_8%3a6.9.11.60+dfsg-1.3ubuntu0.22.04.5_all.deb ...
Unpacking libimage-magick-perl (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Selecting previously unselected package libmagickwand-6.q16-6:amd64.
Preparing to unpack
.../08-libmagickwand-6.q16-6_8%3a6.9.11.60+dfsg-1.3ubuntu0.22.04.5_amd64.deb ...
Unpacking libmagickwand-6.q16-6:amd64 (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Selecting previously unselected package poppler-data.
Preparing to unpack .../09-poppler-data_0.4.11-1_all.deb ...
Unpacking poppler-data (0.4.11-1) ...
Selecting previously unselected package libtext-iconv-perl.
Preparing to unpack .../10-libtext-iconv-perl_1.7-7build3_amd64.deb ...
Unpacking libtext-iconv-perl (1.7-7build3) ...
Selecting previously unselected package libaspell15:amd64.
Preparing to unpack .../11-libaspell15_0.60.8-4build1_amd64.deb ...
Unpacking libaspell15:amd64 (0.60.8-4build1) ...
Selecting previously unselected package dictionaries-common.
```

```
Preparing to unpack .../12-dictionaries-common_1.28.14_all.deb ...
Adding 'diversion of /usr/share/dict/words to /usr/share/dict/words.pre-
dictionaries-common by dictionaries-common'
Unpacking dictionaries-common (1.28.14) ...
Selecting previously unselected package aspell.
Preparing to unpack .../13-aspell_0.60.8-4build1_amd64.deb ...
Unpacking aspell (0.60.8-4build1) ...
Selecting previously unselected package aspell-en.
Preparing to unpack .../14-aspell-en_2018.04.16-0-1_all.deb ...
Unpacking aspell-en (2018.04.16-0-1) ...
Selecting previously unselected package hunspell-en-us.
Preparing to unpack .../15-hunspell-en-us_1%3a2020.12.07-2_all.deb ...
Unpacking hunspell-en-us (1:2020.12.07-2) ...
Selecting previously unselected package libhunspell-1.7-0:amd64.
Preparing to unpack .../16-libhunspell-1.7-0_1.7.0-4build1_amd64.deb ...
Unpacking libhunspell-1.7-0:amd64 (1.7.0-4build1) ...
Selecting previously unselected package libenchant-2-2:amd64.
Preparing to unpack .../17-libenchant-2-2_2.3.2-1ubuntu2_amd64.deb ...
Unpacking libenchant-2-2:amd64 (2.3.2-1ubuntu2) ...
Selecting previously unselected package enchant-2.
Preparing to unpack .../18-enchant-2_2.3.2-1ubuntu2_amd64.deb ...
Unpacking enchant-2 (2.3.2-1ubuntu2) ...
Selecting previously unselected package fonts-urw-base35.
Preparing to unpack .../19-fonts-urw-base35_20200910-1_all.deb ...
Unpacking fonts-urw-base35 (20200910-1) ...
Selecting previously unselected package libgs9-common.
Preparing to unpack .../20-libgs9-common_9.55.0~dfsg1-0ubuntu5.11_all.deb ...
Unpacking libgs9-common (9.55.0~dfsg1-0ubuntu5.11) ...
Selecting previously unselected package libidn12:amd64.
Preparing to unpack .../21-libidn12_1.38-4ubuntu1_amd64.deb ...
Unpacking libidn12:amd64 (1.38-4ubuntu1) ...
Selecting previously unselected package libijs-0.35:amd64.
Preparing to unpack .../22-libijs-0.35_0.35-15build2_amd64.deb ...
Unpacking libijs-0.35:amd64 (0.35-15build2) ...
Selecting previously unselected package libjbig2dec0:amd64.
Preparing to unpack .../23-libjbig2dec0_0.19-3build2_amd64.deb ...
Unpacking libjbig2dec0:amd64 (0.19-3build2) ...
Selecting previously unselected package libgs9:amd64.
Preparing to unpack .../24-libgs9_9.55.0~dfsg1-0ubuntu5.11_amd64.deb ...
Unpacking libgs9:amd64 (9.55.0~dfsg1-0ubuntu5.11) ...
Selecting previously unselected package ghostscript.
Preparing to unpack .../25-ghostscript_9.55.0~dfsg1-0ubuntu5.11_amd64.deb ...
Unpacking ghostscript (9.55.0~dfsg1-0ubuntu5.11) ...
Selecting previously unselected package libnetpbm10.
Preparing to unpack .../26-libnetpbm10_2%3a10.0-15.4_amd64.deb ...
Unpacking libnetpbm10 (2:10.0-15.4) ...
Selecting previously unselected package netpbm.
Preparing to unpack .../27-netpbm_2%3a10.0-15.4_amd64.deb ...
```

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Unpacking netpbm (2:10.0-15.4) ...
Selecting previously unselected package fig2dev.
Preparing to unpack .../28-fig2dev_1%3a3.2.8b-1_amd64.deb ...
Unpacking fig2dev (1:3.2.8b-1) ...
Selecting previously unselected package fonts-noto-mono.
Preparing to unpack .../29-fonts-noto-mono_20201225-1build1_all.deb ...
Unpacking fonts-noto-mono (20201225-1build1) ...
Selecting previously unselected package libproxy1v5:amd64.
Preparing to unpack .../30-libproxy1v5_0.4.17-2_amd64.deb ...
Unpacking libproxy1v5:amd64 (0.4.17-2) ...
Selecting previously unselected package glib-networking-common.
Preparing to unpack .../31-glib-networking-common_2.72.0-1_all.deb ...
Unpacking glib-networking-common (2.72.0-1) ...
Selecting previously unselected package glib-networking-services.
Preparing to unpack .../32-glib-networking-services_2.72.0-1_amd64.deb ...
Unpacking glib-networking-services (2.72.0-1) ...
Selecting previously unselected package session-migration.
Preparing to unpack .../33-session-migration_0.3.6_amd64.deb ...
Unpacking session-migration (0.3.6) ...
Selecting previously unselected package gsettings-desktop-schemas.
Preparing to unpack .../34-gsettings-desktop-schemas_42.0-1ubuntu1_all.deb ...
Unpacking gsettings-desktop-schemas (42.0-1ubuntu1) ...
Selecting previously unselected package glib-networking:amd64.
Preparing to unpack .../35-glib-networking_2.72.0-1_amd64.deb ...
Unpacking glib-networking:amd64 (2.72.0-1) ...
Selecting previously unselected package gsfonts.
Preparing to unpack .../36-gsfonts_1%3a8.11+urwcyr1.0.7~pre44-4.5_all.deb ...
Unpacking gsfonts (1:8.11+urwcyr1.0.7~pre44-4.5) ...
Selecting previously unselected package imagemagick-6.q16.
Preparing to unpack
.../37-imagemagick-6.q16_8%3a6.9.11.60+dfsg-1.3ubuntu0.22.04.5_amd64.deb ...
Unpacking imagemagick-6.q16 (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Selecting previously unselected package imagemagick.
Preparing to unpack
.../38-imagemagick_8%3a6.9.11.60+dfsg-1.3ubuntu0.22.04.5_amd64.deb ...
Unpacking imagemagick (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Selecting previously unselected package librsvg2-common:amd64.
Preparing to unpack .../39-librsvg2-common_2.52.5+dfsg-3ubuntu0.2_amd64.deb ...
Unpacking librsvg2-common:amd64 (2.52.5+dfsg-3ubuntu0.2) ...
Selecting previously unselected package libgslcblas0:amd64.
Preparing to unpack .../40-libgslcblas0_2.7.1+dfsg-3_amd64.deb ...
Unpacking libgslcblas0:amd64 (2.7.1+dfsg-3) ...
Selecting previously unselected package libgsl27:amd64.
Preparing to unpack .../41-libgsl27_2.7.1+dfsg-3_amd64.deb ...
Unpacking libgsl27:amd64 (2.7.1+dfsg-3) ...
Selecting previously unselected package lib2geom1.1.0:amd64.
Preparing to unpack .../42-lib2geom1.1.0_1.1-2build1_amd64.deb ...
Unpacking lib2geom1.1.0:amd64 (1.1-2build1) ...
```

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Selecting previously unselected package libsigc++-2.0-0v5:amd64.
Preparing to unpack .../43-libsigc++-2.0-0v5_2.10.4-2ubuntu3_amd64.deb ...
Unpacking libsigc++-2.0-0v5:amd64 (2.10.4-2ubuntu3) ...
Selecting previously unselected package libglibmm-2.4-1v5:amd64.
Preparing to unpack .../44-libglibmm-2.4-1v5_2.66.2-2_amd64.deb ...
Unpacking libglibmm-2.4-1v5:amd64 (2.66.2-2) ...
Selecting previously unselected package libatkmm-1.6-1v5:amd64.
Preparing to unpack .../45-libatkmm-1.6-1v5_2.28.2-1build1_amd64.deb ...
Unpacking libatkmm-1.6-1v5:amd64 (2.28.2-1build1) ...
Selecting previously unselected package libcairomm-1.0-1v5:amd64.
Preparing to unpack .../46-libcairomm-1.0-1v5_1.12.2-4build3_amd64.deb ...
Unpacking libcairomm-1.0-1v5:amd64 (1.12.2-4build3) ...
Selecting previously unselected package librevenge-0.0-0:amd64.
Preparing to unpack .../47-librevenge-0.0-0_0.0.4-6ubuntu7_amd64.deb ...
Unpacking librevenge-0.0-0:amd64 (0.0.4-6ubuntu7) ...
Selecting previously unselected package libcdr-0.1-1:amd64.
Preparing to unpack .../48-libcdr-0.1-1_0.1.6-2build2_amd64.deb ...
Unpacking libcdr-0.1-1:amd64 (0.1.6-2build2) ...
Selecting previously unselected package libdbus-glib-1-2:amd64.
Preparing to unpack .../49-libdbus-glib-1-2_0.112-2build1_amd64.deb ...
Unpacking libdbus-glib-1-2:amd64 (0.112-2build1) ...
Selecting previously unselected package libgspell-1-common.
Preparing to unpack .../50-libgspell-1-common_1.9.1-4_all.deb ...
Unpacking libgspell-1-common (1.9.1-4) ...
Selecting previously unselected package libgspell-1-2:amd64.
Preparing to unpack .../51-libgspell-1-2_1.9.1-4_amd64.deb ...
Unpacking libgspell-1-2:amd64 (1.9.1-4) ...
Selecting previously unselected package libpangomm-1.4-1v5:amd64.
Preparing to unpack .../52-libpangomm-1.4-1v5_2.46.2-1_amd64.deb ...
Unpacking libpangomm-1.4-1v5:amd64 (2.46.2-1) ...
Selecting previously unselected package libgtkmm-3.0-1v5:amd64.
Preparing to unpack .../53-libgtkmm-3.0-1v5_3.24.5-1build1_amd64.deb ...
Unpacking libgtkmm-3.0-1v5:amd64 (3.24.5-1build1) ...
Selecting previously unselected package libmagick++-6.q16-8:amd64.
Preparing to unpack
.../54-libmagick++-6.q16-8_8%3a6.9.11.60+dfsg-1.3ubuntu0.22.04.5_amd64.deb ...
Unpacking libmagick++-6.q16-8:amd64 (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Selecting previously unselected package libpoppler-glib8:amd64.
Preparing to unpack .../55-libpoppler-glib8_22.02.0-2ubuntu0.8_amd64.deb ...
Unpacking libpoppler-glib8:amd64 (22.02.0-2ubuntu0.8) ...
Selecting previously unselected package libpotrace0:amd64.
Preparing to unpack .../56-libpotrace0_1.16-2_amd64.deb ...
Unpacking libpotrace0:amd64 (1.16-2) ...
Selecting previously unselected package libsoup2.4-common.
Preparing to unpack .../57-libsoup2.4-common_2.74.2-3ubuntu0.5_all.deb ...
Unpacking libsoup2.4-common (2.74.2-3ubuntu0.5) ...
Selecting previously unselected package libsoup2.4-1:amd64.
Preparing to unpack .../58-libsoup2.4-1_2.74.2-3ubuntu0.5_amd64.deb ...
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Unpacking libsoup2.4-1:amd64 (2.74.2-3ubuntu0.5) ...
Selecting previously unselected package libvisio-0.1-1:amd64.
Preparing to unpack .../59-libvisio-0.1-1_0.1.7-1build5_amd64.deb ...
Unpacking libvisio-0.1-1:amd64 (0.1.7-1build5) ...
Selecting previously unselected package libwpd-0.10-10:amd64.
Preparing to unpack .../60-libwpd-0.10-10_0.10.3-2build1_amd64.deb ...
Unpacking libwpd-0.10-10:amd64 (0.10.3-2build1) ...
Selecting previously unselected package libwpg-0.3-3:amd64.
Preparing to unpack .../61-libwpg-0.3-3_0.3.3-1build3_amd64.deb ...
Unpacking libwpg-0.3-3:amd64 (0.3.3-1build3) ...
Selecting previously unselected package inkscape.
Preparing to unpack .../62-inkscape_1.1.2-3ubuntu1_amd64.deb ...
Unpacking inkscape (1.1.2-3ubuntu1) ...
Selecting previously unselected package libdjvulibre-text.
Preparing to unpack .../63-libdjvulibre-text_3.5.28-2build2_all.deb ...
Unpacking libdjvulibre-text (3.5.28-2build2) ...
Selecting previously unselected package libdjvulibre21:amd64.
Preparing to unpack .../64-libdjvulibre21_3.5.28-2build2_amd64.deb ...
Unpacking libdjvulibre21:amd64 (3.5.28-2build2) ...
Selecting previously unselected package libjxr0:amd64.
Preparing to unpack .../65-libjxr0_1.2~git20170615.f752187-5_amd64.deb ...
Unpacking libjxr0:amd64 (1.2~git20170615.f752187-5) ...
Selecting previously unselected package libjxr-tools.
Preparing to unpack .../66-libjxr-tools_1.2~git20170615.f752187-5_amd64.deb ...
Unpacking libjxr-tools (1.2~git20170615.f752187-5) ...
Selecting previously unselected package libwmflite-0.2-7:amd64.
Preparing to unpack .../67-libwmflite-0.2-7_0.2.12-5ubuntu1_amd64.deb ...
Unpacking libwmflite-0.2-7:amd64 (0.2.12-5ubuntu1) ...
Selecting previously unselected package libmagickcore-6.q16-6-extra:amd64.
Preparing to unpack .../68-libmagickcore-6.q16-6-extra_8%3a6.9.11.60+dfsg-
1.3ubuntu0.22.04.5_amd64.deb ...
Unpacking libmagickcore-6.q16-6-extra:amd64
(8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Selecting previously unselected package libwmf-0.2-7:amd64.
Preparing to unpack .../69-libwmf-0.2-7_0.2.12-5ubuntu1_amd64.deb ...
Unpacking libwmf-0.2-7:amd64 (0.2.12-5ubuntu1) ...
Selecting previously unselected package libwmf-bin.
Preparing to unpack .../70-libwmf-bin_0.2.12-5ubuntu1_amd64.deb ...
Unpacking libwmf-bin (0.2.12-5ubuntu1) ...
Selecting previously unselected package python3-soupsieve.
Preparing to unpack .../71-python3-soupsieve_2.3.1-1_all.deb ...
Unpacking python3-soupsieve (2.3.1-1) ...
Selecting previously unselected package python3-bs4.
Preparing to unpack .../72-python3-bs4_4.10.0-2_all.deb ...
Unpacking python3-bs4 (4.10.0-2) ...
Selecting previously unselected package python3-chardet.
Preparing to unpack .../73-python3-chardet_4.0.0-1_all.deb ...
Unpacking python3-chardet (4.0.0-1) ...
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Selecting previously unselected package python3-webencodings.
Preparing to unpack .../74-python3-webencodings_0.5.1-4_all.deb ...
Unpacking python3-webencodings (0.5.1-4) ...
Selecting previously unselected package python3-html5lib.
Preparing to unpack .../75-python3-html5lib_1.1-3_all.deb ...
Unpacking python3-html5lib (1.1-3) ...
Selecting previously unselected package python3-lxml:amd64.
Preparing to unpack .../76-python3-lxml_4.8.0-1build1_amd64.deb ...
Unpacking python3-lxml:amd64 (4.8.0-1build1) ...
Selecting previously unselected package python3-numpy.
Preparing to unpack .../77-python3-numpy_1%3a1.21.5-1ubuntu22.04.1_amd64.deb ...
Unpacking python3-numpy (1:1.21.5-1ubuntu22.04.1) ...
Selecting previously unselected package python3-scour.
Preparing to unpack .../78-python3-scour_0.38.2-2_all.deb ...
Unpacking python3-scour (0.38.2-2) ...
Setting up libtext-iconv-perl (1.7-7build3) ...
Setting up session-migration (0.3.6) ...
Created symlink /etc/systemd/user/graphical-session-pre.target.wants/session-
migration.service → /usr/lib/systemd/user/session-migration.service.
Setting up imagemagick-6-common (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Setting up libproxy1v5:amd64 (0.4.17-2) ...
Setting up libpoppler-glib8:amd64 (22.02.0-2ubuntu0.8) ...
Setting up fonts-noto-mono (20201225-1build1) ...
Setting up libwmflite-0.2-7:amd64 (0.2.12-5ubuntu1) ...
Setting up libgslcblas0:amd64 (2.7.1+dfsg-3) ...
Setting up libgspell-1-common (1.9.1-4) ...
Setting up dictionaries-common (1.28.14) ...
Setting up gawk (1:5.1.0-1ubuntu0.1) ...
Setting up libaspell15:amd64 (0.60.8-4build1) ...
Setting up libijs-0.35:amd64 (0.35-15build2) ...
Setting up libjxr0:amd64 (1.2~git20170615.f752187-5) ...
Setting up libgsl27:amd64 (2.7.1+dfsg-3) ...
Setting up libnetpbm10 (2:10.0-15.4) ...
Setting up fonts-urw-base35 (20200910-1) ...
Setting up python3-webencodings (0.5.1-4) ...
Setting up librevenge-0.0-0:amd64 (0.0.4-6ubuntu7) ...
Setting up poppler-data (0.4.11-1) ...
Setting up python3-chardet (4.0.0-1) ...
Setting up libwmf-0.2-7:amd64 (0.2.12-5ubuntu1) ...
Setting up libjbig2dec0:amd64 (0.19-3build2) ...
Setting up libsigc++-2.0-0v5:amd64 (2.10.4-2ubuntu3) ...
Setting up libdbus-glib-1-2:amd64 (0.112-2build1) ...
Setting up gsffonts (1:8.11+urwcyr1.0.7~pre44-4.5) ...
Setting up libidn12:amd64 (1.38-4ubuntu1) ...
Setting up lib2geom1.1.0:amd64 (1.1-2build1) ...
Setting up aspell (0.60.8-4build1) ...
Setting up librsvg2-common:amd64 (2.52.5+dfsg-3ubuntu0.2) ...
Setting up netpbm (2:10.0-15.4) ...
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Setting up python3-html5lib (1.1-3) ...
Setting up python3-numpy (1:1.21.5-1ubuntu22.04.1) ...
Setting up libfftw3-double3:amd64 (3.3.8-2ubuntu8) ...
Setting up libsoup2.4-common (2.74.2-3ubuntu0.5) ...
Setting up liblqr-1-0:amd64 (0.4.2-2.1) ...
Setting up python3-lxml:amd64 (4.8.0-1build1) ...
Setting up hunspell-en-us (1:2020.12.07-2) ...
Setting up fonts-droid-fallback (1:6.0.1r16-1.1build1) ...
Setting up python3-scour (0.38.2-2) ...
Setting up libdjvulibre-text (3.5.28-2build2) ...
Setting up libhunspell-1.7-0:amd64 (1.7.0-4build1) ...
Setting up glib-networking-common (2.72.0-1) ...
Setting up libwpd-0.10-10:amd64 (0.10.3-2build1) ...
Setting up python3-soupsieve (2.3.1-1) ...
Setting up libvisio-0.1-1:amd64 (0.1.7-1build5) ...
Setting up libpotrace0:amd64 (1.16-2) ...
Setting up libgs9-common (9.55.0~dfsg1-0ubuntu5.11) ...
Setting up gsettings-desktop-schemas (42.0-1ubuntu1) ...
Setting up glib-networking-services (2.72.0-1) ...
Setting up libglibmm-2.4-1v5:amd64 (2.66.2-2) ...
Setting up libwmf-bin (0.2.12-5ubuntu1) ...
Setting up libjxr-tools (1.2~git20170615.f752187-5) ...
Setting up libgs9:amd64 (9.55.0~dfsg1-0ubuntu5.11) ...
Setting up libenchant-2-2:amd64 (2.3.2-1ubuntu2) ...
Setting up libdjvulibre21:amd64 (3.5.28-2build2) ...
Setting up aspell-en (2018.04.16-0-1) ...
Setting up enchant-2 (2.3.2-1ubuntu2) ...
Setting up libcdr-0.1-1:amd64 (0.1.6-2build2) ...
Setting up ghostscript (9.55.0~dfsg1-0ubuntu5.11) ...
Setting up fig2dev (1:3.2.8b-1) ...
Setting up python3-bs4 (4.10.0-2) ...
Setting up libcairomm-1.0-1v5:amd64 (1.12.2-4build3) ...
Setting up libmagickcore-6.q16-6:amd64 (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Setting up libpangomm-1.4-1v5:amd64 (2.46.2-1) ...
Setting up libwpg-0.3-3:amd64 (0.3.3-1build3) ...
Setting up libmagickwand-6.q16-6:amd64 (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Setting up libatkmm-1.6-1v5:amd64 (2.28.2-1build1) ...
Setting up libmagick++-6.q16-8:amd64 (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Setting up libgspell-1-2:amd64 (1.9.1-4) ...
Setting up libmagickcore-6.q16-6-extra:amd64
(8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Setting up libimage-magick-q16-perl (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Setting up libgtkmm-3.0-1v5:amd64 (3.24.5-1build1) ...
Setting up imagemagick-6.q16 (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
update-alternatives: using /usr/bin/compare-im6.q16 to provide /usr/bin/compare
(compare) in auto mode
update-alternatives: using /usr/bin/compare-im6.q16 to provide /usr/bin/compare-
im6 (compare-im6) in auto mode
```

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update-alternatives: using /usr/bin/animate-im6.q16 to provide /usr/bin/animate
/animate) in auto mode
update-alternatives: using /usr/bin/animate-im6.q16 to provide /usr/bin/animate-
im6 (animate-im6) in auto mode
update-alternatives: using /usr/bin/convert-im6.q16 to provide /usr/bin/convert
(convert) in auto mode
update-alternatives: using /usr/bin/convert-im6.q16 to provide /usr/bin/convert-
im6 (convert-im6) in auto mode
update-alternatives: using /usr/bin/composite-im6.q16 to provide
/usr/bin/composite (composite) in auto mode
update-alternatives: using /usr/bin/composite-im6.q16 to provide
/usr/bin/composite-im6 (composite-im6) in auto mode
update-alternatives: using /usr/bin/conjure-im6.q16 to provide /usr/bin/conjure
(conjure) in auto mode
update-alternatives: using /usr/bin/conjure-im6.q16 to provide /usr/bin/conjure-
im6 (conjure-im6) in auto mode
update-alternatives: using /usr/bin/import-im6.q16 to provide /usr/bin/import
(import) in auto mode
update-alternatives: using /usr/bin/import-im6.q16 to provide /usr/bin/import-
im6 (import-im6) in auto mode
update-alternatives: using /usr/bin/identify-im6.q16 to provide
/usr/bin/identify (identify) in auto mode
update-alternatives: using /usr/bin/identify-im6.q16 to provide
/usr/bin/identify-im6 (identify-im6) in auto mode
update-alternatives: using /usr/bin/stream-im6.q16 to provide /usr/bin/stream
(stream) in auto mode
update-alternatives: using /usr/bin/stream-im6.q16 to provide /usr/bin/stream-
im6 (stream-im6) in auto mode
update-alternatives: using /usr/bin/display-im6.q16 to provide /usr/bin/display
(display) in auto mode
update-alternatives: using /usr/bin/display-im6.q16 to provide /usr/bin/display-
im6 (display-im6) in auto mode
update-alternatives: using /usr/bin/montage-im6.q16 to provide /usr/bin/montage
(montage) in auto mode
update-alternatives: using /usr/bin/montage-im6.q16 to provide /usr/bin/montage-
im6 (montage-im6) in auto mode
update-alternatives: using /usr/bin/mogrify-im6.q16 to provide /usr/bin/mogrify
(mogrify) in auto mode
update-alternatives: using /usr/bin/mogrify-im6.q16 to provide /usr/bin/mogrify-
im6 (mogrify-im6) in auto mode
Setting up libimage-magick-perl (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Setting up imagemagick (8:6.9.11.60+dfsg-1.3ubuntu0.22.04.5) ...
Processing triggers for libgdk-pixbuf-2.0-0:amd64 (2.42.8+dfsg-1ubuntu0.3) ...
Processing triggers for mailcap (3.70+nmu1ubuntu1) ...
Processing triggers for fontconfig (2.13.1-4.2ubuntu5) ...
Processing triggers for hicolor-icon-theme (0.17-2) ...
Processing triggers for libglib2.0-0:amd64 (2.72.4-0ubuntu2.5) ...
Processing triggers for libc-bin (2.35-0ubuntu3.8) ...
```

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/sbin/ldconfig.real: /usr/local/lib/libtbb.so.12 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libtcm_debug.so.1 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libur_loader.so.0 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libur_adapter_opencl.so.0 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libhwloc.so.15 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libtbbbind_2_5.so.3 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libtbbbind_2_0.so.3 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libtcm.so.1 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libtbbmalloc.so.2 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libumf.so.0 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libur_adapter_level_zero.so.0 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libtbbbind.so.3 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libtbbmalloc_proxy.so.2 is not a symbolic link

Processing triggers for man-db (2.10.2-1) ...
Setting up glib-networking:amd64 (2.72.0-1) ...
Setting up libsoup2.4-1:amd64 (2.74.2-3ubuntu0.5) ...
Setting up inkscape (1.1.2-3ubuntu1) ...
Processing triggers for dictionaries-common (1.28.14) ...
aspell-autobuildhash: processing: en [en-common].
aspell-autobuildhash: processing: en [en-variant_0].
aspell-autobuildhash: processing: en [en-variant_1].
aspell-autobuildhash: processing: en [en-variant_2].
aspell-autobuildhash: processing: en [en-w_accents-only].
aspell-autobuildhash: processing: en [en-wo_accents-only].
aspell-autobuildhash: processing: en [en_AU-variant_0].
aspell-autobuildhash: processing: en [en_AU-variant_1].
aspell-autobuildhash: processing: en [en_AU-w_accents-only].
aspell-autobuildhash: processing: en [en_AU-wo_accents-only].
aspell-autobuildhash: processing: en [en_CA-variant_0].
aspell-autobuildhash: processing: en [en_CA-variant_1].
aspell-autobuildhash: processing: en [en_CA-w_accents-only].
aspell-autobuildhash: processing: en [en_CA-wo_accents-only].
```

```
aspell-autobuildhash: processing: en [en_GB-is-e-w_accents-only].  
aspell-autobuildhash: processing: en [en_GB-is-e-wo_accents-only].  
aspell-autobuildhash: processing: en [en_GB-ize-w_accents-only].  
aspell-autobuildhash: processing: en [en_GB-ize-wo_accents-only].  
aspell-autobuildhash: processing: en [en_GB-variant_0].  
aspell-autobuildhash: processing: en [en_GB-variant_1].  
aspell-autobuildhash: processing: en [en_US-w_accents-only].  
aspell-autobuildhash: processing: en [en_US-wo_accents-only].  
Processing triggers for libc-bin (2.35-0ubuntu3.8) ...  
/sbin/ldconfig.real: /usr/local/lib/libtbb.so.12 is not a symbolic link  
  
/sbin/ldconfig.real: /usr/local/lib/libtcm_debug.so.1 is not a symbolic link  
  
/sbin/ldconfig.real: /usr/local/lib/libur_loader.so.0 is not a symbolic link  
  
/sbin/ldconfig.real: /usr/local/lib/libur_adapter_opencl.so.0 is not a symbolic link  
link  
  
/sbin/ldconfig.real: /usr/local/lib/libhwloc.so.15 is not a symbolic link  
  
/sbin/ldconfig.real: /usr/local/lib/libtbbbind_2_5.so.3 is not a symbolic link  
  
/sbin/ldconfig.real: /usr/local/lib/libtbbbind_2_0.so.3 is not a symbolic link  
  
/sbin/ldconfig.real: /usr/local/lib/libtcm.so.1 is not a symbolic link  
  
/sbin/ldconfig.real: /usr/local/lib/libtbbmalloc.so.2 is not a symbolic link  
  
/sbin/ldconfig.real: /usr/local/lib/libumf.so.0 is not a symbolic link  
  
/sbin/ldconfig.real: /usr/local/lib/libur_adapter_level_zero.so.0 is not a  
symbolic link  
  
/sbin/ldconfig.real: /usr/local/lib/libtbbbind.so.3 is not a symbolic link  
  
/sbin/ldconfig.real: /usr/local/lib/libtbbmalloc_proxy.so.2 is not a symbolic  
link  
  
Reading package lists... Done  
Building dependency tree... Done  
Reading state information... Done  
The following additional packages will be installed:  
dvisvgm fonts-lato fonts-lmodern fonts-texgyre libapache-pom-jav  
libcommons-logging-jav  
libcommons-parent-jav  
libfontbox-jav  
libkpathsea6  
libpdfbox-jav  
libptexenc1 libruby3.0  
libsyntax2 libteckit0 libtexlua53  
libtexluajit2 libwoff1 libzip-0-13 lmodern preview-latex-style  
rake ruby  
ruby-net-telnet ruby-rubygems ruby-webbrick ruby-xmlrpc  
ruby3.0  
rubygems-integration t1utils teckit tex-common tex-gyre  
texlive-base
```

```

texlive-binaries texlive-latex-base texlive-latex-recommended
texlive-pictures texlive-plain-generic tipa xfonts-encodings xfonts-utils
Suggested packages:
  libavalon-framework-java libcommons-logging-java-doc
  libexcalibur-logkit-java liblog4j1.2-java ri ruby-dev bundler debhelper
  perl-tk xpdf | pdf-viewer xzdec texlive-fonts-recommended-doc
  texlive-latex-base-doc python3-pgments icc-profiles libfile-which-perl
  libspreadsheet-parseexcel-perl texlive-latex-extra-doc
  texlive-latex-recommended-doc texlive-luatex texlive-pstricks dot2tex prerex
  texlive-pictures-doc vprerex default-jre-headless tipa-doc
The following NEW packages will be installed:
  dvisvgm fonts-lato fonts-lmodern fonts-texgyre libapache-pom-java
  libcommons-logging-java libcommons-parent-java libfontbox-java libkpathsea6
  libpdfbox-java libptexenc1 libruby3.0 libsyntax2 libteckit0 libtexlua53
  libtexluajit2 libwoff1 libzip-0-13 lmodern preview-latex-style rake ruby
  ruby-net-telnet ruby-rubygems ruby-webrick ruby-xmlrpc ruby3.0
  rubygems-integration t1utils teckit tex-common tex-gyre texlive-base
  texlive-binaries texlive-fonts-recommended texlive-latex-base
  texlive-latex-extra texlive-latex-recommended texlive-pictures
  texlive-plain-generic texlive-xetex tipa xfonts-encodings xfonts-utils
0 upgraded, 44 newly installed, 0 to remove and 37 not upgraded.
Need to get 165 MB of archives.
After this operation, 509 MB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-lato all 2.0-2.1
[2,696 kB]
Get:2 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tex-common all 6.17
[33.7 kB]
Get:3 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libkpathsea6
amd64 2021.20210626.59705-1ubuntu0.2 [60.4 kB]
Get:4 http://archive.ubuntu.com/ubuntu jammy/main amd64 libwoff1 amd64
1.0.2-1build4 [45.2 kB]
Get:5 http://archive.ubuntu.com/ubuntu jammy/universe amd64 dvisvgm amd64
2.13.1-1 [1,221 kB]
Get:6 http://archive.ubuntu.com/ubuntu jammy/universe amd64 fonts-lmodern all
2.004.5-6.1 [4,532 kB]
Get:7 http://archive.ubuntu.com/ubuntu jammy/universe amd64 fonts-texgyre all
20180621-3.1 [10.2 MB]
Get:8 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libapache-pom-java
all 18-1 [4,720 B]
Get:9 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libcommons-parent-
java all 43-1 [10.8 kB]
Get:10 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libcommons-logging-
java all 1.2-2 [60.3 kB]
Get:11 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libptexenc1
amd64 2021.20210626.59705-1ubuntu0.2 [39.1 kB]
Get:12 http://archive.ubuntu.com/ubuntu jammy/main amd64 rubygems-integration
all 1.18 [5,336 B]
Get:13 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 ruby3.0 amd64

```

3.0.2-7ubuntu2.10 [50.1 kB]
Get:14 http://archive.ubuntu.com/ubuntu jammy/main amd64 ruby-rubygems all
3.3.5-2 [228 kB]
Get:15 http://archive.ubuntu.com/ubuntu jammy/main amd64 ruby amd64 1:3.0~exp1
[5,100 B]
Get:16 http://archive.ubuntu.com/ubuntu jammy/main amd64 rake all 13.0.6-2 [61.7
kB]
Get:17 http://archive.ubuntu.com/ubuntu jammy/main amd64 ruby-net-telnet all
0.1.1-2 [12.6 kB]
Get:18 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 ruby-webrick
all 1.7.0-3ubuntu0.1 [52.1 kB]
Get:19 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 ruby-xmlrpc all
0.3.2-1ubuntu0.1 [24.9 kB]
Get:20 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libruby3.0
amd64 3.0.2-7ubuntu2.10 [5,114 kB]
Get:21 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libsynctex2
amd64 2021.20210626.59705-1ubuntu0.2 [55.6 kB]
Get:22 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libteckit0 amd64
2.5.11+ds1-1 [421 kB]
Get:23 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libtexlua53
amd64 2021.20210626.59705-1ubuntu0.2 [120 kB]
Get:24 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libtexluajit2
amd64 2021.20210626.59705-1ubuntu0.2 [267 kB]
Get:25 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libzzip-0-13 amd64
0.13.72+dfsg.1-1.1 [27.0 kB]
Get:26 http://archive.ubuntu.com/ubuntu jammy/main amd64 xfonts-encodings all
1:1.0.5-0ubuntu2 [578 kB]
Get:27 http://archive.ubuntu.com/ubuntu jammy/main amd64 xfonts-utils amd64
1:7.7+6build2 [94.6 kB]
Get:28 http://archive.ubuntu.com/ubuntu jammy/universe amd64 lmodern all
2.004.5-6.1 [9,471 kB]
Get:29 http://archive.ubuntu.com/ubuntu jammy/universe amd64 preview-latex-style
all 12.2-1ubuntu1 [185 kB]
Get:30 http://archive.ubuntu.com/ubuntu jammy/main amd64 t1utils amd64
1.41-4build2 [61.3 kB]
Get:31 http://archive.ubuntu.com/ubuntu jammy/universe amd64 teckit amd64
2.5.11+ds1-1 [699 kB]
Get:32 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tex-gyre all
20180621-3.1 [6,209 kB]
Get:33 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64 texlive-
binaries amd64 2021.20210626.59705-1ubuntu0.2 [9,860 kB]
Get:34 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-base all
2021.20220204-1 [21.0 MB]
Get:35 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-fonts-
recommended all 2021.20220204-1 [4,972 kB]
Get:36 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-latex-base
all 2021.20220204-1 [1,128 kB]
Get:37 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libfontbox-java all

```
1:1.8.16-2 [207 kB]
Get:38 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libpdfbox-java all
1:1.8.16-2 [5,199 kB]
Get:39 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-latex-
recommended all 2021.20220204-1 [14.4 MB]
Get:40 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-pictures
all 2021.20220204-1 [8,720 kB]
Get:41 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-latex-extra
all 2021.20220204-1 [13.9 MB]
Get:42 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-plain-
generic all 2021.20220204-1 [27.5 MB]
Get:43 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tipa all 2:1.3-21
[2,967 kB]
Get:44 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-xetex all
2021.20220204-1 [12.4 MB]
Fetched 165 MB in 3s (50.8 MB/s)
Extracting templates from packages: 100%
Preconfiguring packages ...
Selecting previously unselected package fonts-lato.
(Reading database ... 133823 files and directories currently installed.)
Preparing to unpack .../00-fonts-lato_2.0-2.1_all.deb ...
Unpacking fonts-lato (2.0-2.1) ...
Selecting previously unselected package tex-common.
Preparing to unpack .../01-tex-common_6.17_all.deb ...
Unpacking tex-common (6.17) ...
Selecting previously unselected package libkpathsea6:amd64.
Preparing to unpack .../02-libkpathsea6_2021.20210626.59705-1ubuntu0.2_amd64.deb
...
Unpacking libkpathsea6:amd64 (2021.20210626.59705-1ubuntu0.2) ...
Selecting previously unselected package libwoff1:amd64.
Preparing to unpack .../03-libwoff1_1.0.2-1build4_amd64.deb ...
Unpacking libwoff1:amd64 (1.0.2-1build4) ...
Selecting previously unselected package dvisvgm.
Preparing to unpack .../04-dvisvgm_2.13.1-1_amd64.deb ...
Unpacking dvisvgm (2.13.1-1) ...
Selecting previously unselected package fonts-lmodern.
Preparing to unpack .../05-fonts-lmodern_2.004.5-6.1_all.deb ...
Unpacking fonts-lmodern (2.004.5-6.1) ...
Selecting previously unselected package fonts-texgyre.
Preparing to unpack .../06-fonts-texgyre_20180621-3.1_all.deb ...
Unpacking fonts-texgyre (20180621-3.1) ...
Selecting previously unselected package libapache-pom-java.
Preparing to unpack .../07-libapache-pom-java_18-1_all.deb ...
Unpacking libapache-pom-java (18-1) ...
Selecting previously unselected package libcommons-parent-java.
Preparing to unpack .../08-libcommons-parent-java_43-1_all.deb ...
Unpacking libcommons-parent-java (43-1) ...
Selecting previously unselected package libcommons-logging-java.
```

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Preparing to unpack .../09-libcommons-logging-java_1.2-2_all.deb ...
Unpacking libcommons-logging-java (1.2-2) ...
Selecting previously unselected package libptexenc1:amd64.
Preparing to unpack .../10-libptexenc1_2021.20210626.59705-1ubuntu0.2_amd64.deb
...
Unpacking libptexenc1:amd64 (2021.20210626.59705-1ubuntu0.2) ...
Selecting previously unselected package rubygems-integration.
Preparing to unpack .../11-rubygems-integration_1.18_all.deb ...
Unpacking rubygems-integration (1.18) ...
Selecting previously unselected package ruby3.0.
Preparing to unpack .../12-ruby3.0_3.0.2-7ubuntu2.10_amd64.deb ...
Unpacking ruby3.0 (3.0.2-7ubuntu2.10) ...
Selecting previously unselected package ruby-rubygems.
Preparing to unpack .../13-ruby-rubygems_3.3.5-2_all.deb ...
Unpacking ruby-rubygems (3.3.5-2) ...
Selecting previously unselected package ruby.
Preparing to unpack .../14-ruby_1%3a3.0~exp1_amd64.deb ...
Unpacking ruby (1:3.0~exp1) ...
Selecting previously unselected package rake.
Preparing to unpack .../15-rake_13.0.6-2_all.deb ...
Unpacking rake (13.0.6-2) ...
Selecting previously unselected package ruby-net-telnet.
Preparing to unpack .../16-ruby-net-telnet_0.1.1-2_all.deb ...
Unpacking ruby-net-telnet (0.1.1-2) ...
Selecting previously unselected package ruby-webrick.
Preparing to unpack .../17-ruby-webrick_1.7.0-3ubuntu0.1_all.deb ...
Unpacking ruby-webrick (1.7.0-3ubuntu0.1) ...
Selecting previously unselected package ruby-xmlrpc.
Preparing to unpack .../18-ruby-xmlrpc_0.3.2-1ubuntu0.1_all.deb ...
Unpacking ruby-xmlrpc (0.3.2-1ubuntu0.1) ...
Selecting previously unselected package libruby3.0:amd64.
Preparing to unpack .../19-libruby3.0_3.0.2-7ubuntu2.10_amd64.deb ...
Unpacking libruby3.0:amd64 (3.0.2-7ubuntu2.10) ...
Selecting previously unselected package libsynctex2:amd64.
Preparing to unpack .../20-libsynctex2_2021.20210626.59705-1ubuntu0.2_amd64.deb
...
Unpacking libsynctex2:amd64 (2021.20210626.59705-1ubuntu0.2) ...
Selecting previously unselected package libteckit0:amd64.
Preparing to unpack .../21-libteckit0_2.5.11+ds1-1_amd64.deb ...
Unpacking libteckit0:amd64 (2.5.11+ds1-1) ...
Selecting previously unselected package libtexlua53:amd64.
Preparing to unpack .../22-libtexlua53_2021.20210626.59705-1ubuntu0.2_amd64.deb
...
Unpacking libtexlua53:amd64 (2021.20210626.59705-1ubuntu0.2) ...
Selecting previously unselected package libtexluajit2:amd64.
Preparing to unpack
.../23-libtexluajit2_2021.20210626.59705-1ubuntu0.2_amd64.deb ...
Unpacking libtexluajit2:amd64 (2021.20210626.59705-1ubuntu0.2) ...
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Selecting previously unselected package libzzip-0-13:amd64.
Preparing to unpack .../24-libzzip-0-13_0.13.72+dfsg.1-1.1_amd64.deb ...
Unpacking libzzip-0-13:amd64 (0.13.72+dfsg.1-1.1) ...
Selecting previously unselected package xfonts-encodings.
Preparing to unpack .../25-xfonts-encodings_1%3a1.0.5-0ubuntu2_all.deb ...
Unpacking xfonts-encodings (1:1.0.5-0ubuntu2) ...
Selecting previously unselected package xfonts-utils.
Preparing to unpack .../26-xfonts-utils_1%3a7.7+6build2_amd64.deb ...
Unpacking xfonts-utils (1:7.7+6build2) ...
Selecting previously unselected package lmodern.
Preparing to unpack .../27-lmodern_2.004.5-6.1_all.deb ...
Unpacking lmodern (2.004.5-6.1) ...
Selecting previously unselected package preview-latex-style.
Preparing to unpack .../28-preview-latex-style_12.2-1ubuntu1_all.deb ...
Unpacking preview-latex-style (12.2-1ubuntu1) ...
Selecting previously unselected package t1utils.
Preparing to unpack .../29-t1utils_1.41-4build2_amd64.deb ...
Unpacking t1utils (1.41-4build2) ...
Selecting previously unselected package teckit.
Preparing to unpack .../30-teckit_2.5.11+ds1-1_amd64.deb ...
Unpacking teckit (2.5.11+ds1-1) ...
Selecting previously unselected package tex-gyre.
Preparing to unpack .../31-tex-gyre_20180621-3.1_all.deb ...
Unpacking tex-gyre (20180621-3.1) ...
Selecting previously unselected package texlive-binaries.
Preparing to unpack .../32-texlive-
binaries_2021.20210626.59705-1ubuntu0.2_amd64.deb ...
Unpacking texlive-binaries (2021.20210626.59705-1ubuntu0.2) ...
Selecting previously unselected package texlive-base.
Preparing to unpack .../33-texlive-base_2021.20220204-1_all.deb ...
Unpacking texlive-base (2021.20220204-1) ...
Selecting previously unselected package texlive-fonts-recommended.
Preparing to unpack .../34-texlive-fonts-recommended_2021.20220204-1_all.deb ...
Unpacking texlive-fonts-recommended (2021.20220204-1) ...
Selecting previously unselected package texlive-latex-base.
Preparing to unpack .../35-texlive-latex-base_2021.20220204-1_all.deb ...
Unpacking texlive-latex-base (2021.20220204-1) ...
Selecting previously unselected package libfontbox-java.
Preparing to unpack .../36-libfontbox-java_1%3a1.8.16-2_all.deb ...
Unpacking libfontbox-java (1:1.8.16-2) ...
Selecting previously unselected package libpdfbox-java.
Preparing to unpack .../37-libpdfbox-java_1%3a1.8.16-2_all.deb ...
Unpacking libpdfbox-java (1:1.8.16-2) ...
Selecting previously unselected package texlive-latex-recommended.
Preparing to unpack .../38-texlive-latex-recommended_2021.20220204-1_all.deb ...
Unpacking texlive-latex-recommended (2021.20220204-1) ...
Selecting previously unselected package texlive-pictures.
Preparing to unpack .../39-texlive-pictures_2021.20220204-1_all.deb ...
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Unpacking texlive-pictures (2021.20220204-1) ...
Selecting previously unselected package texlive-latex-extra.
Preparing to unpack .../40-texlive-latex-extra_2021.20220204-1_all.deb ...
Unpacking texlive-latex-extra (2021.20220204-1) ...
Selecting previously unselected package texlive-plain-generic.
Preparing to unpack .../41-texlive-plain-generic_2021.20220204-1_all.deb ...
Unpacking texlive-plain-generic (2021.20220204-1) ...
Selecting previously unselected package tipa.
Preparing to unpack .../42-tipa_2%3a1.3-21_all.deb ...
Unpacking tipa (2:1.3-21) ...
Selecting previously unselected package texlive-xetex.
Preparing to unpack .../43-texlive-xetex_2021.20220204-1_all.deb ...
Unpacking texlive-xetex (2021.20220204-1) ...
Setting up fonts-lato (2.0-2.1) ...
Setting up libwoff1:amd64 (1.0.2-1build4) ...
Setting up libtexlua53:amd64 (2021.20210626.59705-1ubuntu0.2) ...
Setting up libtexluajit2:amd64 (2021.20210626.59705-1ubuntu0.2) ...
Setting up libfontbox-java (1:1.8.16-2) ...
Setting up rubygems-integration (1.18) ...
Setting up libzzip-0-13:amd64 (0.13.72+dfsg.1-1.1) ...
Setting up tex-common (6.17) ...
update-language: texlive-base not installed and configured, doing nothing!
Setting up libteckit0:amd64 (2.5.11+ds1-1) ...
Setting up libapache-pom-java (18-1) ...
Setting up ruby-net-telnet (0.1.1-2) ...
Setting up xfonts-encodings (1:1.0.5-0ubuntu2) ...
Setting up t1utils (1.41-4build2) ...
Setting up fonts-texgyre (20180621-3.1) ...
Setting up libkpathsea6:amd64 (2021.20210626.59705-1ubuntu0.2) ...
Setting up ruby-webrick (1.7.0-3ubuntu0.1) ...
Setting up fonts-lmodern (2.004.5-6.1) ...
Setting up ruby-xmlrpc (0.3.2-1ubuntu0.1) ...
Setting up libsynctex2:amd64 (2021.20210626.59705-1ubuntu0.2) ...
Setting up teckit (2.5.11+ds1-1) ...
Setting up libpdfbox-java (1:1.8.16-2) ...
Setting up preview-latex-style (12.2-1ubuntu1) ...
Setting up libcommons-parent-java (43-1) ...
Setting up dvisvgm (2.13.1-1) ...
Setting up libcommons-logging-java (1.2-2) ...
Setting up xfonts-utils (1:7.7+6build2) ...
Setting up libptexenc1:amd64 (2021.20210626.59705-1ubuntu0.2) ...
Setting up texlive-binaries (2021.20210626.59705-1ubuntu0.2) ...
update-alternatives: using /usr/bin/xdvi-xaw to provide /usr/bin/xdvi.bin
(xdvi.bin) in auto mode
update-alternatives: using /usr/bin/bibtex.original to provide /usr/bin/bibtex
(bibtex) in auto mode
Setting up lmodern (2.004.5-6.1) ...
Setting up texlive-base (2021.20220204-1) ...
```

```
/usr/bin/ucfr
/usr/bin/ucfr
/usr/bin/ucfr
/usr/bin/ucfr
mktexlsr: Updating /var/lib/texmf/ls-R-TEXLIVEDIST...
mktexlsr: Updating /var/lib/texmf/ls-R-TEXMFMAIN...
mktexlsr: Updating /var/lib/texmf/ls-R...
mktexlsr: Done.
tl-paper: setting paper size for dvips to a4:
/var/lib/texmf/dvips/config/config-paper.ps
tl-paper: setting paper size for dvipdfmx to a4:
/var/lib/texmf/dvipdfmx/dvipdfmx-paper.cfg
tl-paper: setting paper size for xdvi to a4: /var/lib/texmf/xdvi/XDvi-paper
tl-paper: setting paper size for pdftex to a4: /var/lib/texmf/tex/generic/tex-
ini-files/pdftexconfig.tex
Setting up tex-gyre (20180621-3.1) ...
Setting up texlive-plain-generic (2021.20220204-1) ...
Setting up texlive-latex-base (2021.20220204-1) ...
Setting up texlive-latex-recommended (2021.20220204-1) ...
Setting up texlive-pictures (2021.20220204-1) ...
Setting up texlive-fonts-recommended (2021.20220204-1) ...
Setting up tipa (2:1.3-21) ...
Setting up texlive-latex-extra (2021.20220204-1) ...
Setting up texlive-xetex (2021.20220204-1) ...
Setting up rake (13.0.6-2) ...
Setting up libruby3.0:amd64 (3.0.2-7ubuntu2.10) ...
Setting up ruby3.0 (3.0.2-7ubuntu2.10) ...
Setting up ruby (1:3.0~exp1) ...
Setting up ruby-rubygems (3.3.5-2) ...
Processing triggers for man-db (2.10.2-1) ...
Processing triggers for mailcap (3.70+nmu1ubuntu1) ...
Processing triggers for fontconfig (2.13.1-4.2ubuntu5) ...
Processing triggers for libc-bin (2.35-0ubuntu3.8) ...
/sbin/ldconfig.real: /usr/local/lib/libtbb.so.12 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libtcm_debug.so.1 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libur_loader.so.0 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libur_adapter_openc1.so.0 is not a symbolic
link
/sbin/ldconfig.real: /usr/local/lib/libhwloc.so.15 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libtbbbind_2_5.so.3 is not a symbolic link
/sbin/ldconfig.real: /usr/local/lib/libtbbbind_2_0.so.3 is not a symbolic link
```

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/sbin/ldconfig.real: /usr/local/lib/libtcm.so.1 is not a symbolic link  
/sbin/ldconfig.real: /usr/local/lib/libtbbmalloc.so.2 is not a symbolic link  
/sbin/ldconfig.real: /usr/local/lib/libumf.so.0 is not a symbolic link  
/sbin/ldconfig.real: /usr/local/lib/libur_adapter_level_zero.so.0 is not a  
symbolic link  
/sbin/ldconfig.real: /usr/local/lib/libtbbbind.so.3 is not a symbolic link  
/sbin/ldconfig.real: /usr/local/lib/libtbbmalloc_proxy.so.2 is not a symbolic  
link  
  
Processing triggers for tex-common (6.17) ...  
Running updmap-sys. This may take some time... done.  
Running mktexlsr /var/lib/texmf ... done.  
Building format(s) --all.  
This may take some time... done.
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[58]: %shell jupyter nbconvert --to pdf '/content/drive/MyDrive/Colab Notebooks/  
˓→Shruthi_AAI_510_IN1_Final_Project_Group_3.ipynb'
```

```
[NbConvertApp] Converting notebook /content/drive/MyDrive/Colab  
Notebooks/Shruthi_AAI_510_IN1_Final_Project_Group_3.ipynb to pdf  
[NbConvertApp] Support files will be in  
Shruthi_AAI_510_IN1_Final_Project_Group_3_files/  
[NbConvertApp] Making directory  
. ./Shruthi_AAI_510_IN1_Final_Project_Group_3_files  
[NbConvertApp] Writing 482832 bytes to notebook.tex  
[NbConvertApp] Building PDF  
[NbConvertApp] Running xelatex 3 times: ['xelatex', 'notebook.tex', '-quiet']  
[NbConvertApp] Running bibtex 1 time: ['bibtex', 'notebook']  
[NbConvertApp] WARNING | bibtex had problems, most likely because there were no  
citations  
[NbConvertApp] PDF successfully created  
[NbConvertApp] Writing 4256397 bytes to /content/drive/MyDrive/Colab  
Notebooks/Shruthi_AAI_510_IN1_Final_Project_Group_3.pdf
```

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[58]:
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[ ]:
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